FCC 47 CFR § 2.1093

RF EXPOSURE EVALUATION REPORT
(TAS validation Report)

FOR

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

MODEL NUMBER: SM-S921B/DS, SM-S921B

FCC ID: A3LSMS921B

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V1	10/23/2023	Initial Issue	-
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Attestation of Test Results

Applicant Name	SAMSUNG ELECTRONICS CO.,LTD.
FCC ID	A3LSMS921B
Model Number	SM-S921B/DS, SM-S921B
Applicable Standards	FCC 47 CFR § 2.1093
Date Tested	10/13/2023 to 10/23/2023
Test Results	Pass

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

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1. Introduction

The equipment under test (EUT) has both SAMSUNG Smartphone (FCC ID : A3LSMS921B), it contains both S.LSI TAS supporting WWAN technologies (2G/3G/4G/5G-Sub6) and Qualcomm FastConnect TAS supporting WLAN technologies (2.4GHz/5GHz/6GHz). Both TAS chipset are enabled with each TAS (Time Average SAR) algorithm has been designed to meet the compliance limits over the required duration, while still allowing dynamic control of transmit power for meeting system performance.
And The EUT has also supports to BT/NFC technologies, but There are not support to TAS algorithm.
This document consists of TAS algorithm description, validation methodology, test cases, test procedures and test results. In order to demonstrate that TAS algorithm meets FCC requirements for SAR exposure.

1.1. S.LSI TAS operation for WWAN technologies

The RF exposure limit is defined based on time-average exposure during a certain amount of time window. Basically, the length of time window is adjustable in current TAS algorithm implementation. As representative values, following time window sizes are introduced in the report. Time window size 100 seconds, 60 seconds are used for SAR (below 3GHz), SAR (3-6GHz) respectively. TAS algorithm ensures the DUT can meet the FCC compliance at all times over test duration. Samsung S.LSI proprietary TAS algorithm considers cellular RAT(Radio Access Technology), and connectivity technologies such as Wi-Fi and BT because the DUT should keep the total amount of radiation below the level defined by regulations. To do this, modem controls transmitter power in real time.

At a very high level, the TAS algorithm consists of the following:

Maximum Tx power limits for a particular RAT is calculated considering SAR compliance using some pre-characterization data.

Instantaneous Tx power can go over Tx power limit but average value during any measurement window will be maintained below the Tx power limit.

In a simultaneous multi-RAT scenario, TAS algorithm also has to meet TER, which is sum of actual SAR to the compliance limit across all RATs. TER or the DUT will be equal to or less than 1.0 at all time.

To preserve the radio link quality and call connection, TAS algorithm provides the concept or priority of each RAT’s transmit power. For instance, a certain minimum value of max transmit power limit will be ensured for anchor RAT such as LTE in EN-DC.

Algorithm Operation:

Samsung S.LSI proprietary TAS algorithm operates as follows:

Define the minimum duration of SAR calculation. This duration is the ‘SAR average window’ consists of N slots. Any measurement duration of time-averaging duration as specified by FCC for the particular RAT will then consist of M such windows. The product of FCC limit of SAR limit (or equivalently the Tx power for this limit as used in the algorithm) and M is then defined as a SAR budget for such measurement durations.

For a particular window, calculate the amount of average SAR consumed during the window duration by computing average of instantaneous transmit power value per slot. Because SAR value is not given directly, Tx power value is used to calculate consumed SAR value.

Estimates the total SAR consumed during the SAR measurement duration is the past which includes the above window. This value will be the sum of SAR consumed by all windows un the measurement duration.

Monitor the remaining SAR budget continuously for every window and control the maximum Tx power for the next window to comply with SAR regulation.

1.2. Qualcomm FastConnect TAS operation for WLAN technologies

Regulatory RF exposure limits are defined with respect to time-averaged RF exposure. Qualcomm FastConnect TAS algorithm perform transmit power control to ensures at all times the wireless device is in compliance with the configured limit of RF exposure averaged over a defined time window denoted as T_{SAR} for SAR.

The Qualcomm FastConnect TAS support maximum time-averaging windows (denoted as T_{SAR}) as defined by the FCC that:
For FCC, a 30 second time-averaging window is used by Qualcomm FastConnect TAS for WLAN operation in 2.4GHz, 5GJz, and 6GHz WLAN Bands.

Algorithm Operation:

Qualcomm FastConnect TAS manage the instantaneous transmit power to maintain the time-averaged power and associated RF exposure is below the regulatory compliance limit.

If the time-averaged transmit power approaches the SAR compliance power, then the instantaneous transmit power is limited to ensure the time-averaged transmit power does not exceed the SAR compliance power in any T_{SAR} time window.

The wireless device can instantaneously transmit at high transmit powers for a short time durations before limiting the power to maintain time-averaged SAR compliance.

2. Tx Varying Transmission Test Cases and Test Proposal

2.1. WWAN technologies supports S.LSI TAS algorithm

The following scenarios are covered in this report to demonstrate compliance with FCC RF exposure in Tx varying transmission conditions.

1. During a time-varying Tx power transmission – to prove that TAS feature accounts for Tx power variations in time accurately.

2. During a call disconnect and re-establish scenario – to prove that the TAS feature accounts for history of Tx power from past accurately.

3. During a technology/band handover – to prove that TAS feature accounts for history across transitions in band/technology.

4. During RSI (Radio SAR index) change – to prove that TAS feature functions correctly to meet compliance limits across RSI changes.

5. During time averaging window change – to prove that TAS feature properly handles the change from one time averaging window to another as specified by FCC, and meets the normalized FCC limit of 1.0 at all time.

6. During SAR exposure switch – to prove that TAS feature accounts for history across transitions in NAS(EN-DC) power sharing.

7. During UL CA – to prove that TAS feature can handle adding/removing CC and can handle both single CC and CA.

8. During Spatial TAS operation – to prove that TAS feature functions correctly to meet compliance limit during Spatial TAS operation.

As described in linearity analysis in SAR characterization report, the RF exposure is proportional to the Tx power for FR1. Thus, we rely on conducted power measurements (FR1) in each dynamic case to demonstrate that overall RF exposure is within the FCC limit. The overall procedure for validating the test is summarized below:

1. Measure conducted power (FR1) over time, denoted as $TxPower(t)$, with i

2. Convert measured powers to RF exposure values using linear relationship shown below. In below expression, $Plimit$,$FR1$ would be the measured power at which FR1 technology meets measured SAR level of SAR_design_target.

$$SAR(t) = \frac{TxPower(t)}{P_{limit,FR1}} \times SAR\_design\_target \qquad \text{(equation : 2.1)}$$

3. Compute the average RF exposure over the most recent measurement duration which are denoted as $TSAR$ for FR1. These durations are as specified by FCC. This measurement duration interval is then given by [$t - TSAR$, t] for FR1.

4. Divide the RF exposure for FR1 by corresponding FCC limits and ensure the sum denoted as TER (total exposure ratio) is less than 1 for all t. Please refer following to following equations

which describe the calculation of TER and its target constraint. The expressions below is general considering a number of FR1 radio in general denoted by $LSAR$.

- For FR1 transmissions only:

$$\sum_{l_{SAR}=0}^{L_{SAR}-1} \frac{\frac{1}{T_{SAR}} \int_{t-T_{SAR}}^{t} SAR_{l_{SAR}}}{FCC\ \ SAR_{limit}} \leq 1 \qquad \text{(equation : 2.2)}$$

2.2. WLAN technologies supports Qualcomm FastConnect TAS algorithm

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

1. During a time-varing Tx power transmission: To prove that the Qualcomm FastConnect TAS accounts for Tx power variations in time accurately.

2. During technology/band handover: To prove that the Qualcomm FastConnect TAS functions correctly during transitions in technology/band.

3. During antenna switch: To prove that the Qualcomm FastConnect TAS functions correctly during transitions in antenna.

4. During change in device state: To prove that the Qualcomm FastConnect TAS functions correctly during transitions in device state, say, from body-worn state to hotspot, or say, from extremity mode to body-worn state, etc. Devices state here refers to all the device configurations required to be tested by FCC, for example, head position, body-worn position, hotspot mode, and extremity.

5. SAR exposure switching between two active radios (radio1 and radio2): To prove that the Qualcomm FastConnect TAS 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 SAR characterization report, the RF exposure is proportional to the Tx power for WLAN. Thus, time-averaging algorithm validation can be effectively performed through conducted power measurement. To have high confidence in this validation, but also be practical, the strategy for the validation including both power measurement and RF exposure measurement is outlined as follows:

Conducted power power measurement:

- Measure conducted Tx power for *WLAN techs*
- Convert it into RF exposure and divide by respective FCC limits to get normalized exposure
- Perform time-averaging over predefined time windows
- Demonstrate that the total normalized time-averaged RF exposure is less than 1.0 for all transmission scenarios;
  - For frequency below 6GHz or if regulator requires SAR for WLAN 6GHz band.

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

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

Where, *conducted_Tx_power (t)*, *conducted_Tx_power_*P_{limit}, and *1g_or_10gSAR_*P_{limit} correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR or 10gSAR* values at P_{limit} for the worst-case radio configuration within the tested technology/band/Antenna/DSI. T_{SAR} is the time window for f < 6GHz radio defined by FCC;

RF Exposure(SAR) measurement:

- Demonstrate the total RF exposure averaged over predefined time windows does not exceed FCC's SAR limit, through time-averaged SAR measurements for only scenario 1 to add confidence in the Qualcomm FastConnect TAS validation, while avoiding the complexity in SAR measurement
  - For frequency below 6GHz or if regulator requires SAR for WLAN 6GHz band.

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

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

Where, *pointSAR(t)*, *pointSAR_*P_{limit}, and *1g_or_10gSAR_*P_{limit} correspond to the measured instantaneous point SAR, measured point SAR at P_{limit} and measured *1gSAR* or *10gSAR* values at P_{limit} corresponding to f < 6 GHz transmission for the worst-case radio configuration within the tested technology/band/Antenna/DSI.

3. SAR Time Averaging Validation Test Procedures for S.LSI TAS

In this section, we cover the test plan and test procedure for validating Samsung S.LSI TAS feature for FR1 scenarios.

3.1. Test sequence determination for validation

Two sequences for time varying Tx power are pre-defined as given below for FR1 cases.

1. Test Sequence A which is generated with one or two levels where one of the level is maximum power level (Pmax) which is applied at least for 100s. Based on the second level this test sequence is sub-categorized into four different sequence used.

   a. Test Sequence A.i where after Pmax, a second level of Plimit is requested till the end of the test
   b. Test Sequence A.ii where after Pmax, a second level of Pmax-3dB is requested till the end of the test
   c. Test Sequence A.iii where after Pmax, a second level of Plimit-3dB is requested till the end of the test
   d. Test Sequence A.iv where only Pmax is requested till the end of the test

2. Test Sequence B is generated at multiple power levels that are specified in the Appendix as a function of Pmax and Plimit.

3.2. Test configuration selection criteria for validating TAS

This section provides general guidance for selecting test cases in TAS feature validation. Modifications of the test cases are possible to study other specific scenarios.

3.2.1 Test configuration selection for time-varying Tx power transmission

The Samsung S.LSI TAS algorithm is independent of band, modes or channel of any technology. Hence, we can validate using one or two combinations of band/mode/channel per technology. The criteria for selecting these would be based on the relative value of Plimit and Pmax. Essentially, we need to pick this combination such that Plimit is less than Pmax so that the TAS algorithm will enforce power restriction. Two bands can be selected to different values of Plimit - one corresponding to lowest value and another being highest but still less than Pmax.

3.2.2 Test configuration selection for change in call

The criteria to select the technology/band for transition between call setup and call drop is to choose the one with least Plimit. The test is performed with DUT requested power at Pmax so that the Samsung S.LSI TAS feature enforces power restriction for longest duration. The call change is performed when the DUT is operating with restricted power. One such test is sufficient since behavior is not dependent on band/technology.

3.2.3 Test configuration for change in technology/Band/window

FCC specifies different measurement durations for time averaging based on operating frequency. The change of operating frequency can result in change of time window for averaging, for e.g. change from 100s averaging for frequency below 3GHz to 60s averaging for frequency above 3GHz in FR1. The criteria for selecting test case to demonstrate compliance across time window change is to pick a technology/band corresponding to each time window such that Plimit is less than Pmax.

3.2.4 Test configuration for change in RSI (Radio SAR Index)

The criteria for selecting test case to demonstrate compliance across RSI change within a radio. The two RSI states are chosen by pick a technology/band such that Plimit is less than Pmax for both states.

3.2.5 Test configuration for SAR exposure switching

The criteria for selecting test case is to pick an LTE band and a NR band with Plimit lower than Pmax in each case. The test is performed with both RATs connected in an NSA(EN-DC) scenario. In the first portion of the test, DUT is requested to transmit at maximum power for NR and minimum power for LTE. In the second portion of the test, DUT is requested to transmit at maximum power for both NR and LTE. In the final portion of the test, DUT is requested to transmit at minimum power for NR and maximum power for LTE.

3.2.6 Test configuration for TAS to non TAS Handover

This test scenario is similar section 3.2.3. The difference is that one tech support TAS feature and the other tech does not support TAS feature. This test is conducted according to the test procedures provided in Samsung S.LSI.

3.2.7 Test configuration for Uplink CA

The criteria for selecting this test case is to demonstrate the compliance of the TAS algorithm when an LTE transmission is done over multiple CC. This test shows that the TAS algorithm compliance is independent on the Transmission scenarios (single CC or CA).

3.2.8 Test configuration for Spatial TAS

The criteria of selecting these tests configuration is to demonstrate the compliance of the TAS algorithm while transmitting on multiple antennas with a coupling factor of 0. This spatial TAS algorithm will show that we can achieve enhanced performance based on the antenna coupling while ensuring compliance with FCC target level.

3.3 Test procedures for conducted power measurements

This section provides general conducted power measurement procedures to perform compliance test under dynamic scenarios described in Section 2.

3.3.1 Time-varying Tx power transmission scenario

This test is performed with two pre-defined test sequences as described in Section 3.1 for all technologies operating on sub-6GHz applying to both LTE and NR as selected in Section 3.2.1. The purpose of the test is to demonstrate the maximum power limiting enforcement and that the time-averaged SAR does not exceed the FCC limit at all times.

Test procedure:

1. Using the Pmax and Plimit, generate the test sequence of power levels for each selected technology/band. Both test sequences A and B are generated. Maximum power can be changed according to DUT test results.

2. Establish the connection of the DUT to the call box in the selected RAT, with the call box requesting the DUT Tx power to be according to the sequence determined in Step 1. An initial value of Tx power will be set to 0dBm for 100s before the desired test sequence starts to help with post-processing of the time-average value with the very first value in the sequence. This is illustrated in the figure below.

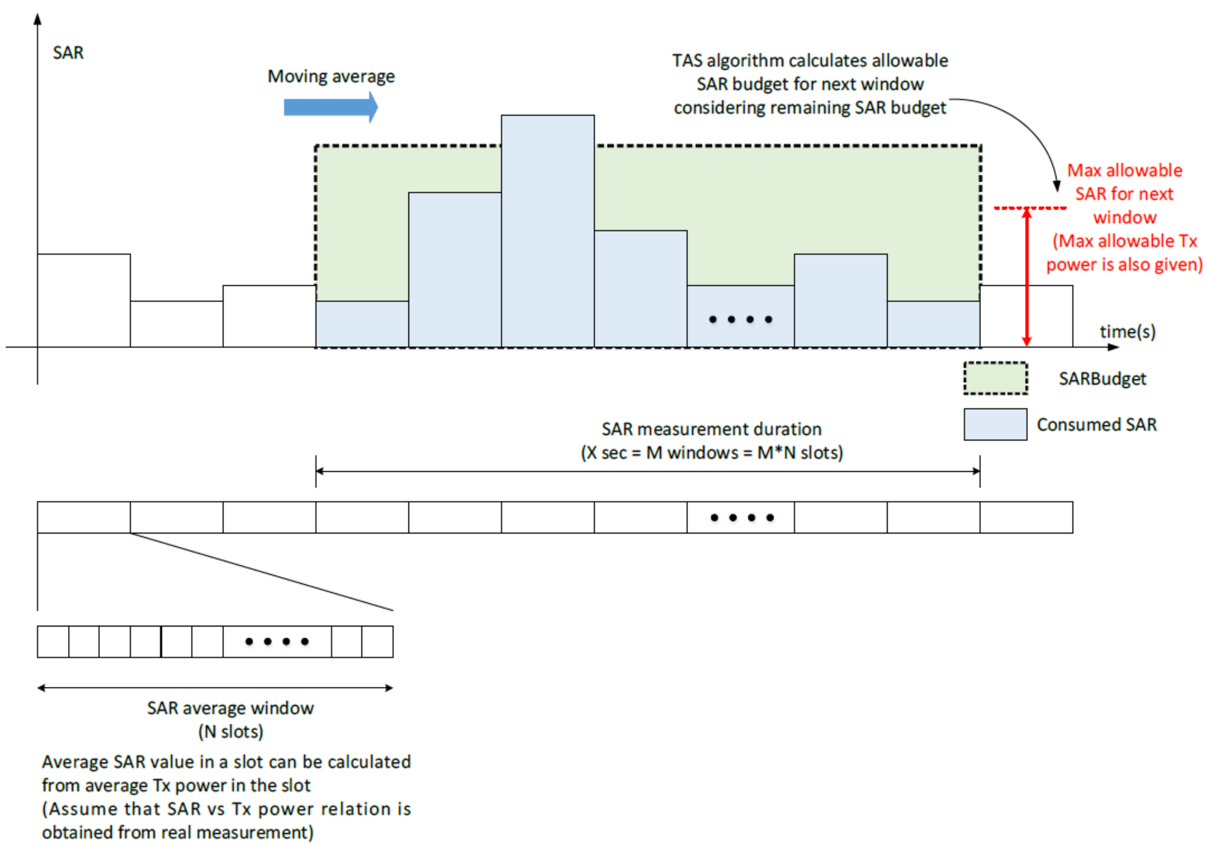


Figure 3.3-1 SAR measurement from Tx power using block-wise processing

3. Release connection

4. After the completion of the test, prepare one plot with the following information;

   a. Instantaneous Tx power versus time measured in Step 2.
   b. Requested Tx power versus time used in Step 2.
   c. Time-averaged power over 100s using instantaneous values from Step 2.
   d. Power level Plimit which is determined as meeting SAR target.

5. Make a second plot containing the following information:
   a. Computed time-averaged 1gSAR versus time determined in Step 2.
   b. FCC 1gSAR limit of 1.6W/kg.

The pass condition is to demonstrate time-averaged 1gSAR versus time shown in Step 5 value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. We would also demonstrate that time-averaged power does not exceed the Plimit at any time in the plot in Step 4.

3.3.2 Change in call scenario

This test is to demonstrate that Samsung S.LSI TAS feature correctly accounts for past Tx powers during time-averaging when a new call is established. The call change has to be carried out when the power limit enforcement is ongoing.

Test procedure:

1. Establish radio connection of DUT with call box e.g. using LTE technology.
2. Configure call box to set DUT Tx power to a low value of -10dBm for 100s.
3. Configure call box to send “ALL UP” power control commands and continue LTE transmission from DUT so that maximum power of Pmax is achieved.
4. After 60s of transmission at Pmax power level, release the call from call box.
5. After 10s, re-establish the LTE connection from call box to DUT and repeat sending “ALL UP” power control to bring the Tx power to Pmax level again and continue till the end of the test.
6. Release LTE connection.
7. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Requested Tx power versus time (c) Time-averaged power over 100s using instantaneous values and (d) Power level Plimit which is determined as meeting SAR target
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time and (b) FCC 1gSAR limit of 1.6W/kg

Pass condition is to demonstrate time-averaged 1gSAR value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. It is required to check if SAR calculation is accounting for call drop and connection. Current TAS algorithm software makes the UE estimate the exact amount of Tx power and average SAR even during call drop and call re-establishment event. The UE stores time information when it goes into a sleep mode and wake-up to calculate Tx power on / off duration.

3.3.3 Change in technology/band/window

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of technology/band and consequently time window as necessary during handover scenarios. Since both Plimit and window duration can change across bands, we have to use separate equations below for converting Tx power to SAR as well as apply some combined SAR exposure criteria as shown below.

$$SAR_1(t) = \frac{TxPower_1(t)}{P_{limit,1,FR1}} * SAR\_design\_target_1 \quad \text{(equation : 3.3.3.1)}$$

$$SAR_2(t) = \frac{TxPower_2(t)}{P_{limit,2,FR1}} * SAR\_design\_target_2 \quad \text{(equation : 3.3.3.2)}$$

where $Plimit$,1,FR1 would correspond to measured power at which first technology/band meets measured SAR level of SAR_design_target1 as described in Table 6.2.1 with time-averaging duration of T1,SAR . Similarly, the quantities $Plimit$,2,FR1 , SAR_design_target2 , T2,SAR are defined for the second technology/band. When first band is chosen below 3GHz, we would have T1,SAR = 100s, and by choosing second band to be above 3GHz, we would use T2,SAR = 60s. On the other hand, when first band is chosen above 3GHz and second band below 3GHz, we would use T1,SAR = 60s and T1,SAR = 100s.

Test procedure for switching from 100s to 60s and vice-versa :

1. Establish radio connection of DUT with call box e.g. using LTE technology in band A (e.g. B2) which has 100s averaging duration.
2. Configure call box to set DUT Tx power to a low value of -10dBm for 160s.
3. Configure call box to send “ALL UP” power control commands and continue LTE transmission From DUT so that maximum power of Pmax is achieved. Continue transmission at the maximum power for at least 140s.
4. Change band from band A (e.g. B2) to another LTE band B (e.g. B48), which should correspond to a change in averaging duration from 100s to 60s. Continue call in band B with call box requesting maximum power for at least 200s.
5. Change band from band B(e.g. B48) back to the first band A(e.g. B2) and continue call at maximum power for at least 120s.
6. Release LTE connection.
7. After the completion of the test, prepare one plot with the following information for each band (a) Instantaneous Tx power versus time (b) Time-averaged power for each band according to their averaging duration and (c) Plimit corresponding to each band.
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each band (b) Sum of time-averaged SAR computed according to Eqn (3.3.3.1) and (3.3.3.2), and (c) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate total time-averaged 1gSAR value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when band change occurs in-between.

Test procedure for switching from 60s to 100s and vice-versa :

1. Establish radio connection of DUT with call box e.g. using LTE technology in band B (e.g. B48) which has 60s averaging duration.
2. Configure call box to set DUT Tx power to a low value of -10dBm for 160s.
3. Configure call box to send “ALL UP” power control commands and continue LTE transmission from DUT so that maximum power of Pmax is achieved. Continue transmission at the maximum power for at least 140s.
4. Change band from band B (e.g. B48) to another LTE band A (e.g. B2), which should correspond to a change in averaging duration from 60s to 100s. Continue call in band A with call box requesting maximum power for at least 120s
5. Change band from band A(e.g. B2) back to the first band B(e.g. B48) and continue call at maximum power for at least 180s.
6. Release LTE connection
7. After the completion of the test, prepare one plot with the following information for each band (a) Instantaneous Tx power versus time (b) Time-averaged power for each band according to their averaging duration and (c) Plimit corresponding to each band
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each band (b) Sum of time-averaged SAR computed according to Eqn (3.3.3.1) and (3.3.3.2), and (c) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate total time-averaged 1gSAR value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when band change occurs in-between.

Test procedure for handover between two TAS RATs :

1. Establish radio connection of DUT with call box.
2. Configure call box to set DUT Tx power to a low value of -10dBm for 100s.
3. Configure call box to send “ALL UP” power control commands and continue LTE transmission from DUT so that maximum power of Pmax is achieved. Continue transmission at the maximum power for at least 410s.
4. Change RAT from NR to LTE and configure call box to send “ALL UP” power control commands in LTE
5. Continue call in LTE at maximum power for 400s.
6. Release LTE connection
7. After the completion of the test, prepare one plot with the following information for each RAT (a) Instantaneous Tx power versus time (b) Time-averaged power for each band according to their averaging duration and (c) Plimit corresponding to each RAT
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each RAT (b) Sum of time-averaged SAR computed according to Eqn (3.3.3.1) and (3.3.3.2), and (c) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate total time-averaged 1gSAR value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when RAT change occurs in-between.

3.3.4 Change in RSI (Radio SAR Index)

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of RSI resulting from different SAR index state detected by host platform software. It involves changing the Plimit value during the test for the same technology to emulate RSI change, while the SAR_design_target remains the same. Note that the DUT has a proximity sensor to manage extremity exposure, which is represented using RSI (number = related proximity senor scenario) ; the head exposure can be distinguished through audio receiver mode, represented as RSI (number = related head exposure scenario); similarly, the body worn with 15mm distance exposure is represented as RSI (number = related head exposure scenario); the other exposure would be updated and defined as other RSI numbers.

Test procedure :

1. Establish radio connection of DUT with call box.
2. Configure DUT to send at low Tx power of 0dBm for 110s and set the RSI index corresponding to Plimit.
3. Configure call box to send “ALL UP” power control commands and continue transmission from DUT so that maximum power of Pmax is achieved. Continue the transmission for 200s.
4. Change the RSI index corresponding to lower value of (Plimit - 3dB) and continue the transmission for another 300s
5. Release the connection.

Pass condition is to demonstrate time-averaged 1gSAR value versus time does not exceed the FCC limit 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when RSI index is changed during the test.

3.3.5 SAR exposure switching

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of dominant SAR exposure radio in the case of two simultaneous active RATs. It involves changing the required power of both radios such that either one or both of the RATs becomes dominant contributor to total exposure ratio at different times of the test.

Test procedure :

1. Establish LTE and NR radio connection in NSA case with both call boxes, e.g. LTE band and NR band.
2. Configure the LTE call box to send “ALL DOWN” power control commands for LTE and configure the NR call box to send “ALL UP” power control commands. This would correspond to NR dominant SAR scenario and continue this stage for about 220s.
3. In the second part of test, configure the LTE call box to sent “ ALL UP” power control commands and all transmissions are continued, resulting in maximum power requested from DUT for both LTE and NR. This stage of test is continued for another 110s.
4. In the third part of test, configure the NR call box to send “ALL DOWN” power control commands so that LTE becomes the dominant SAR radio. This stage is continued for another 110s.
5. Finally, both LTE and NR connections are released.

3.3.6 Change in TAS to non TAS Handover

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of TAS to non TAS handover scenarios. Since Both Plimits can change across bands, we have to use below equations below for converting Tx power to SAR as well as apply some combined SAR exposure criteria as shown below.

$$SAR_1(t) = \frac{TxPower_1(t)}{P_{limit,1,FR1}} * SAR\_design\_target_1$$ (equation : 3.3.3.1)

$$SAR_2(t) = \frac{TxPower_2(t)}{P_{limit,2,FR1}} * SAR\_design\_target_2$$ (equation : 3.3.3.2)

where $Plimit$,1,FR1 would correspond to measured power at which first supported TAS band meets measured SAR level of SAR_design_target1 as described in Table 6.2.1 with time-averaging duration of T1,SAR . Similarly, the quantities $Plimit$,2,FR1 , SAR_design_target2 , T2,SAR are defined for the second Non-TAS band.

Test procedure for switching from TAS to Non TAS Handover :

1. Establish radio connection of DUT with call box e.g. using TAS technology in band A which has 100s averaging duration.
2. Configure call box to set DUT Tx power to a low value of -10dBm for 110s.
3. Configure call box to send “ALL UP” power control commands and continue TAS technology transmission From DUT so that maximum power of Pmax is achieved. Continue transmission at the maximum power for at least 110s.
4. Change band from TAS technology band A to Non TAS technology band B. Continue call in Non TAS technology band B with call box requesting maximum power for at least 390s..
5. Release WCDMA connection.
6. After the completion of the test, prepare one plot with the following information for each band (a) Instantaneous Tx power versus time (b) Time-averaged power for each band according to their averaging duration and (c) Plimit corresponding to each band.
7. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each band (b) Sum of time-averaged SAR computed according to Eqn (3.3.3.1) and (3.3.3.2), and (c) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate total time-averaged 1gSAR value versus time does not exceed the FCC limit of 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when band change occurs in-between.

3.3.7 LTE Uplink CA

The test is to demonstrate that Samsung S.LSI TAS feature can properly handle the SAR exposure for LTE with the additional and / or removal of another intra-band LTE CC.

Test procedure for uplink CA :

1. Establish LTE connection of DUT with call box over Cell1 e.g. one cell of intra band-contiguous LTE CC.
2. Configure call box to send “ALL down” power control commands and continue this stage for about 110s.
3. Configure call box to send “ALL UP” command for transmission on cell 1 and continue transmission for 110s.
4. Establish LTE connection of DUT with call box over Cell 2 E.g. other cell of intra band-contiguous LTE CC.
5. Configure Call box to send “ALL UP” command for transmission on cell 2 and continue transmission for 110s.
6. Release LTE connection for both cells.

Pass condition is to demonstrate time-averaged 1gSAR value versus time does not exceed the FCC limit 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when LTE uplink CA is operated during the test.

3.3.8 Spatial TAS

For the test cases with spatial TAS, we will consider all antennas with antenna groups where each antenna group consist of one antenna and one antenna and one/multiple bands.

Test procedure for LTE Antenna switching with spatial TAS :

1. Establish radio connection of DUT with call box e.g. using LTE technology
2. Configure call box to set DUT Tx power to a low value of -10dBm for 100s.
3. Configure call box to send “ALL UP” power control commands and continue LTE transmission from DUT so that maximum power of Pmax is achieved for 240s.
4. Change the band from LTE Band A to LTE Band B so that the transmitting antenna changes and continue transmission for 140s (below 3Ghz) / 90s (above 3GHz).
5. Change the band from LTE Band B to LTE Band A so that the transmitting antenna changes and continue transmission till the end of the test.
6. Release LTE connection.

Test procedure for SA FR1 Antenna switching with spatial TAS :

1. Establish radio connection of DUT with call box e.g. using NR technology
2. Configure call box to set DUT Tx power to a low value of -10dBm for 140s.
3. Configure call box to send “ALL UP” power control commands and continue NR transmission from DUT so that maximum power of Pmax is achieved for 140s.
4. Change the band from NR Band A to NR Band B so that the transmitting antenna changes and continue transmission for 140s.
5. Change the band from NR Band B to NR Band A so that the transmitting antenna changes and continue transmission till the end of the test.
6. Release NR connection.

Test procedure for NSA with spatial TAS :

1. Establish LTE and NR radio connection in NSA case with both call boxes.
2. Configure the LTE call box to send “ALL Down” power control commands for LTE and configure the NR call box to send “ALL Down” power control commands and continue for 150s.
3. Configure LTE call box to send “ALL UP” power control commands for LTE while keeping the configuration of the NR call box at “ALL Down” power control commands. This would correspond to LTE dominant SAR scenario and continue this stage for about 140s.
4. Configure the NR call box to send “ALL UP” power control commands and all transmissions are continued, resulting in maximum power requested from DUT for both LTE and NR. This stage of test is continued for another 140s.
5. Configure the LTE call box to send “ALL Down” power control commands so that NR becomes the dominant SAR radio and continue transmission till the end of the test.
6. Finally, both LTE and NR connections are released.

Test procedure for NSA antenna switching with spatial TAS :

1. Establish LTE and NR radio connection in NSA case with both call boxes.
2. Configure the LTE call box to send “ALL Down” power control commands for LTE and configure the NR call box to send “ALL Down” power control commands and continue for 150s.
3. Configure LTE call box to send “ALL UP” power control commands for LTE and configure the NR call box to send “ALL Down” power control commands. This would correspond to LTE dominant SAR scenario and continue this stage for about 200s.
4. Configure the NR call box to send “ALL UP” power control commands and all transmissions are continued, resulting in maximum power requested from DUT for both LTE and NR. This stage of test is continued for another 200s.
5. Chage NR Band to other band so that NR transmitting antenna is switched to other antenna and continue transmission for 200s.
6. Configure the LTE call box to send “ALL Down” power control commands so that NR becomes the dominant SAR radio and continue transmission till the end of the test.
7. Finally, both LTE and NR connections are released.

4. SAR Time Averaging Validation Test Procedures for Qualcomm FastConnect TAS

The conducted power measurement method is used for all validation test sequences. These tests demonstrate the power enforcement by FastConnect TAS where Plimit could vary before and after transition.

4.1. Test selection for validating TAS

4.1.1 Test selection for Time-Varying Test Sequence

Select one representative test channel from all the available radio configurations (band/ant(s)/DSI) that has Pmax > Plimit + device uncertainty.

- If Pmax < Plimit + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plimit dBm) value.
- If Pmax > Plimit + device uncertainty for more than one radio configuration. Then, order of preference is given by:
    - If multiple radio configurations (band/ant(s)/DSI) meet this criteria, then SISO is preferred over MIMO due to simplified test setup.
    - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plimit dBm) dB delta.
- Test to be performed at two bands for Time-Varying Test sequence test. If only one band within a configuration has Pmax > Plimit and Plimit > Pmax in all other configurations, then only one band needs to be tested.
- Test is not required if Plimit > Pmax for all radio configurations.

Note: The same selection criteria are applicable for both conducted & radiated tests.

4.1.2 Test selection for Change in Antenna

This test scenario does not apply if SISO mode diversity is not supported. (e.g., CDD is enable and always use MIMO). The criteria to select test configuration for change in Antenna measurement is:

- The antenna selected for this test should be in the same antenna group.
- Whenever possible and supported by the EUT, first select antenna switch configuration within the same band/DSI (i.e., same band and DSI combination), and having different Plimit, and having both Pmax > Plimit + device uncertainty where possible. Otherwise, select at least one antenna having Pmax > Plimit + device uncertainty.
    - If multiple radio configurations (band/DSI) meet Pmax > Plimit + device uncertainty, then select the configuration that has largest (Pmax dBm – Plimit dBm) dB delta.
    - If Pmax < Plimit + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plimit dBm) value.
- If the EUT does not support antenna switch within the same band, but has multiple transmitting antenna to support different frequency bands, then antenna switch test should be performed in combination with Change in WLAN band test scenario.
- Test for Change in Antenna is not required if all Plimit > Pmax for all radio configurations.

4.1.3 Test selection for Change in device state index (DSI)

This test scenario does not apply if multiple DSI is not supported in the device. The criteria to select test configuration for Change in DSI measurement is:

- Select a band/antenna having the Pmax > Plimit + device uncertainty within any DSI, and for the same band/antenna(s) having a different Plimit in any other DSI. Both the selected DSIs should have Pmax > Plimit + device uncertainty where possible. Otherwise, select at least one DSI having Pmax > Plimit + device uncertainty.
- If Pmax < Plimit + device uncertainty for all band/antenna(s), then select radio configuration with largest (Pmax dBm – Plimit dBm) value.
- If Pmax > Plimit + device uncertainty for more than one radio configuration, then order of preference is given by:
    - If multiple radio configurations (band/ant(s)/DSI) meet this criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
    - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plimit dBm) dB delta.
- Test for change in DSI is not required if all Plimit > Pmax for all radio configurations.

4.1.4 Test selection for Change in WLAN band

The criteria to select test configuration for Change in WLAN band measurement is:

- First select both bands in a DSI having Pmax > Plimit + device uncertainty where possible. Otherwise, select at least one band having Pmax > Plimit + device uncertainty.
- If Pmax < Plimit + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plimit dBm) value.
- If Pmax > Plimit + device uncertainty for more than one radio configuration, Then, order of preference is given by:
    - If multiple radio configurations (band/ant(s)/DSI) meet this criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
    - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plimit dBm) dB delta.
- The antennas corresponding to the selected bands should be in the same antenna group
- Test for Change in WLAN band is not required if all Plimit > Pmax for all radio configurations.

4.1.5 Test selection for Simultaneous Transmission

This test scenario does not apply if simultaneous transmission within WLAN bands is not supported in the device. The criteria to select test configuration for Simultaneous Transmission measurement is:

- The band must be selected from supported Simultaneous Transmission configuration. (e.g., WLAN DBS and/or HBS)
- First select both bands in a DSI having Pmax > Plimit + device uncertainty where possible. Otherwise, select at least one band having Pmax > Plimit + device uncertainty.
- If Pmax < Plimit + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plimit dBm) value.
- If Pmax > Plimit + device uncertainty for more than one radio configuration. Then, order of preference is given by:
  - If multiple radio configurations (band/ant(s)/DSI) meet this criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
  - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plimit dBm) dB delta.
- The antennas corresponding to the selected bands should be in the same antenna group.
- Even if a device has Plimit > Pmax for all radio configurations, then “Simultaneous Transmission” test scenario should still be performed for validation of FastConnect TAS device.

Note: For all above test selection. Pmax = min (CTL, Regdomain, TPE/TPC, Rate-to-power) of the selected channel/rate/band. Since FastConnect TAS supports the same Plimit for all modulations in same antenna/band/DSI, the selection of test modulation/channel chooses the highest Pmax modulation.

4.2. Test procedure for conducted power measurements

1. Measure Plimit for modes at validation antenna ports, bands and/or DSIs with FastConnect TAS Peak Exposure Mode enabled with callbox to establish the chosen mode for test. Denote this measured power value as *Conducted_Tx_power_Plimit*.

   Note : The measurement of Peak Exposure Mode should be performed with 70% or higher WLAN duty cycle (for example, using iPerf to generate UL traffic).

2. Set DUT to the intended FastConnect TAS mode.

3. Establish radio link with the callbox in the selected band.

   Note : for the purpose of collecting repeatable time averaged power data, it is recommended to include a section of 30s at the beginning of every test with the device WLAN connection disconnected or turned off or transmitting at a very low duty cycle.

4. Request EUT to transmit in following Transition sequence:

   a. **Time-Varying Test Sequence #1** - Request EUT to transmit maximum power for at least 30s with 100% duty cycle and 50% duty cycle for 60s to determine time-averaged 1gSAR versus time.

Time duration (seconds)	Duty Cycle (%)
30	100%
60	50%

   b. **Change in antenna** – EUT operates at Antenna 1 (e.g., Main antenna port) and requests to transmit at maximum power for at least 60s. Then switch to operation on Antenna 2 (e.g., Aux antenna port), followed by at least 120s of observation.

   c. **Change in device state (DSI)** – EUT operates at DSI 1 and requests to transmit at maximum power for at least 60s.

   d. **Change in WLAN band –** EUT operates at Band 1 and requests to transmit a maximum power for at least 60s. Then it switches to Band 2 using the same antenna port and observes another 120s (observation period includes transition time).

   e. **Simultaneous Transmissions** : First establish WLAN connection with the callbox in radio2 configuration and request radio2 configuration to transmit at maximum duty cycle for at least 120s to test predominantly radio2 SAR exposure scenario. Then add radio1 configuration to the existing radio2 configuration call, and request both radio1 and radio2 to transmit at maximum duty cycle to test radio1 and radio2 SAR exposure scenario for at least 120s. Then drop (or request low duty cycle) for radio2 configuration to test predominantly radio1 SAR exposure scenario for another at least 120s. Record the conducted Tx power for both radio1 and radio2 configurations for the entire duration of this test.

   Note : radio1 and radio2 should operate at different band.

5. Measure and record Tx power versus time.

   a. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1g_or10g SAR value, see Eq. (1a), using step 1 result.
   b. Then perform 30s moving average to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 4-6.

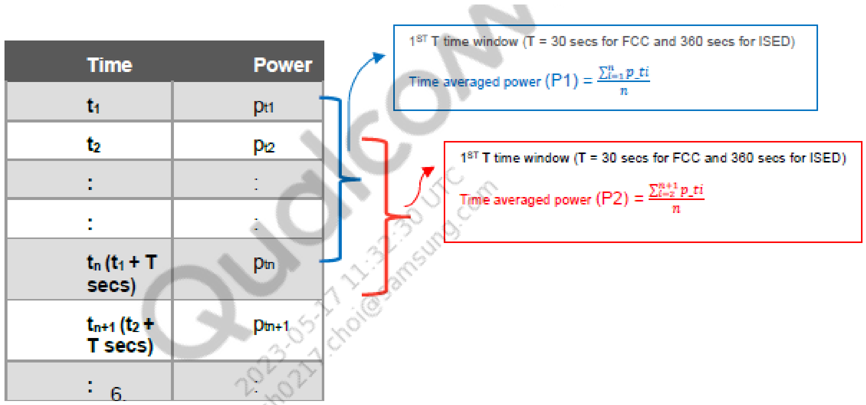


Figure 4-6 Time running/moving average illustration

The following normalization is used to convert 1g_or_10gSAR exposure using Equation (1a) and (1c) in section 2.2 to validate the continuity of RF exposure limit during the transition. The procedures from step1 and step2 in this section should be completed for each configuration under test and use below equations to validated the RF exposure during the transition.

☐ if tested with both radio configurations below 6GHz:

$$1g\_or\_10gSAR_1(t) = \frac{Conducted\_Tx\_power\_1\,(t)}{Conducted\_Tx\_power\_Plim\_1} * 1g\_or\_10gSAR\_Plim\_1 \qquad (4a)$$

$$1g\_or\_10gSAR_2(t) = \frac{Conducted\_Tx\_power\_2\,(t)}{Conducted\_Tx\_power\_Plim\_2} * 1g\_or\_10gSAR\_Plim\_2 \qquad (4b)$$

$$\frac{\frac{1}{TSAR}\left[\int_{t-TSAR}^{t1} 1g\_or\_10gSAR1(t)\,dt + \int_{t-TSAR}^{t} 1g\_or\_10gSAR2(t)\,dt\right]}{FCC\ or\ ICNIRP\ SAR\ limit} \le 1 \qquad (4c)$$

Where, conducted_Tx_power_1(t), conducted_Tx_power_Plimit_1, and 1g_or_10gSAR_Plimit_1 correspond to the instantaneous Tx power, conducted Tx power at Plimit_1 of DUT, and compliance 1g_or10gSAR values of Antenna 1 (or Band 1 or DSI1) at Plimit_1;
Conducted_Tx_power_2(t), conducted_Tx_power_Plimit_2, and 1g_or_10gSAR_Plimit_2 correspond to the instantaneous Tx power, conducted Tx power at Plimit_2 of DUT, and compliance 1g_or_10gSAR values of Antenna 2 (or Band2 or DSI2) at Plimit_2.

Transition from the Antenna 1 (or Band 1or DSI1) to the Antenna 2 (or Band 2 or DSI2) happens at time-instant 't1'.

6. Mark one plot containing:

   a. Computed time-averaged 1g_or_10gSAR versus time from above procedure.
   b. Corresponding regulatory 1g_or_10gSAR limit.

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

4.3. Test procedure for pointSAR measurement test sequence

4.3.1 Test selection criteria

The pointSAR test is performed only with Time-Varying Test Sequence to provide high confidence in the algorithm validation. The radio configuration for this test is selected by following the selection criteria described in Section 4.1.1.

4.3.2 Test procedure

1. For a given radio configuration:
    a. Enable WLAN connection with callbox in FastConnect TAS Peak Exposure Mode and enable high duty cycle Tx while performing the following steps.
    b. Perform the area scan.
    c. Conduct pointSAR measurement at peak location of the area scan for 120s.

    This pointSAR value, pointSAR_Plimit corresponds to pointSAR at the measured Plimit.

    Note: The measurement of Peak Exposure Mode should be performed with 70% or higher WLAN duty cycle (for example, using iPerf to generate UL traffic).

2. Set EUT to intended FastConnect Time-Averaged Exposure Mode with callbox to establish the same chosen radio configuration (mode/channel) for test.
    a. Perform Time-averaged point SAR measurements at the same peak location as Peak Exposure Point SAR measurement for 120s. Note this includes initial 30s with WLAN with very low duty cycle (or WLAN is disconnected) and 90s of high duty cycle (WLAN has to be connected with high uplink traffic).
    b. Once the measurement is done, extract instantaneous pointSAR versus time data, pointSAR(t).
    c. Convert it into instantaneous 1gSAR versus time by using Equation (5a):

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (5a)$$

    Where, pointSAR_Plimit corresponds to the value determined in Step 1, and pointSAR(t) corresponds to instantaneous point SAR determined in Step 2 in this section.

    d. Then perform 30s moving average to determine time-averaged 1gSAR versus time.

3. Make one plot containing :
    a. Computed time-averaged 1g_or_10gSAR versus time determined from Step.2
    b. Regulatory 1g_or_10gSAR limit.

    The validation criteria for pointSAR measurement is, at all times, the time averaged 1g_or_10gSAR versus time shall net exceed the regulatory 1g_or_10gSAR limit.

5 Conducted power Test Configurations & Test Results

5.1. Test case list for WWAN (sub-6) band of S.LSI TAS validation

To validate TAS algorithm in various sub-6GHz conditions, the chosen TC (Test Case) list is defined as in Table 5.1.1.

Table 5.1.1 Sub-6GHz TAS validation test case list

No.	Test Scenarios	Test cases	Test configurations
F_TC 01	Time-varying Tx Power transmission	LTE_Time_Varying_Tx_Power_Case_1	Selected two LTE Bands, Test Seq.A.i
F_TC 02		SA_FR1_Time_Varying_Tx_Power_Case_1	Selected two NR Bands, Test Seq.A.ii
F_TC 03		LTE_Time_Varying_Tx_Power_Case_2	Selected two LTE Bands, Test Seq.B
F_TC 04		SA_FR1_Time_Varying_Tx_Power_Case_2	Selected two NR Bands, Test Seq.B
F_TC 05	Change in call	LTE_Call_Disconnect_Reestablishment	Selected one LTE Band
F_TC 06	Re-selection in call	SA_FR1_to_LTE_RAT_Re-selection	Selected one LTE Band and one NR Band
F_TC 07	Change in band / time window	LTE_Averaging_Time_Window_Change	Switched LTE Band A(100s) to LTE Band B (60s)
F_TC 08		LTE_Averaging_Time_Window_Change 2	Switched LTE Band B(60s) to LTE Band A(100s)
F_TC 09	SAR exposure switch	NSA_FR1_Dominant_Power_Switching	Selected one LTE Band and one NR Band
F_TC 13	Change in RSI	SA_FR1_RF_SAR_Index_Change	Selected one NR Band
F_TC 19	WCDMA Time-varying Tx Power transmission	WCDMA_Time_Varying_Tx_Power_Case_1	Selected two WCDMA Bands, Test Seq.A.iii
F_TC 20		WCDMA_Time_Varying_Tx_Power_Case_2	Selected two WCDMA Bands, Test Seq.B
F_TC 21	2G(GSM) Time-varying Tx Power transmission	GSM_Time_Varying_Tx_Power_Case_1	Selected two GSM Bands, Test Seq.A.iv
F_TC 22		GSM_Time_Varying_Tx_Power_Case_2	Selected two GSM Bands, Test Seq.B
F_TC 23	Antenna Switching with Spatial TAS	LTE_Ant_switching_Spatial_TAS	Selected one LTE Band
F_TC 25	NSA with Spatial TAS	NSA_Spatial_TAS	Selected one NSA configuration
F_TC 26	NSA antenna switching with Spatial TAS	NSA_Ant_switching_Spatial_TAS	Selected two NSA configuration (same LTE anchor)

5.1.1 Conducted Power Test Results for WWAN (Sub-6) TAS validation

5.1.1.1 Measurement set-up

WWAN(GSM/WCDMA/LTE/NR) test setup using The Anritsu MT8821C callbox

The Anritsu MT8821C callbox is used in this test.

Test setup Schematic	Test item(s)	Description(s)	Test setup photo
Figure B-1(a)	Time-varying Tx power transmission test (Section 3.3.1)	Single antenna measurement, one port of callbox	A.1
	Change in Call test (Section 3.3.2)		
Figure B-1(b)	Antenna swithcing with Spatial TAS (Section 3.3.8)	Two antenna measurement, one port of callbox	A.2
Figure B-1(c)	Time-varying Tx power transmission test (Section 3.3.1)	Single antenna measurement, one port of callbox	A.3
	Change in time-window (Section 3.3.3)		
	Change in RSI (Section3.3.4)		
Figure B-1(d)	SAR exposure switch (Section 3.3.5)	Two antenna measurement, two port of callbox	A.4
	NSA with Spatial TAS (Section 3.3.8)		
Figure B-1(e)	FR1 to LTE IRAT Re-selection (Section 3.3.3)	Single antenna measurement, two port of callbox	A.5
Figure B-1(f)	NSA antenna switching with Spatial TAS (Section 3.3.8)	Two antenna measurement, two port of callbox	A.6

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

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

Figure B-1 (a)

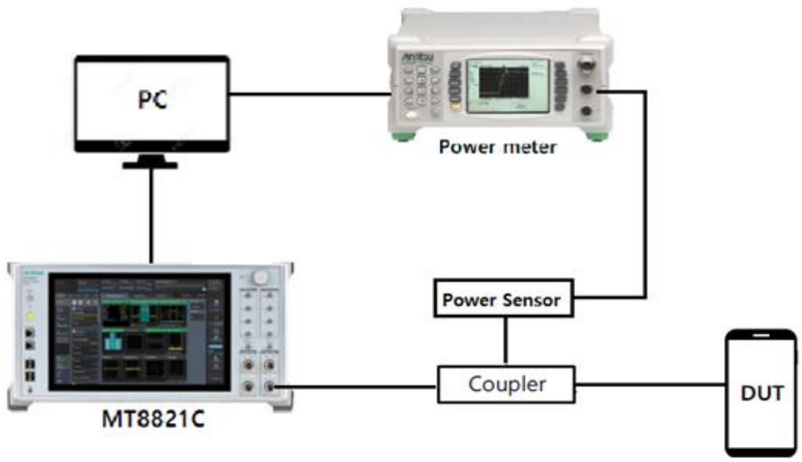


Figure B-1 (b)

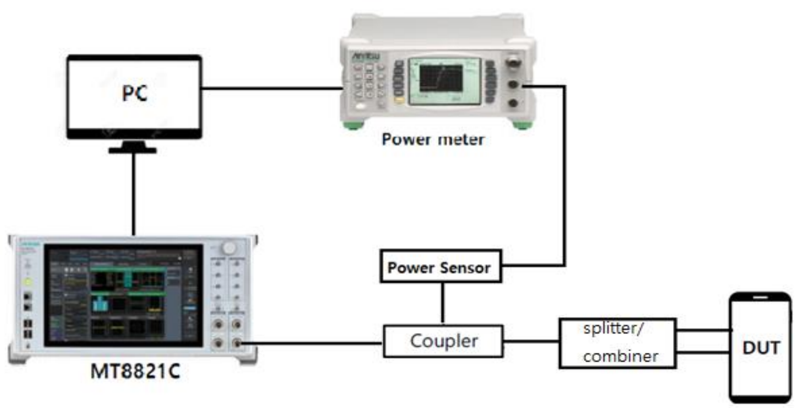


Figure B-1 (c)

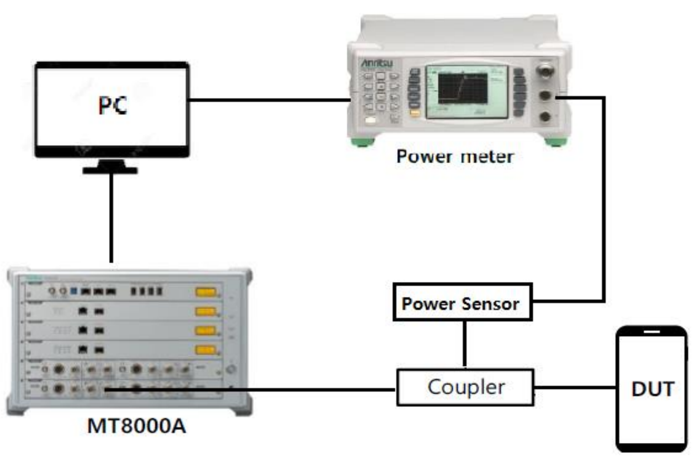


Figure B-1 (d)

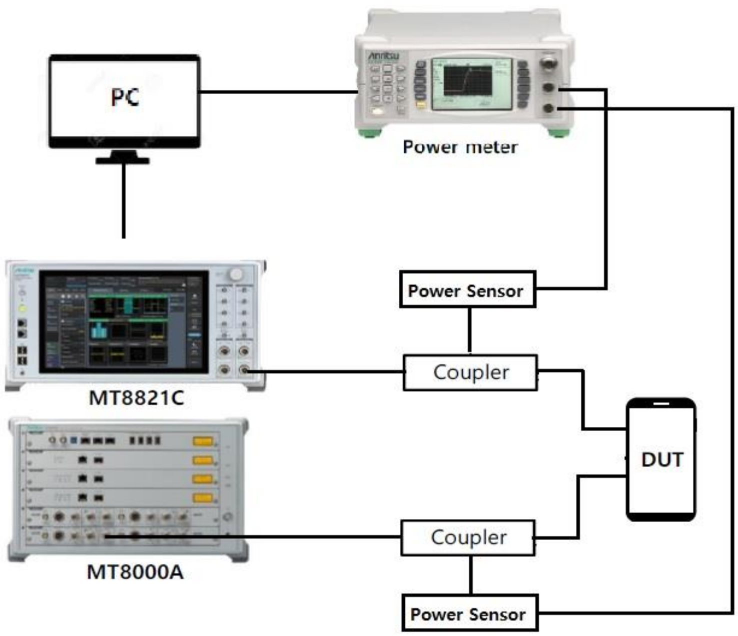


Figure B-1 (e)

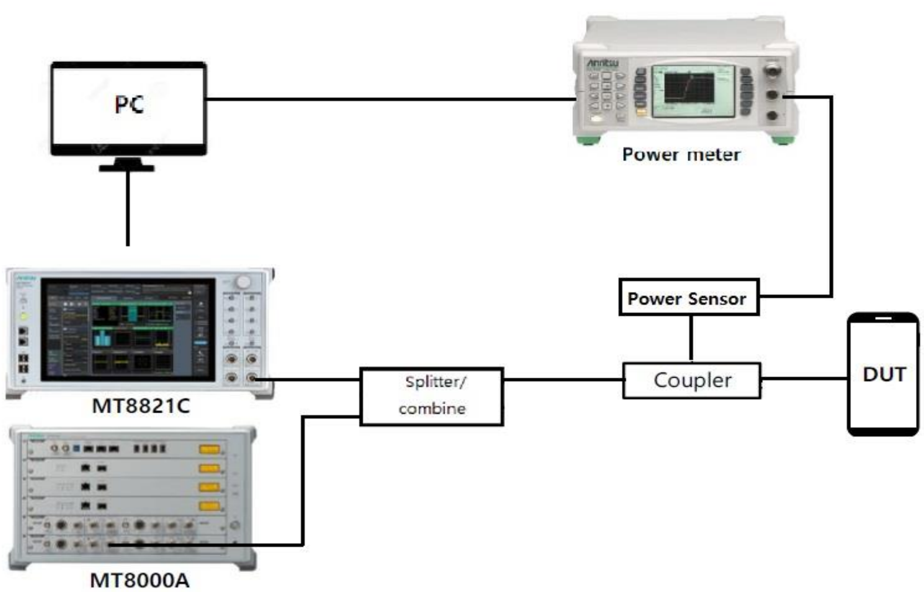


Figure B-1 (f)

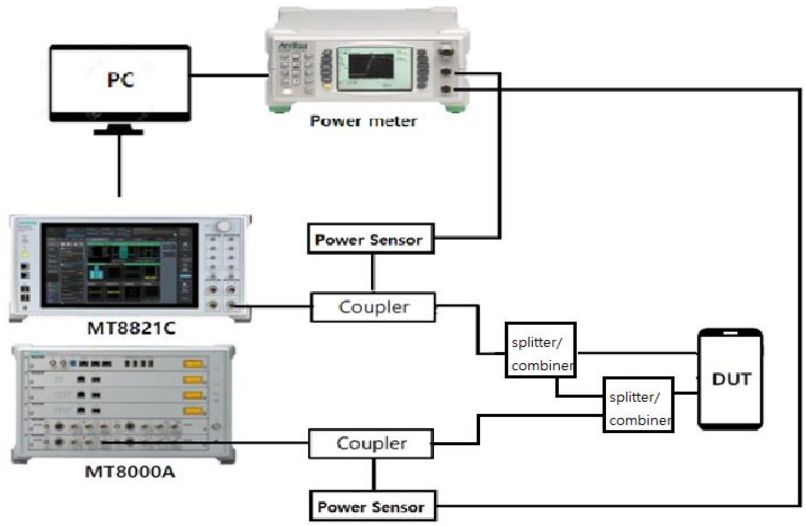


Figure 5.1-1 Test set-up for legacy and sub 6GHz

The test setup for TAS validation with sub-6GHz RATs only is shown in Figure 5.1-1. Normally, a power sensor would measure total power in the entire frequency of its specification e.g. 10MHz to 18GHz for the MA2472D unit. However, when two radios are active, we need to measure their powers separately for using the corresponding SAR mapping table. Therefore, this test setup considers scenarios where two radios would be transmitting from different ports of the DUT so that separate power sensors measure them individually. A common power meter is able to display and record the readings for each sensor at the same time for postprocessing at a PC. The signaling call boxes MT8000A and MT8821C are used to establish the call and data connection to the DUT on those same ports for NR and LTE, respectively. The couplers are able to provide the transmit signal from DUT to power sensors while uplink and downlink signaling messages exchanged with the call boxes on the same paths. We can build scripts to program a certain sequence of power control commands from the call boxes to the DUT which can essentially instruct the DUT to change its transmit power. Thus, if we want DUT to transmit at maximum power in LTE, then continuous power up commands are sent by MT8821C. Similarly, continuous power up commands from MT8000A will try to increase NR power up to its maximum limit. Other power control scenarios which mimic real field behavior such as sequence of power up followed by power down are also possible as described in Section 4.1 and Section 5.1. All the path losses from RF port of DUT to the callbox and the power meters are calibrated and automatically entered as offsets in the callbox and power meter, which are also connected to the control PC used in the test setup. We use an Anritsu AMS tool, which is capable of executing the entire test sequence including requested power variation over time and call setup/disconnect scenarios based on pre-configured test case definition. Power readings for each active technology are recorded every 100ms and dumped in an excel file. A postprocessing tool is used to extract data from the excel file and plot the required metrics such as time-averaged power, SAR and TER values versus time as described in Section 3.3. In summary, the tests have to be executed as following procedure.

1. Measure conduction sub 6GHz Tx power corresponds to SAR regulation.
2. Set sub 6GHz power level with some margin. And start the test
3. Execute time-varying test scenarios. And record sub 6GHz power using sub 6GHz power meter equipment.
4. Plot the recorded results over measurement time. And evaluate the results for validation.

Note that Plimit is different according to the used OEM, so it is necessary to set the Plimit suitable for each terminal.

5.1.1.2 P_{limit} and P_{max} measurement results

The measured $Plimit$ for all the selected radio configurations are listed in Table 5.1.2. $Pmax$ was also measured for radio configurations selected for testing time-varying Tx power transmission scenario in order to generate test sequences following the test procedures. Note that Table 5.1.2 is not actual Plimit corresponding to 1W/kg SAR, but our measured averaged power when forcing Plimit in our SW.

Table 5.1.2 Measured P_{limit} and P_{max} of selected radio configurations

TC #	Test Scenarios	Tech	Band	Ant.	RSI	RB/offset	Mode	Detail	Plimit setting (dBm)	Pmax setting (dBm)	Measured Plimit (dBm)	Measured Pmax (dBm)
F_TC_ 01	Time varying (Seq.A i)	LTE	B2	F	RCV	1/49/20 MHz	QPSK	1g/0mm/Head_Right Tilt	15.5	22.5	14.70	22.70
F_TC_ 03	Time varying (Seq.B)			F	RCV	1/49/20 MHz	QPSK	1g/0mm/Head_Right Tilt	15.5	22.5	14.70	22.70
F_TC_ 01	Time varying (Seq.A i)		B5	E	RCV	1/0/10 MHz	QPSK	1g/0mm/Head_Left Touch	19.5	23.5	18.86	23.97
F_TC_ 03	Time varying (Seq.B)			E	RCV	1/0/10 MHz	QPSK	1g/0mm/Head_Left Touch	19.5	23.5	18.86	23.97
F_TC_ 02	Time varying (Seq.A ii)	NR	Bn5	E	RCV	1/52/20 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Left Touch	19.5	24.0	18.82	23.77
F_TC_ 04	Time varying (Seq.B)			E	RCV	1/52/20 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Left Touch	19.5	24.0	18.82	23.77
F_TC_ 02	Time varying (Seq.A ii)		Bn77	F	RCV	1/136/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.0	24.5	15.07	24.67
F_TC_ 04	Time varying (Seq.B)			F	RCV	1/136/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.0	24.5	15.07	24.67
F_TC_ 05	Change in call (Disconnect-Re-establishment)	LTE	B25	A	Hotspot	1/49/20 MHz	QPSK	1g/10mm/Hotspot_Bottom	18.5	23.0	18.59	22.56
F_TC_ 06	FR1 to LTE IRAT Re-selection	LTE	B12	A	Hotspot	1/0/10 MHz	QPSK	1g/10mm/Hotspot_Rear	23.5	23.5	23.95	23.95
		NR	Bn25	A	Hotspot	1/52/20 MHz	DFT-s OFDM QPSK	1g/10mm/Hotspot_Bottom	19.0	23.5	18.92	23.03
F_TC_ 07	Window change case 1	NR	Bn41 (PC2)	F	RCV	1/1/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	16.0	24.0	16.27	23.86
		NR	Bn77	F	RCV	1/136/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.0	24.5	15.07	24.67
F_TC_ 08	Window change case 2	NR	Bn41	F	RCV	1/1/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	16.0	24.0	16.27	23.86
		NR	Bn77	F	RCV	1/136/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.0	24.5	15.07	24.67
F_TC_ 09	Switch in SAR exspure (FR1 dominant power change)	LTE	B13	A	Hotspot	1/0/10 MHz	QPSK	1g/10mm/Hotspot_Rear	23.5	23.5	23.71	23.71
		NR	Bn66	A	Hotspot	1/1/20 MHz	DFT-s OFDM QPSK	1g/10mm/Hotspot_Bottom	19.5	23.5	19.12	23.27
F_TC_ 13	Change in RSI	NR	Bn25	F	Free	1/52/20 MHz	DFT-s OFDM QPSK	1g/10mm/Hotspot_Top	19.0	23.0	18.37	22.95
					RCV	1/52/20 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.5	23.0	14.83	22.95
F_TC_ 19	Time varying (Seq.A iii)	WCDMA	4	A	Hotspot	-	Rel 99	1g/10mm/Hotspot_Bottom	19.0	23.0	19.21	22.81
F_TC_ 20	Time varying (Seq.B)		4	A	Hotspot	-	Rel 99	1g/10mm/Hotspot_Bottom	19.0	23.0	19.21	22.81
F_TC_ 19	Time varying (Seq.A iii)		5	E	RCV	-	Rel 99	1g/0mm/Head_Left Tilt	18.5	22.0	18.78	23.4
F_TC_ 20	Time varying (Seq.B)		5	E	RCV	-	Rel 99	1g/0mm/Head_Left Tilt	18.5	22.0	18.78	23.4
F_TC_ 21	Time varying (Seq.A iv)	GSM	850	E	RCV	-	GPRS 4 slot	1g/0mm/Head_Left Touch	19.0	24.0	19.41	24.28
F_TC_ 22	Time varying (Seq.B)		850	E	RCV	-	GPRS 4 slot	1g/0mm/Head_Left Touch	19.0	24.0	19.41	24.28
F_TC_ 21	Time varying (Seq.A iv)		1900	A	Hotspot	-	GPRS 4 slot	1g/10mm/Hotspot_Rear	17.8	20.3	17.58	19.72
F_TC_ 22	Time varying (Seq.B)		1900	A	Hotspot	-	GPRS 4 slot	1g/10mm/Hotspot_Rear	17.8	20.3	17.58	19.72
F_TC_ 23	Antenna swtiching with Spatial TAS	LTE	B26	E	Hotspot	1/0/15 MHz	QPSK	1g/10mm/Hotspot_Rear	18.0	23.0	17.81	23.48
		LTE	B41	B	Hotspot	1/0/20 MHz	QPSK	1g/10mm/Hotspot_Bottom	18.5	20.5	18.99	20.42
F_TC_ 25	NSA with Spatial TAS	LTE	B66	A	Hotspot	1/0/20 MHz	QPSK	1g/10mm/Hotspot_Bottom	18.0	22.5	17.04	22.8
		NR	Bn41	F	RCV	1/1/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	16.0	24.0	16.27	23.86
F_TC_ 26	NSA antenna switching with Spatial TAS	LTE	B12	A	Hotspot	1/0/10 MHz	QPSK	1g/10mm/Hotspot_Rear	23.5	23.5	23.95	23.95
		NR	Bn25	A	Hotspot	1/52/20 MHz	DFT-s OFDM QPSK	1g/10mm/Hotspot_Bottom	19.0	23.5	18.92	23.03
		NR	Bn77	F	RCV	1/136/100 MHz	DFT-s OFDM QPSK	1g/0mm/Head_Right Tilt	15.0	24.5	15.07	24.67

Note(s):

1. This device does not support LTE UL CA (inter band -contiguous). So Section 3.3.7 is not consider.

2. This device does not consider about Chage in TAS to non TAS Handover in Section 3.3.6. Because All WWAN bands supports to TAS feature.

Even if the same SAR_design_target is set, the Plimit will be changed according to the used OEM.

**Plimit and Pmax for LTE TDD Band in the table above were written with Burst average power, but the test was conducted with Frame average power.

**Plimit and Pmax for NR FR1 TDD Bands in the table above were written with Frame average power at 88.5% duty cycle using Call box.

***Following S.LSI chipset manufacturer's guide, S.LSI TAS algorithm has the following operation added.

1. For NR FDD Bands, If Plimit is below 18.0 dBm, Peak power is limited Plimit+6dB even if Pmax is more higher.
2. For NR TDD Bands, NR TDD Band is the same as NR FDD band operation (note.1), with an additional power back-off for duty cycle : Peak power = (Plimit + 6dB) + 10*Log10(100%/duty cycle)
3. NR FDD and TDD bands can operates up to Pmax power for only EN-DC(NSA) operation.

Detail of explain refer to operational description.

5.2. Test case list for WLAN bands of Qualcomm FastConnect TAS validation

To validate TAS algorithm in various WLAN conditions, Using the tool provided by Qualcomm, validation items from section 4.1.1 to section 4.1.5 were verified.

5.2.1 Conducted Power Test Results for WLAN TAS validation

5.2.1.1 Measurement set-up

WLAN test setup using The Rohde & Schwarz CMW500 callbox

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

Test setup Schematic	Test item(s)	Description(s)	Test setup photo
Figure C-1(a)	Time-varying Tx power transmission test (Section 4.1.1)	Two antenna measurement, two port (RF1 & RF3 COM) of callbox	A.7
	Change in DSI test (Section 4.1.3)		
Figure C-1(b)	Change in Band and Antenna test (Section 4.1.2/4.1.4)	Three antenna measurement, two port (RF1 & RF3 COM) of callbox	A.8
Figure C-1(c)	SAR exposure switch test (DBS) (Section 4.1.5)	Three antenna measurement, three port (RF1 & RF3 &RF4 COM) of call box	A.9

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

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

Figure C-1 (a)

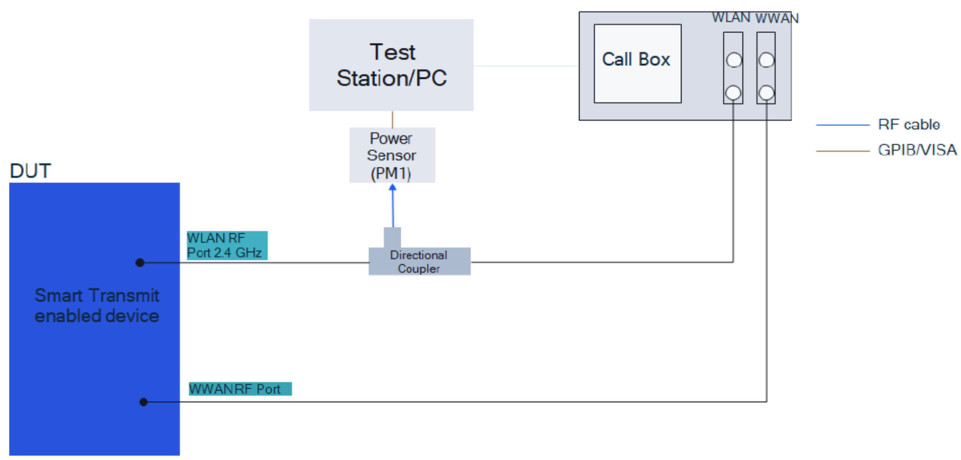


Figure C-1 (b)

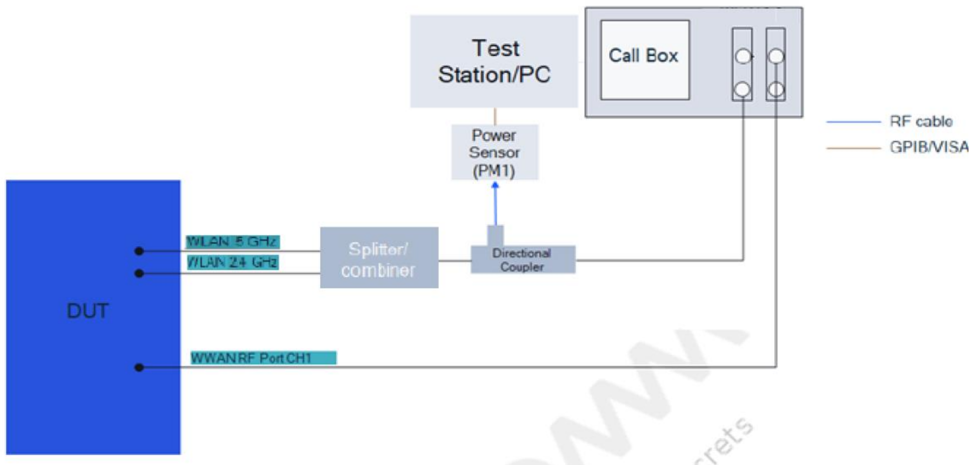
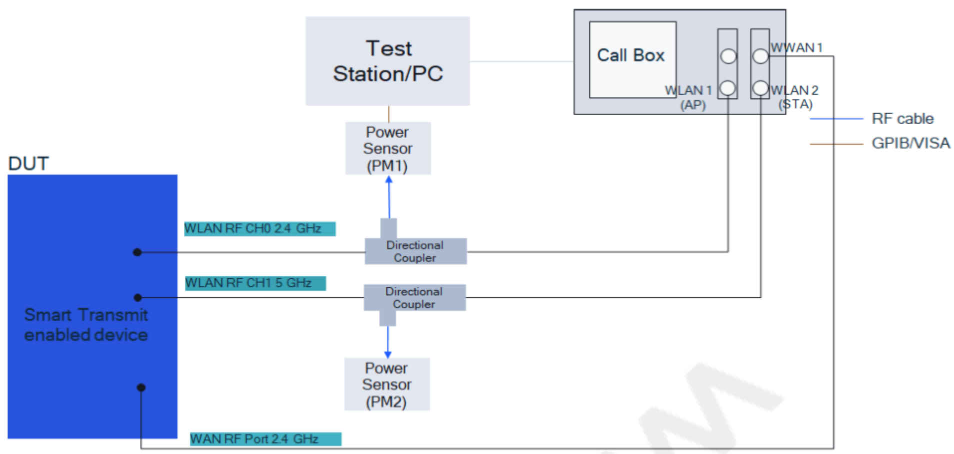


Figure C-1 (c)



Both the callbox and power meter are connected to the PC using LAN port. Two test scripts are custom made for automation, and the test duration set in the test scripts is about 500 seconds. For time-varying Tx power measurement, the PC runs the 1st test script to send LAN commands to control the callbox's requested power versus time, while at the same time to record the conducted power measured at EUT RF port using the power meter. The commands sent to the callbox to request power are:

- 0 dBm for 100 seconds
- Test sequence #1 (defined in Section 3.1 and generated in Section 3.2.1), For 200 seconds
- Stay at the last power level of test sequence #1 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 of WWAN Bands (the 30s-time averaged power of WLAN Bands).

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.

5.2.1.2 P_{limit} and P_{max} measurement results

This measured Plimit for all the selected radio configurations are listed in below Table 5.2.1. Pmax was also measured for radio configurations selected for testing time-varying Tx power transmission scenarios in order to generate test sequences following the test procedures in Section 4.1.

Table 5.2.1 : Measured P_{limit} and P_{max} of selected WLAN radio configurations

Note: the device uncertainty of P_{max} is +1.0dB/-1.5dB as provided by manufacturer.

Test Case	Test Scenario	Tech	Band	Antenna	DSI	Channel	Freq. (MHz)	RB/RB Offset /Bandwidth (MHz)	Mode	SAR Exposure Scenario	Worst configurations	Part 1 Worst Case Measured SAR at Plimit (W/kg)	Plimit (dBm)	measured Plimit (dBm)	Pmax (dBm)	measured Pmax (dBm)
1	Time-varying	WLAN	2.4GHz	Ant.2	1	11	2462	20MHz	802.11 b mode	Head	Left Touch - 0mm	0.308	11.0	11.25	18.0	17.81
		WLAN	5GHz	Ant.1	1	124	5620	20MHz	802.11 a mode	Head	Right Touch -0mm	0.325	11.0	11.92	16.0	15.52
2	Change in Band /Antenna	WLAN	2.4GHz	Ant.1	1	6	2437	20MHz	802.11 ax mode	Head	Right Touch -0mm	0.161	11.0	10.68	16.0	15.16
		WLAN	5GHz	Ant.2	1	100	5500	20MHz	802.11 ax mode	Head	Right Touch -0mm	0.082	11.0	10.97	16.0	16.37
3	Change in DSI	WLAN	2.4GHz	Ant.1	1	6	2437	20MHz	802.11 b mode	Head	Right Touch -0mm	0.161	11.0	11.46	18.0	17.73
		WLAN	2.4GHz	Ant.1	0	6	2437	20MHz	802.11 b mode	Hotspot	Edge Right - 10mm	0.148	14.5	13.74	18.0	17.73
4	DBS SAR vs SAR	WLAN	2.4GHz	Ant.2	0	1	2412	20MHz	802.11 b mode	Hotspot	Rear -10mm	0.079	14.5	13.94	18.0	17.81
		WLAN	5GHz	Ant.2	0	155	5775	20MHz	802.11 ac mode	Hotspot	Rear -10mm	0.039	12.0	12.02	16.0	15.59

5.3 Time-varying Tx power measurement results

WWAN Bands

Following the test procedure in Section 3.3.1, the conducted Tx power measurement results for all selected test cases are listed in this section. In all conducted Tx power plots, the blue line shows the measured instantaneous power using the power meter, the red line shows the time-averaged Tx power and yellow line shows the Plimit value corresponding to design target. In all SAR plots, the dotted blue line shows the time-averaged 1gSAR while the red line shows the corresponding FCC limit of 1.6W/Kg.

Time-varying Tx power measurements were conducted on TC #1 ~ #4 and TC #19 ~ #22 in Table 5.1.2, by generating test sequence A and B given in Section A using measured P_{limit} and measured Pmax (last two columns of Table 5.1.2) for each of these test cases. Measurement results for TC #1 ~ #4 and TC #19 ~ #22 are given in Sections 5.3.1 – 5.3.8.

WLAN Bands

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.(4a), 4(b) and (4c), rewritten below:

☐ if tested with both radio configurations below 6GHz:

$$1g\_or\_10gSAR_1(t) = \frac{Conducted\_Tx\_power\_1\ (t)}{Conducted\_Tx\_power\_Plim\_1} * 1g\_or\_10gSAR\_\ Plim\ \_1 \qquad (4a)$$

$$1g\_or\_10gSAR_2(t) = \frac{Conducted\_Tx\_power\_2\ (t)}{Conducted\_Tx\_power\_Plim\_2} * 1g\_or\_10gSAR\_\ Plim\ \_2 \qquad (4b)$$

$$\frac{\frac{1}{TSAR}\left[\int_{t-TSAR}^{t_1} 1g\_or\_10gSAR1(t)\,dt + \int_{t-TSAR}^{t} 1g\_or\_10gSAR2(t)\,dt\right]}{FCC\ or\ ICNIRP\ SAR\ limit} \le 1 \qquad (4c)$$

Where, *conducted_Tx_power(t)*, *conducted_Tx_power_*P_{limit}, and *1g_or_10gSAR_*P_{limit} correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR* and *10gSAR* value at P_{limit} reported in SAR test report(listed in Table 5.2.1 of this report as well). Following the test procedure in Section 4.2, 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, 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.

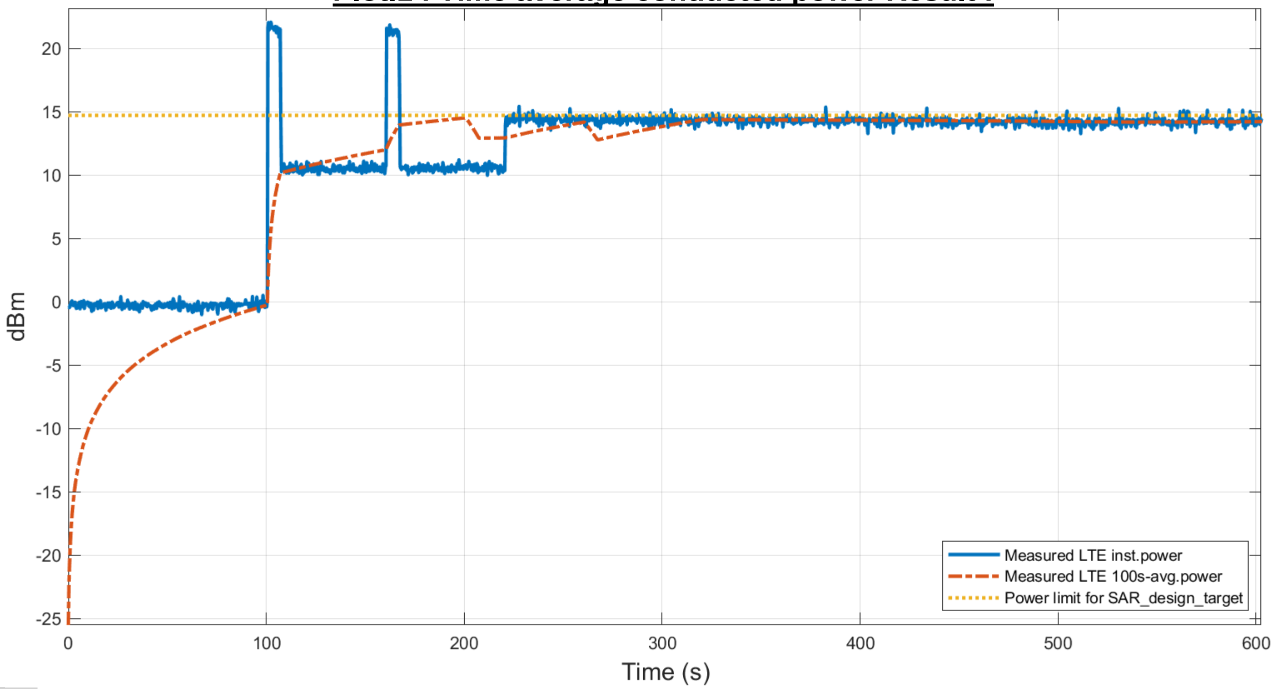
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (4a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Time-varying Tx power measurements were conducted on test case #1 in Table 5.2.1, by generating WLAN test sequence given in Section A using measured P_{limit} and measured Pmax (last two columns of Table 5.2.1) for each of these test cases. Measurement results for test cases #1 are given in Sections 5.3.9 – 5.3.10.

5.3.1 LTE Band 2

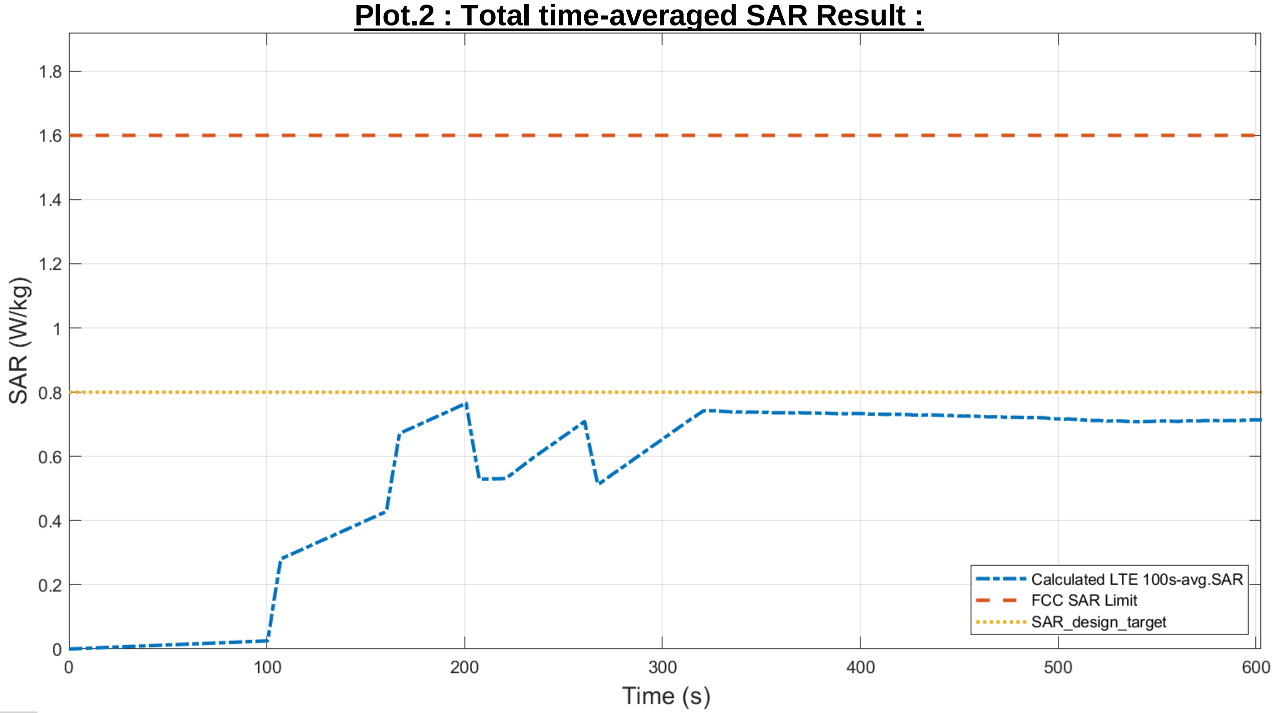
(TC01: LTE Band_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

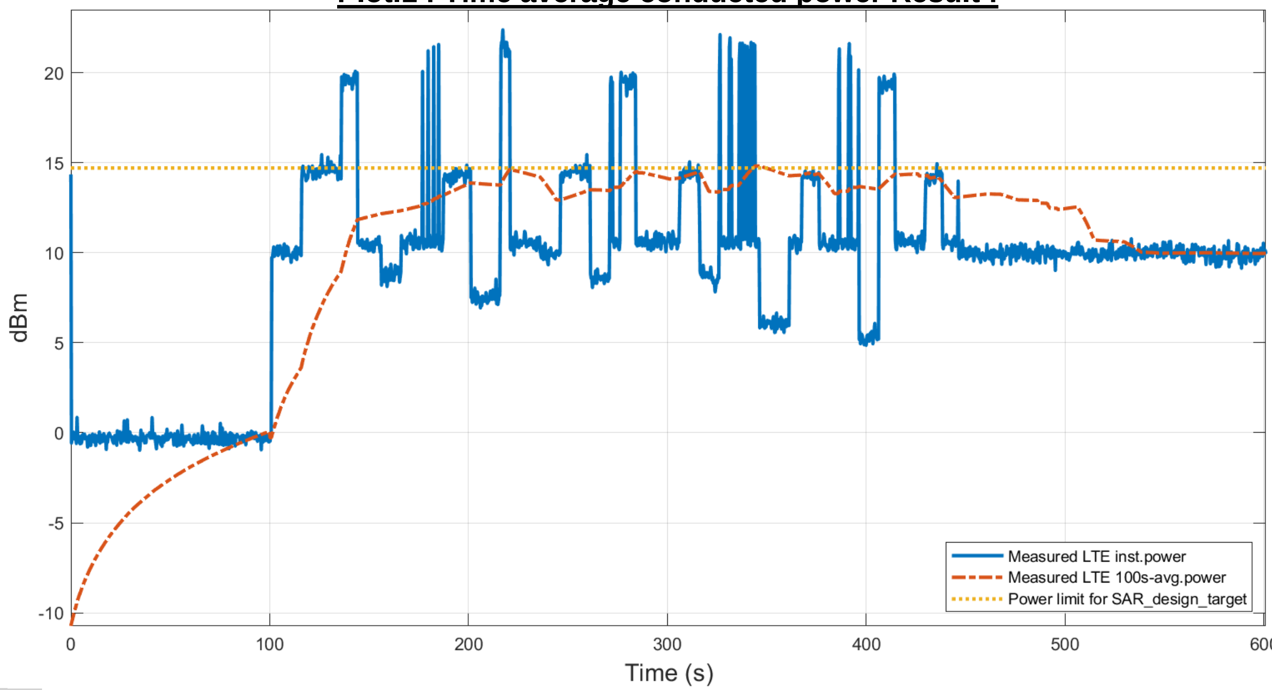


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.766**	W/kg
Device uncertainty	**1.0**	dB

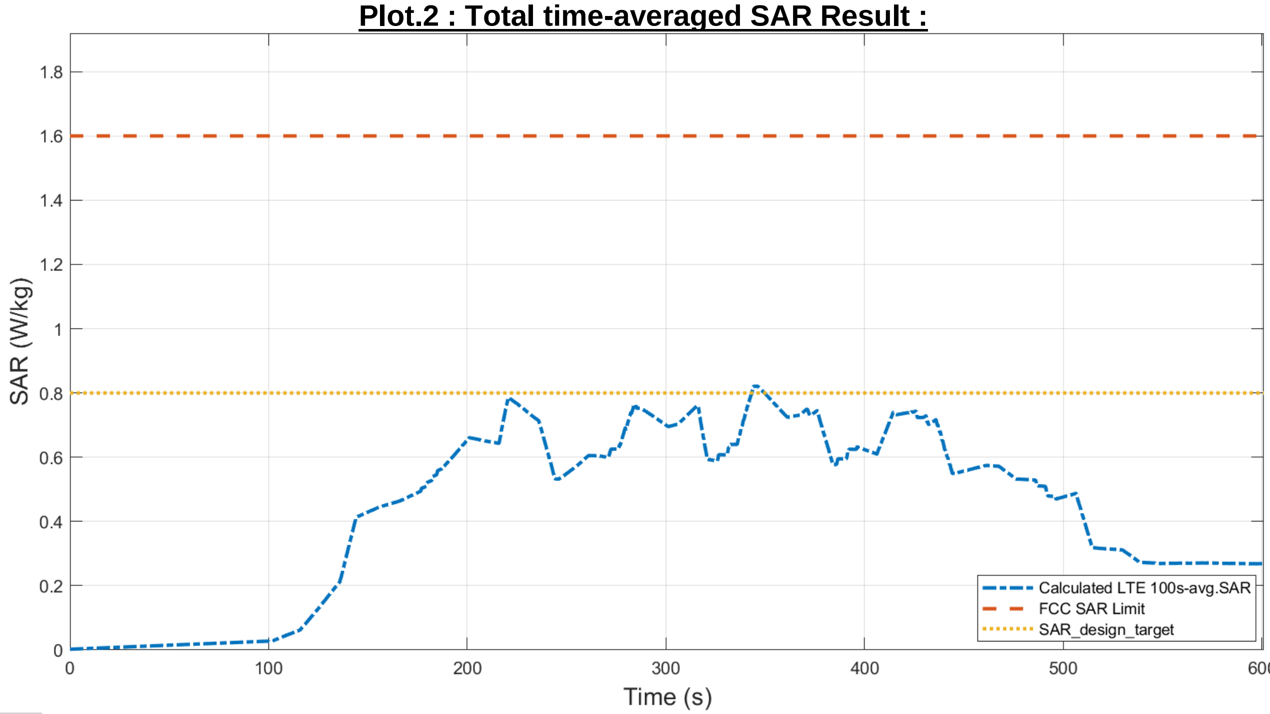
(TC03: LTE Band_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



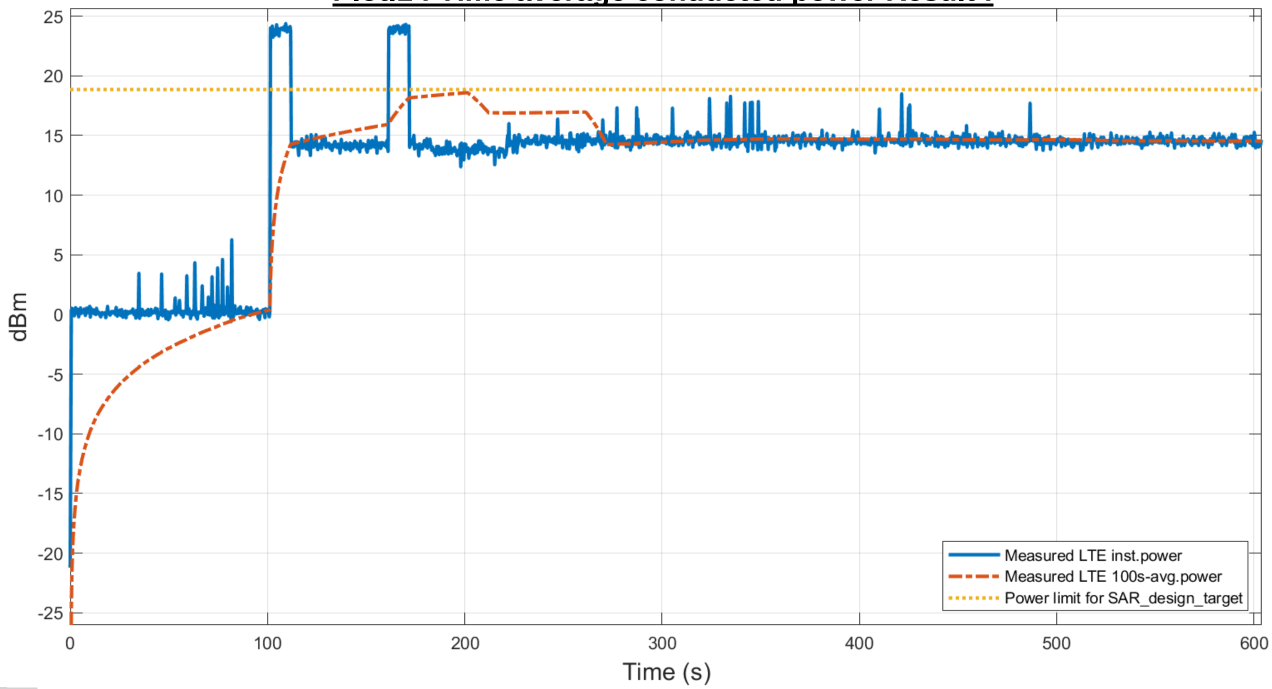
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.821**	W/kg
Device uncertainty	**1.0**	dB

5.3.2 LTE Band 5

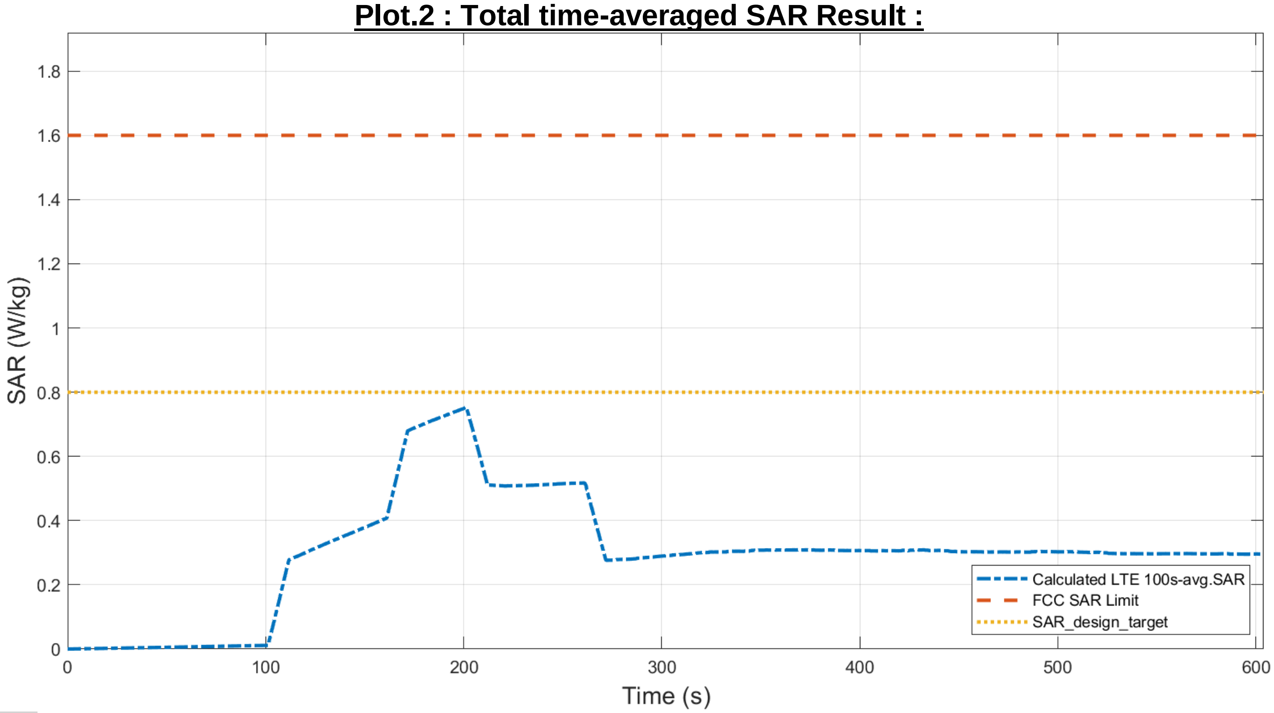
(TC01: LTE Band_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

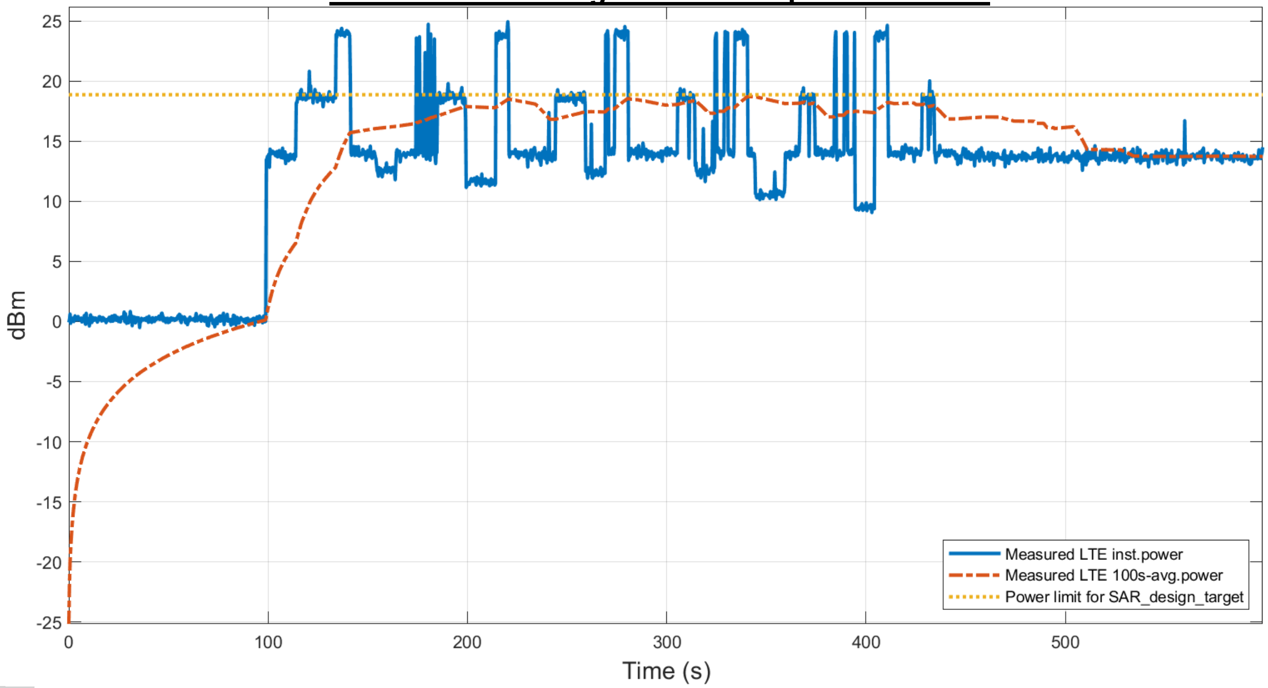


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.753**	W/kg
Device uncertainty	**1.0**	dB

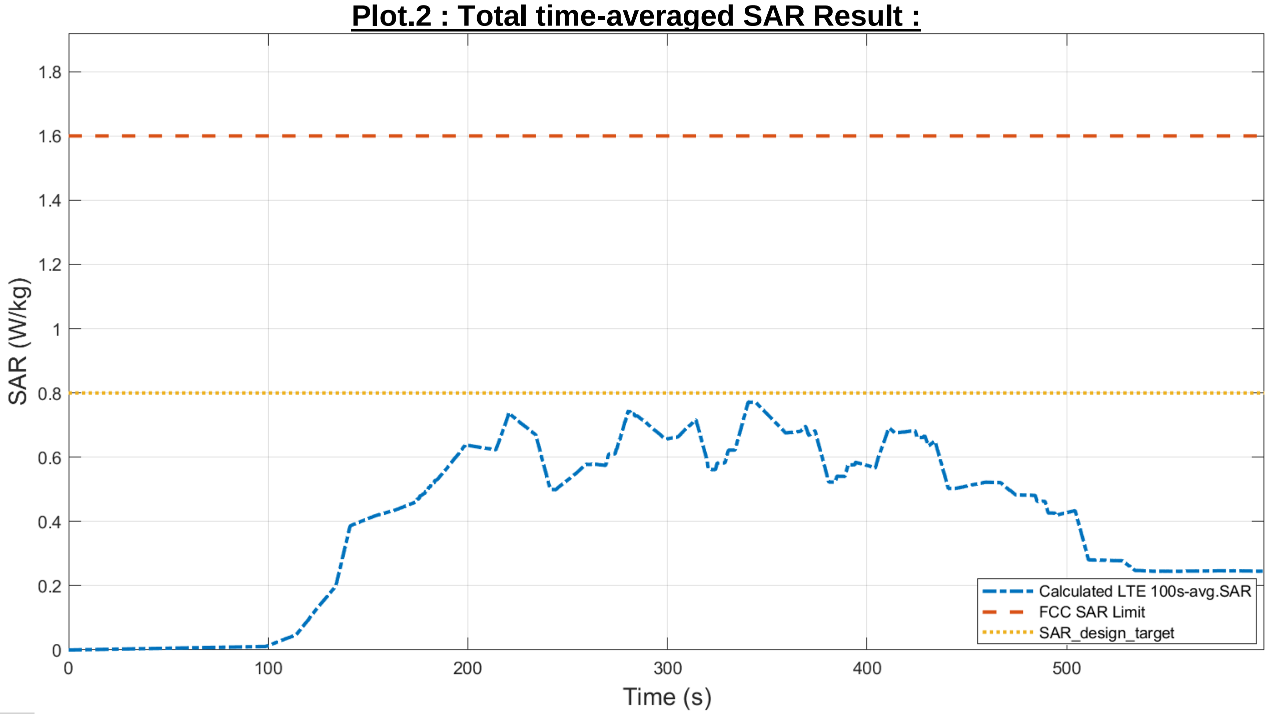
(TC03: LTE Band_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



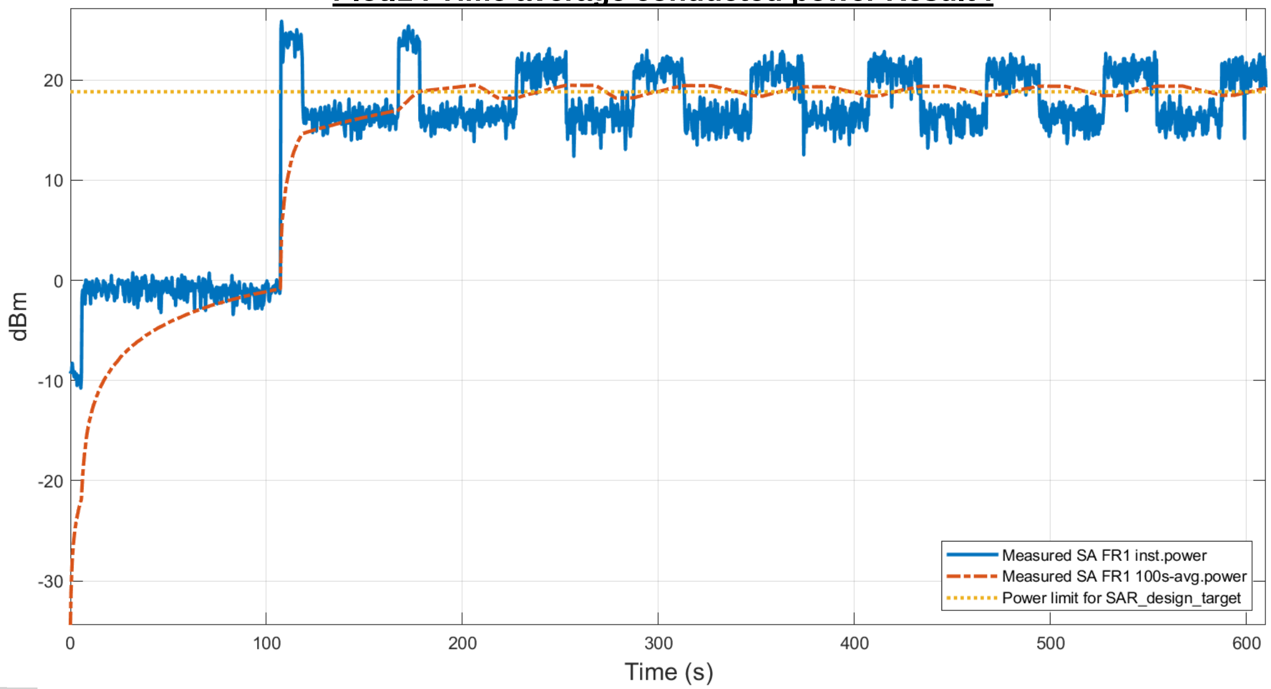
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.772**	W/kg
Device uncertainty	**1.0**	dB

5.3.3 NR Band n5

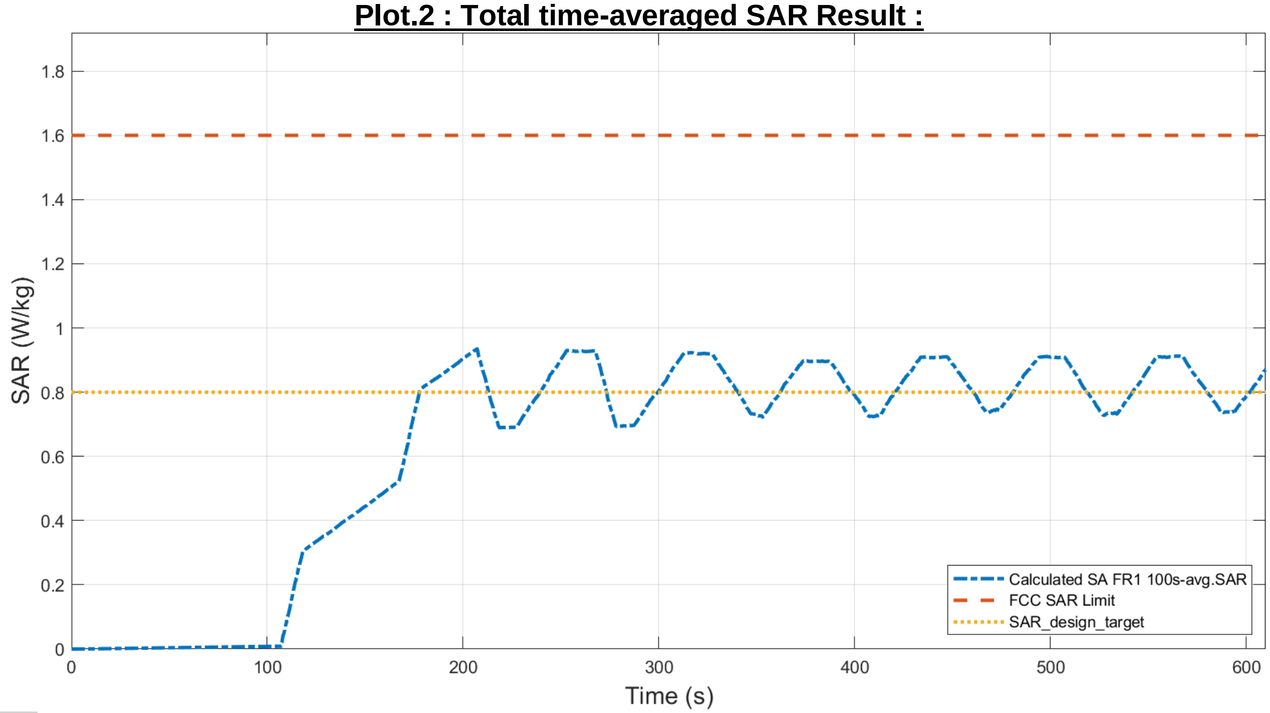
(TC02: SA_FR1_NR Band_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

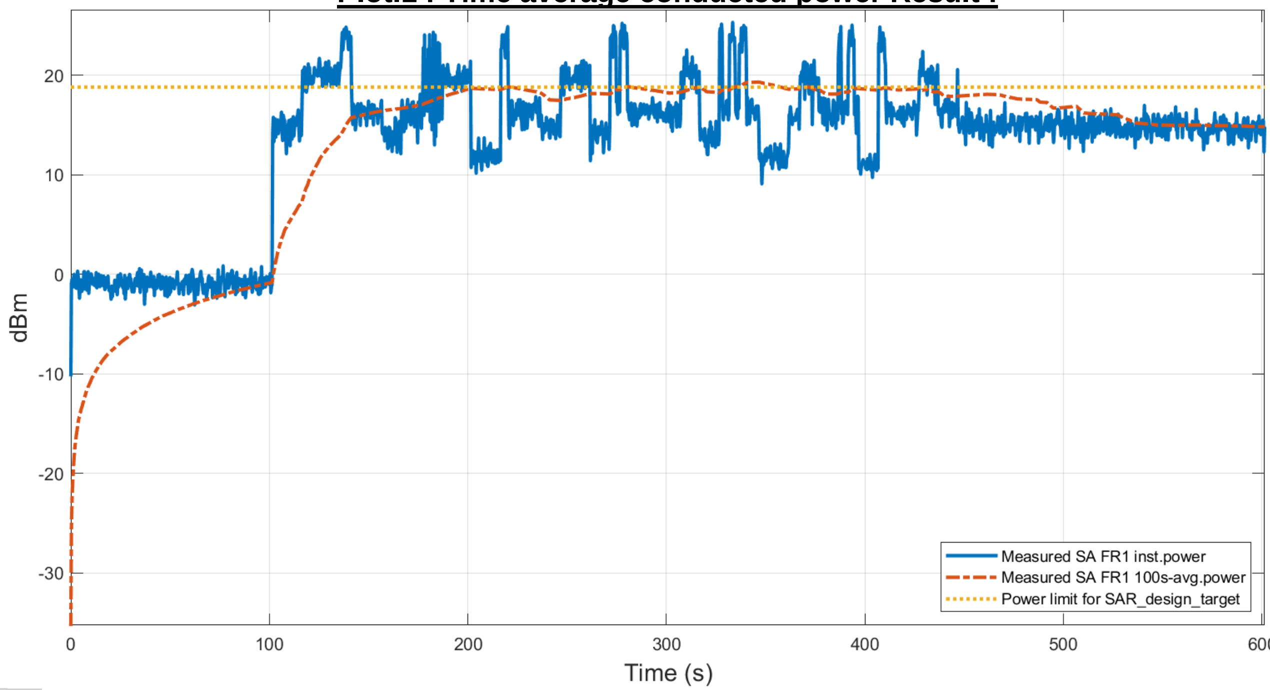


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.935**	W/kg
Device uncertainty	**1.0**	dB

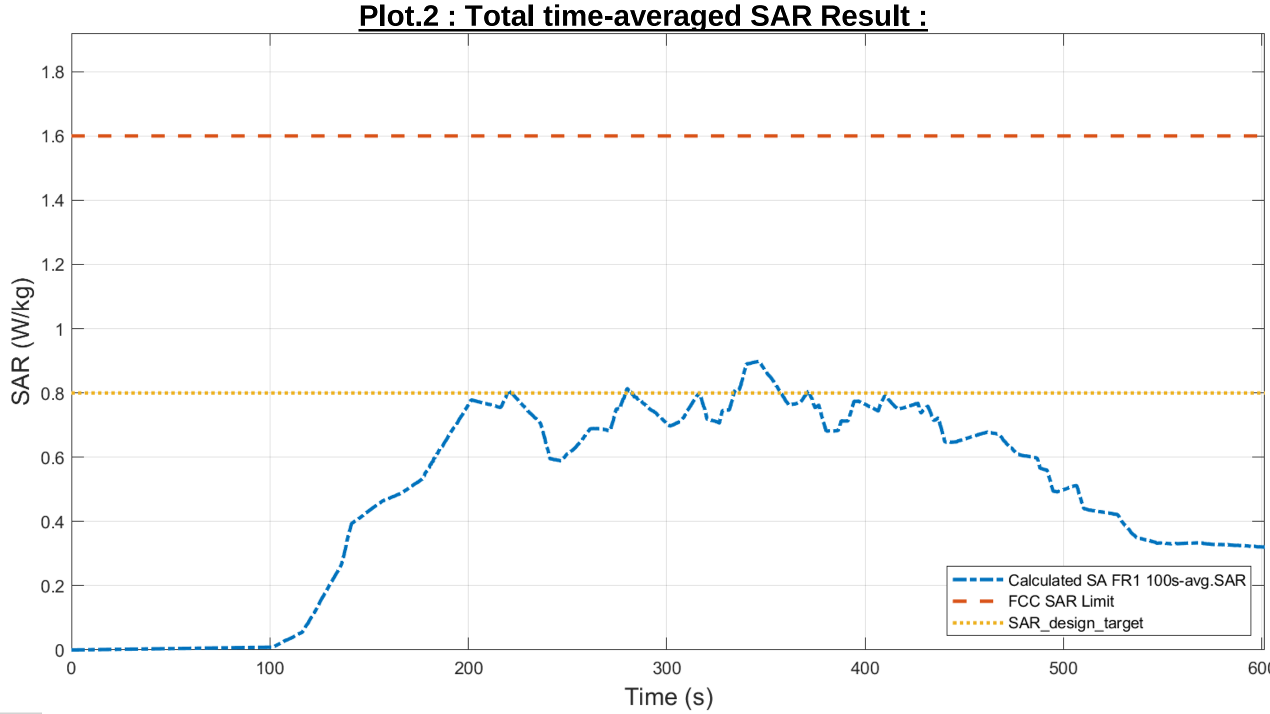
(TC04: SA_FR1_NR Band_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



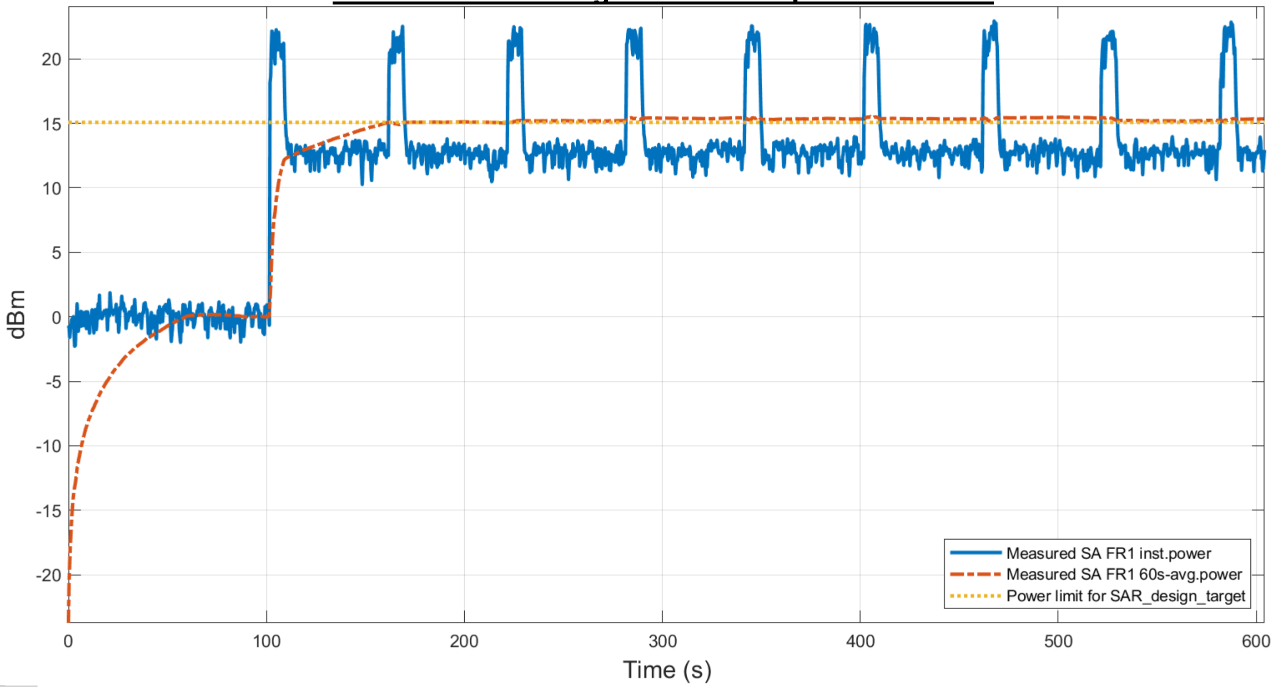
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.899**	W/kg
Device uncertainty	**1.0**	dB

5.3.4 NR Band n77

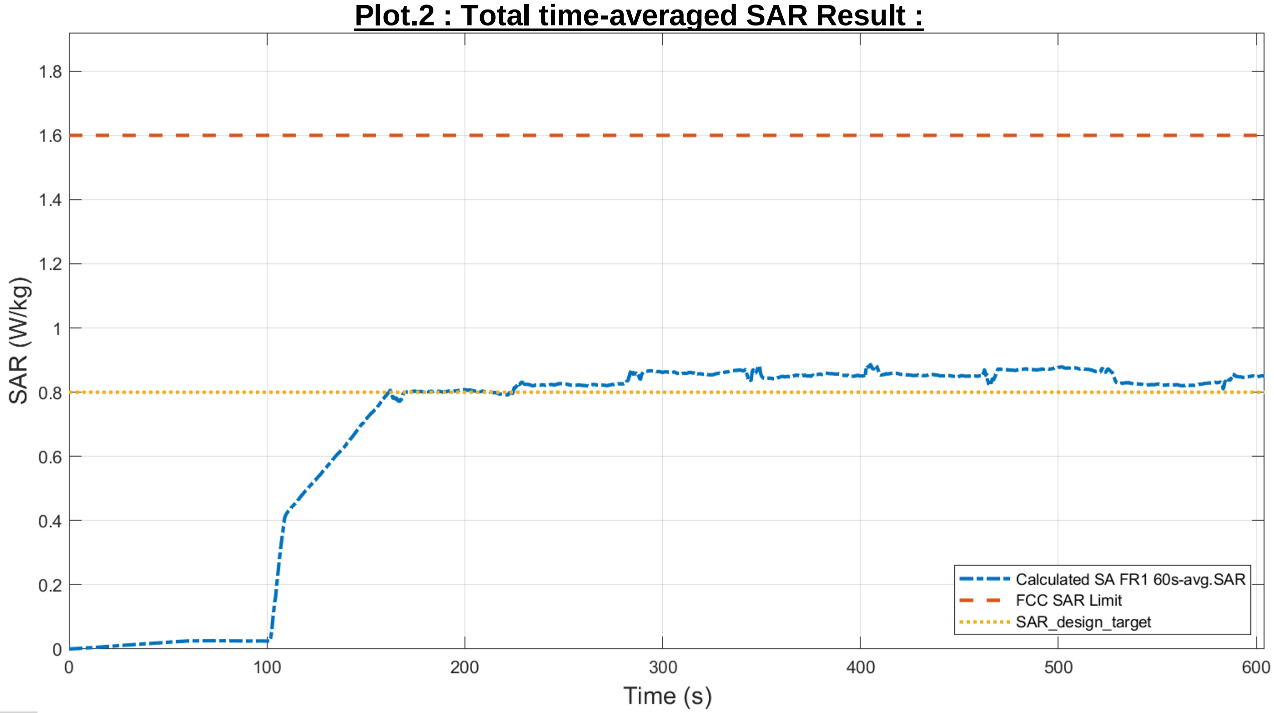
(TC02: SA_FR1_NR Band_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

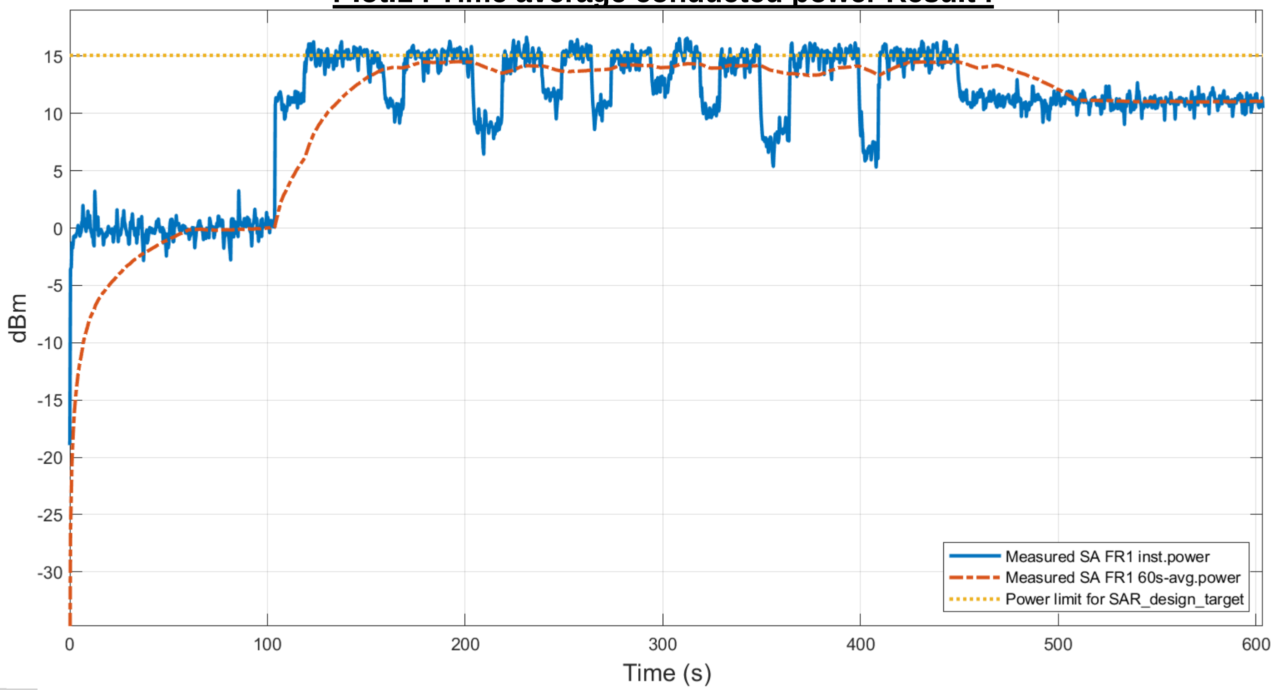


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.886**	W/kg
Device uncertainty	**1.0**	dB

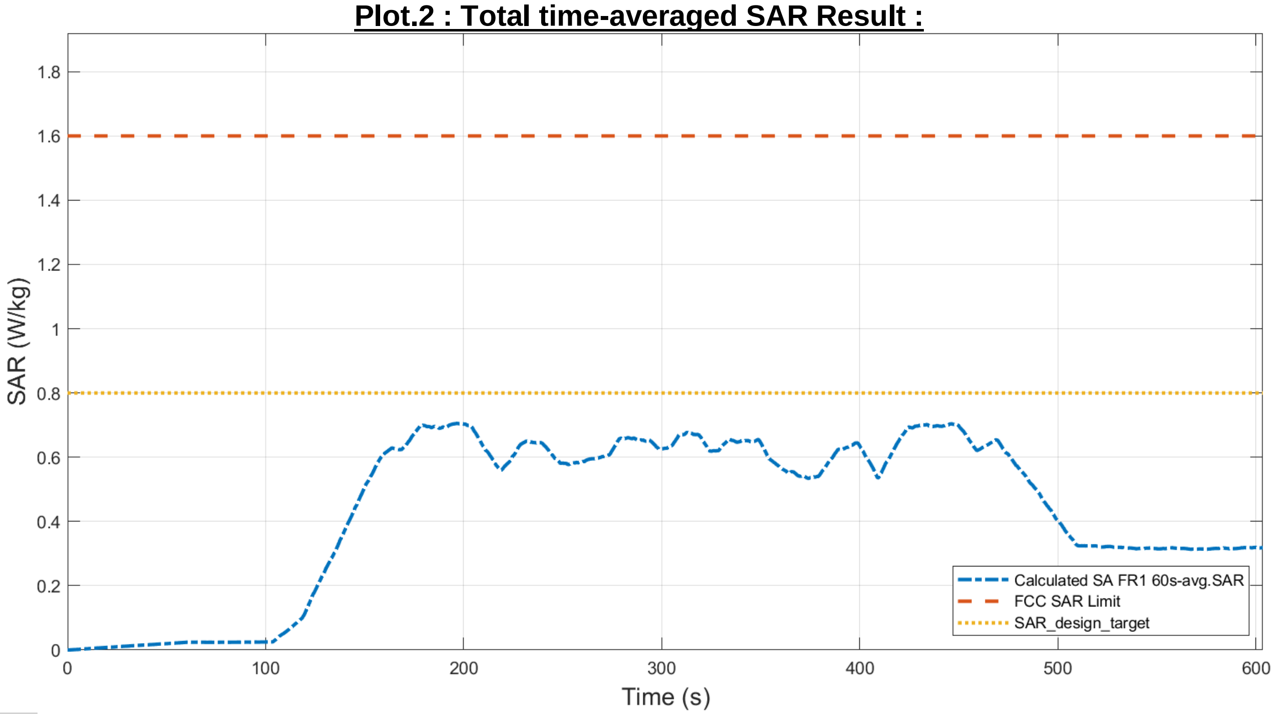
(TC04: SA_FR1_NR Band_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



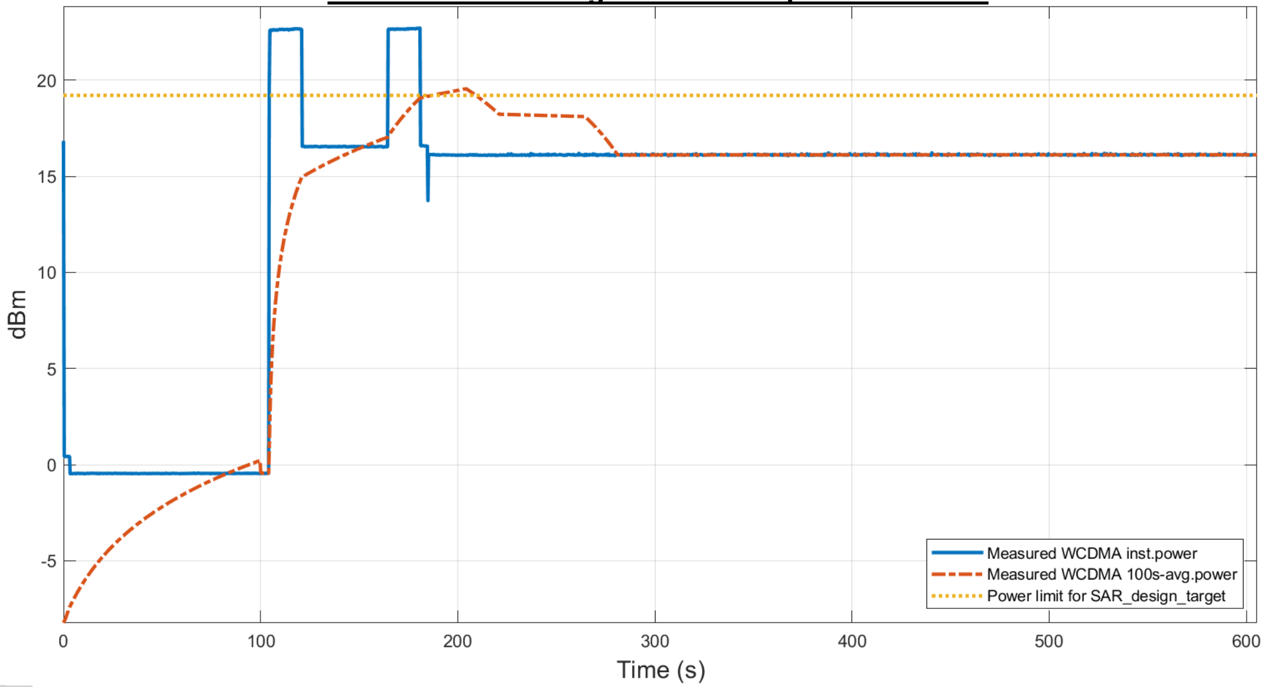
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.705**	W/kg
Device uncertainty	**1.0**	dB

5.3.5 WCDMA Band IV

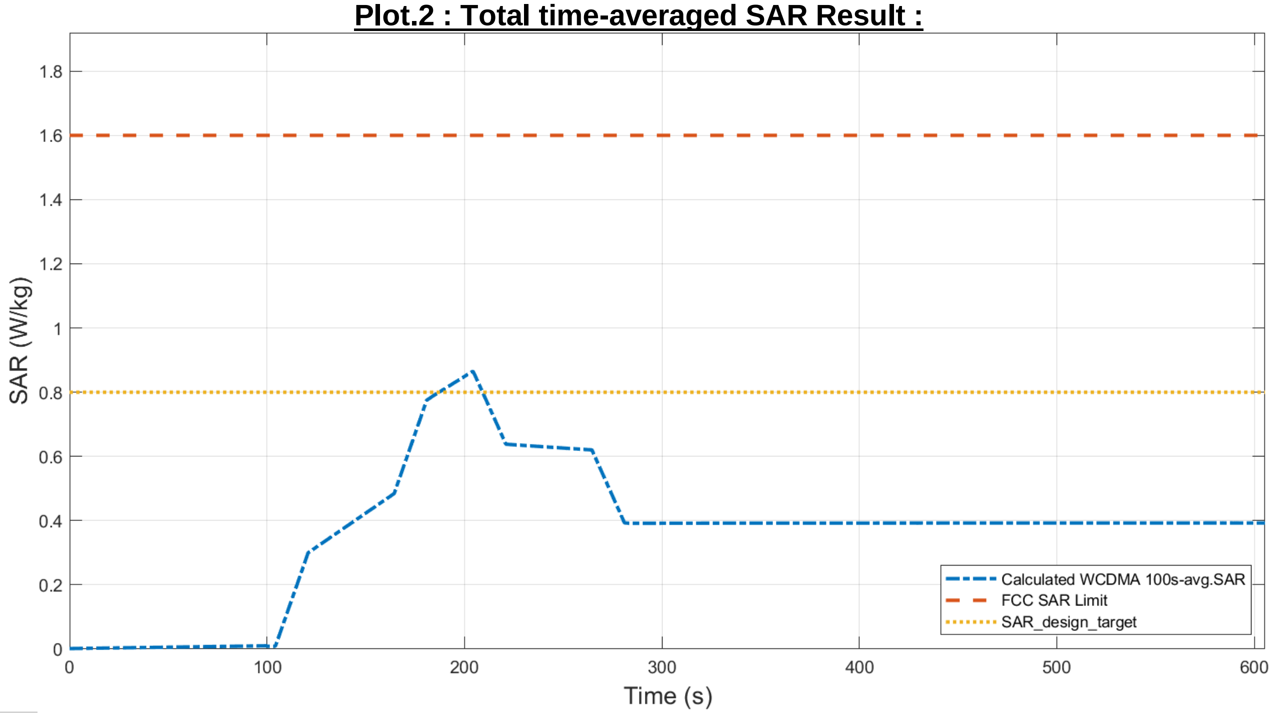
(TC19: WCDMA_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

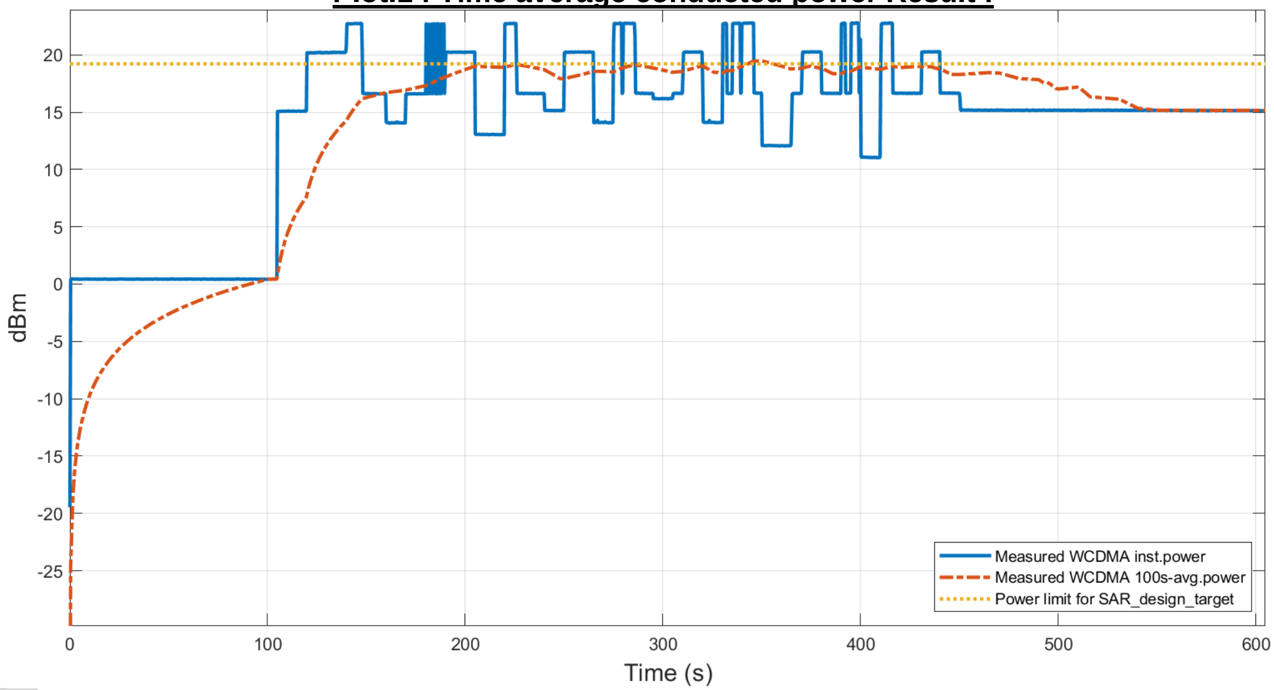


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.865**	W/kg
Device uncertainty	**1.0**	dB

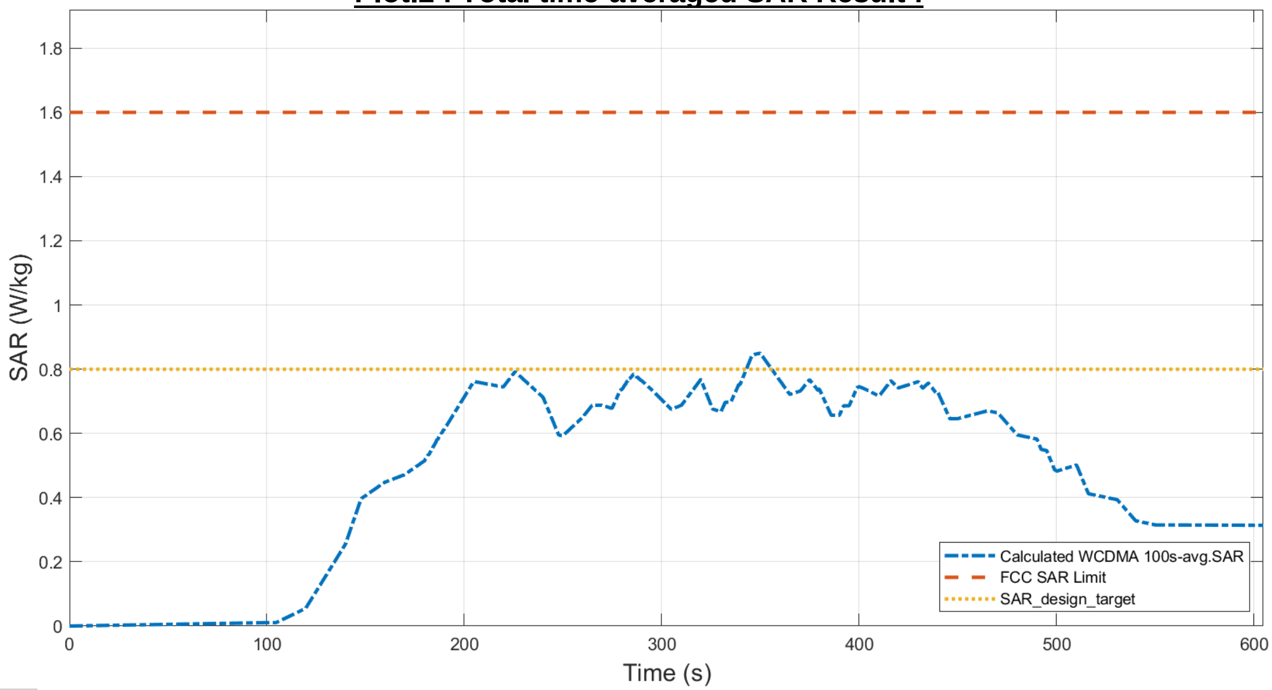
(TC20: WCDMA_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



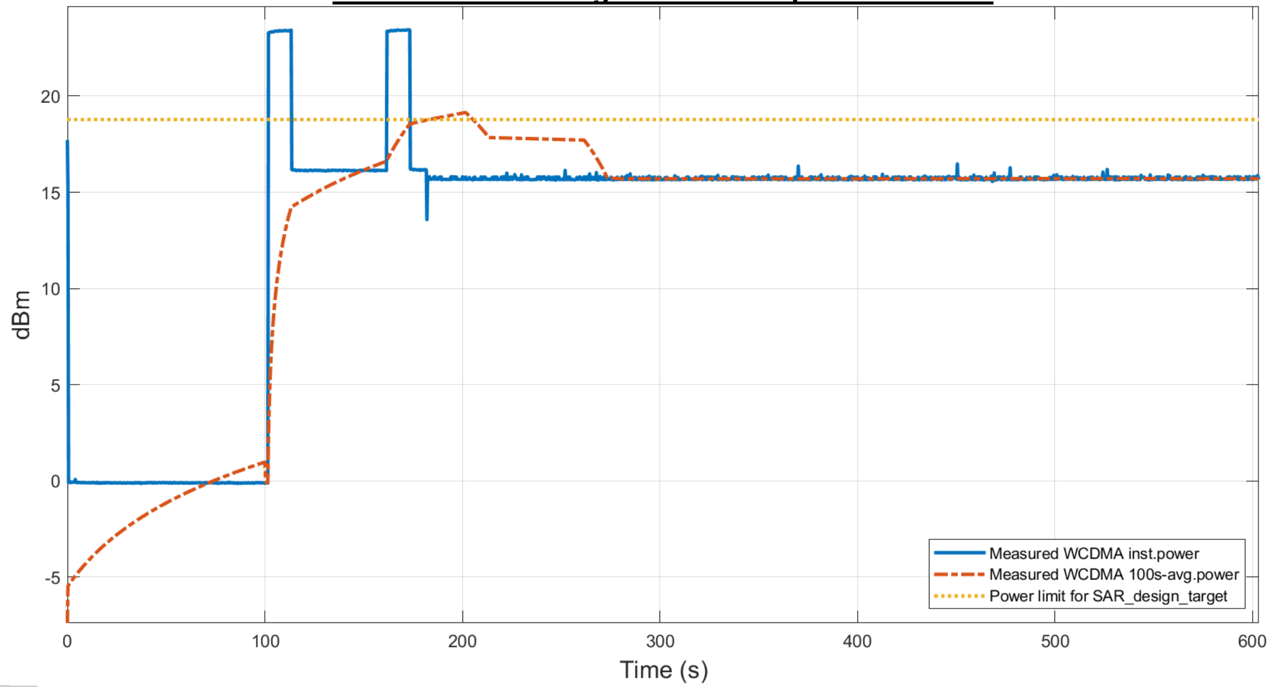
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.850**	W/kg
Device uncertainty	**1.0**	dB

5.3.6 WCDMA Band V

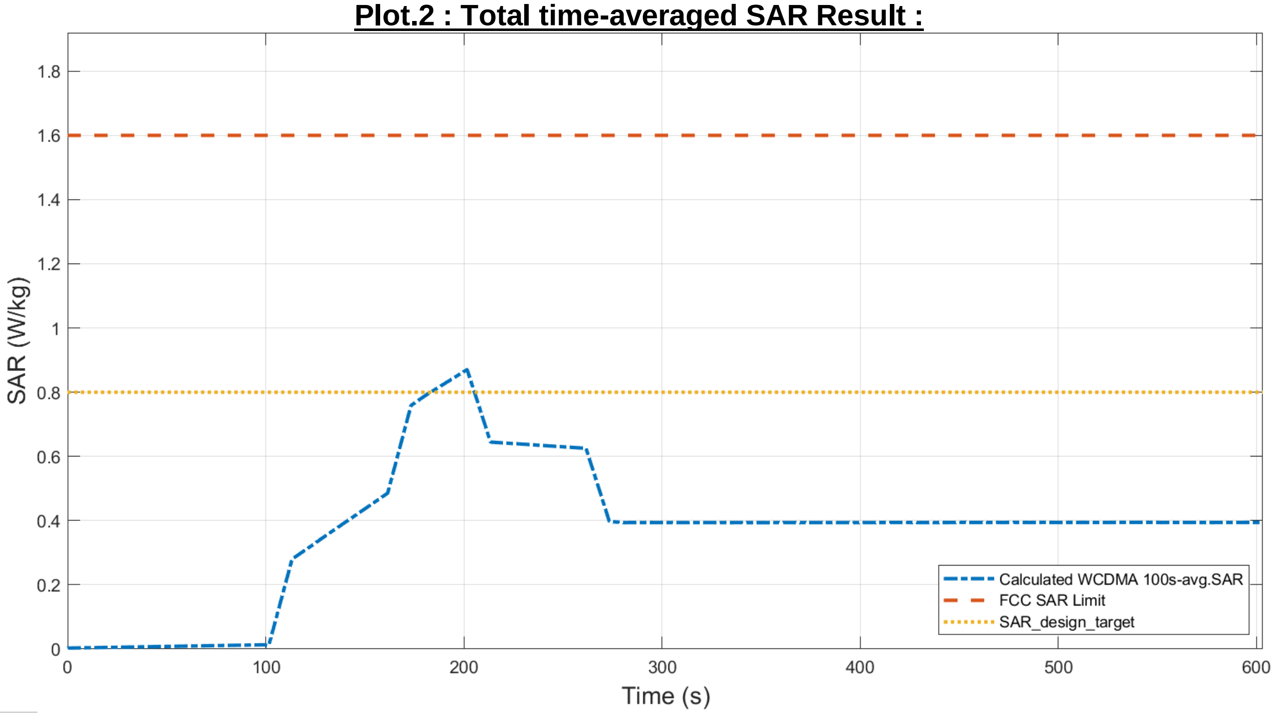
(TC19: WCDMA_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

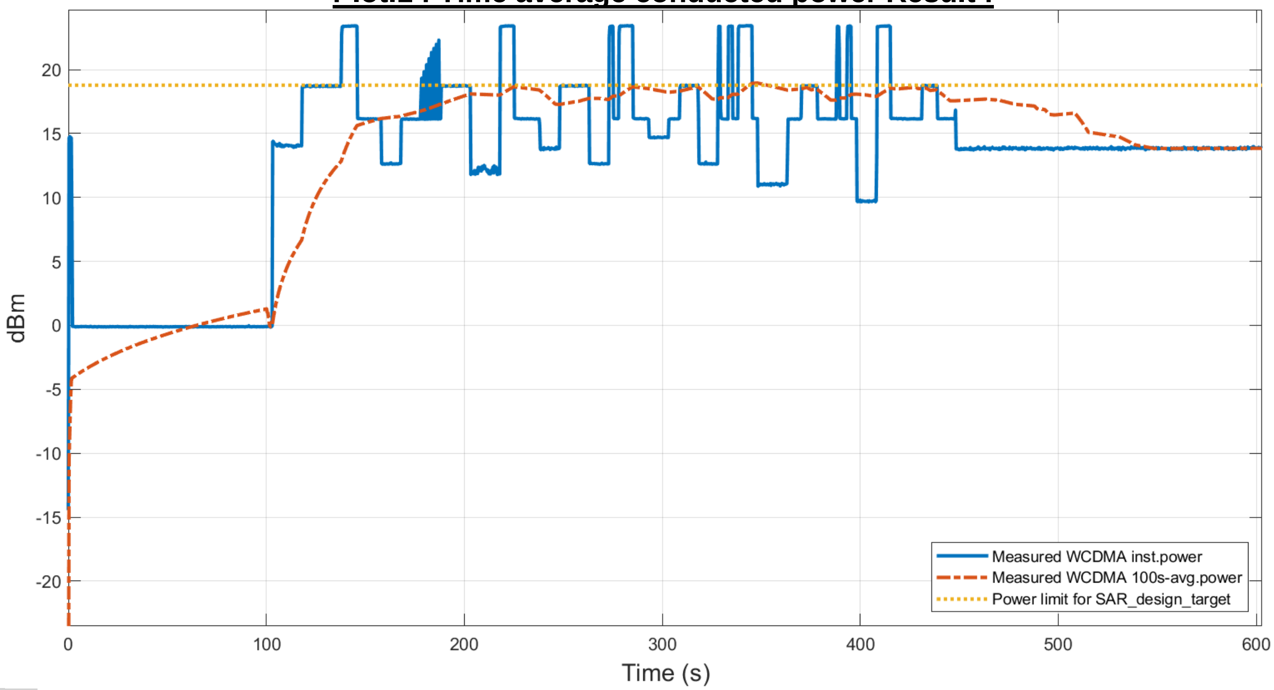


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.870**	W/kg
Device uncertainty	**1.0**	dB

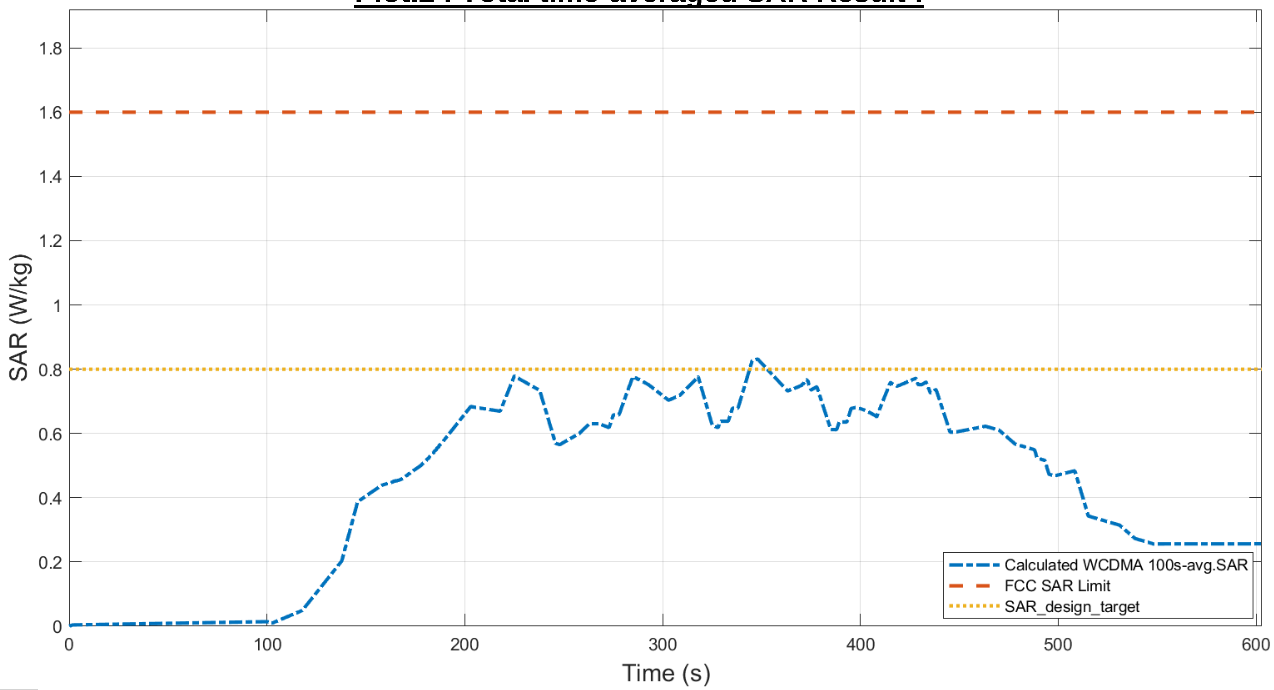
(TC20: WCDMA_Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



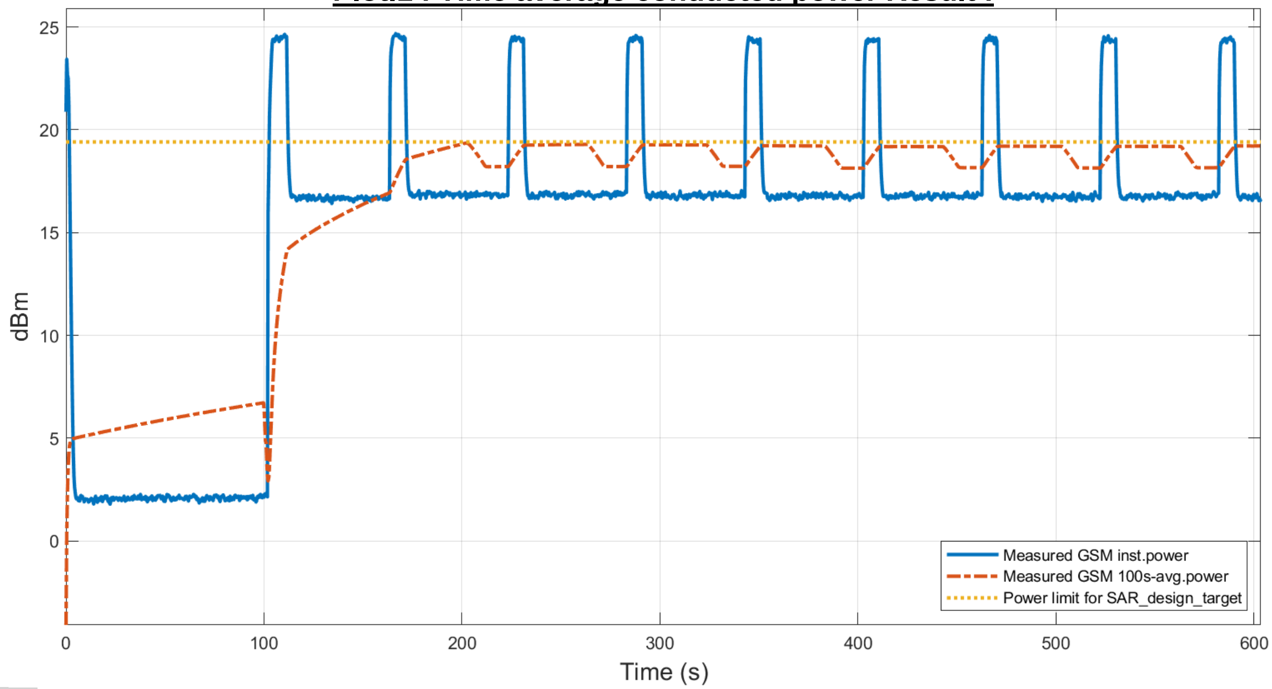
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.832**	W/kg
Device uncertainty	**1.0**	dB

5.3.7 GSM 850

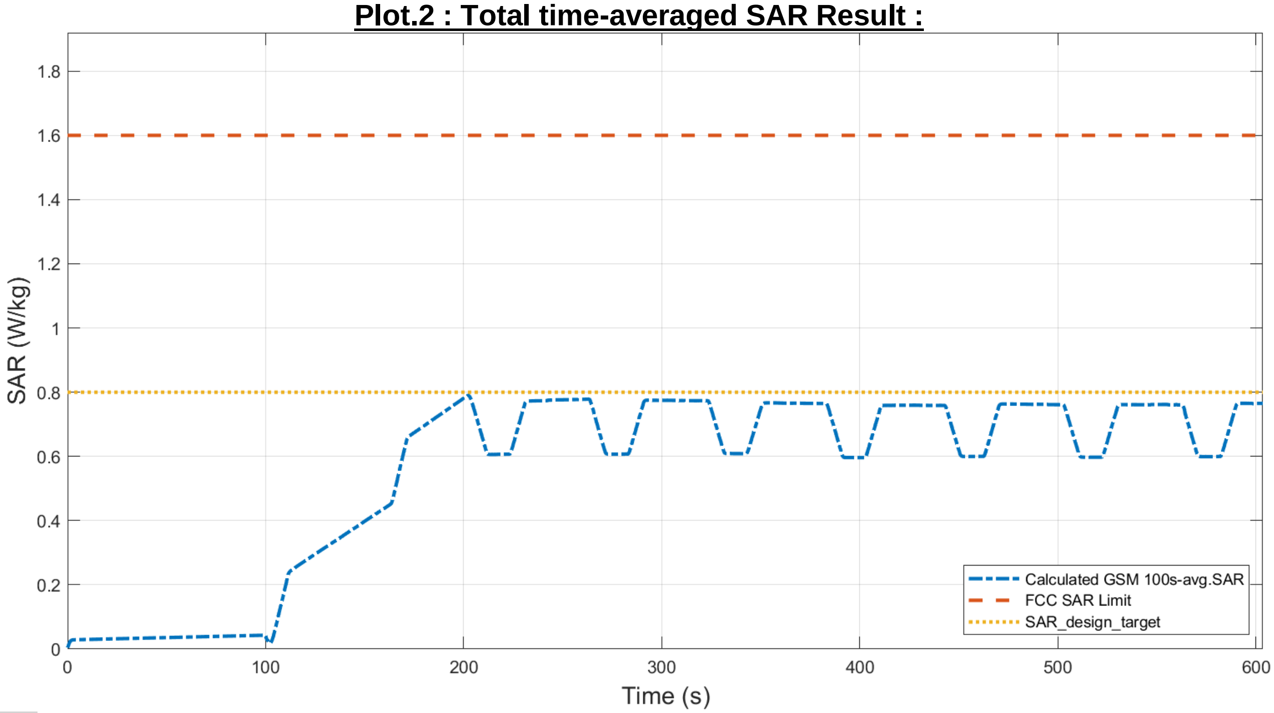
(TC21: GSM_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

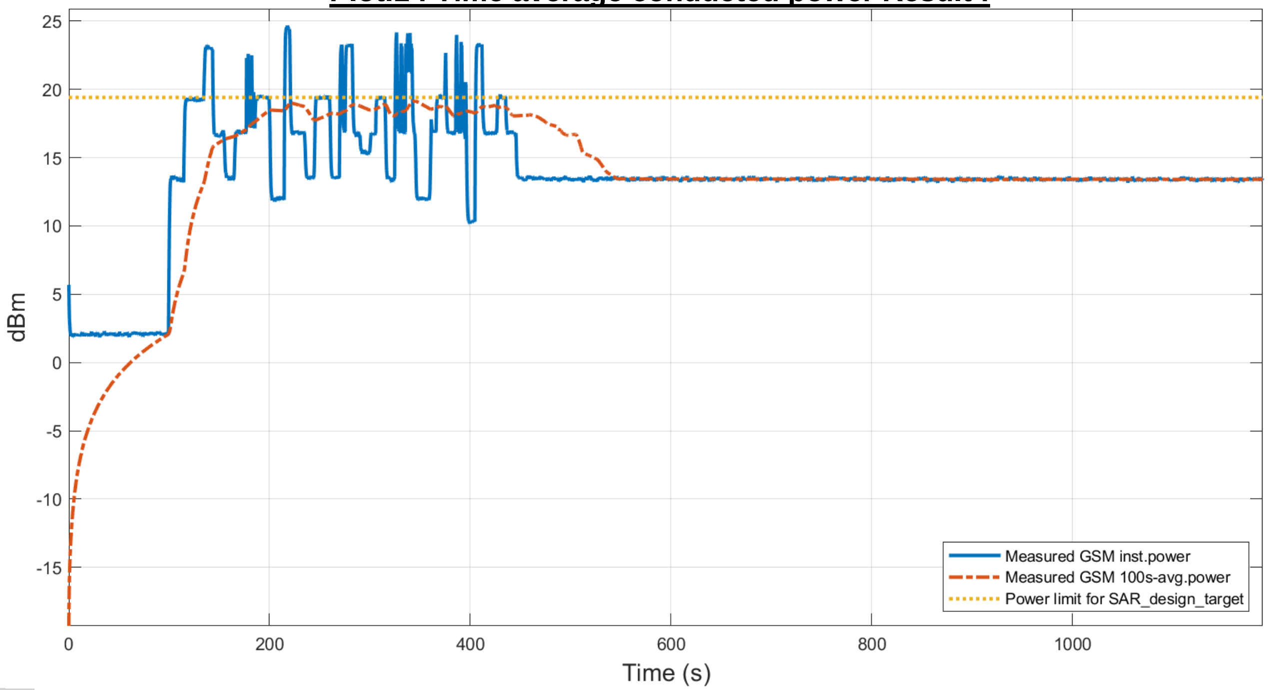


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.790**	W/kg
Device uncertainty	**1.0**	dB

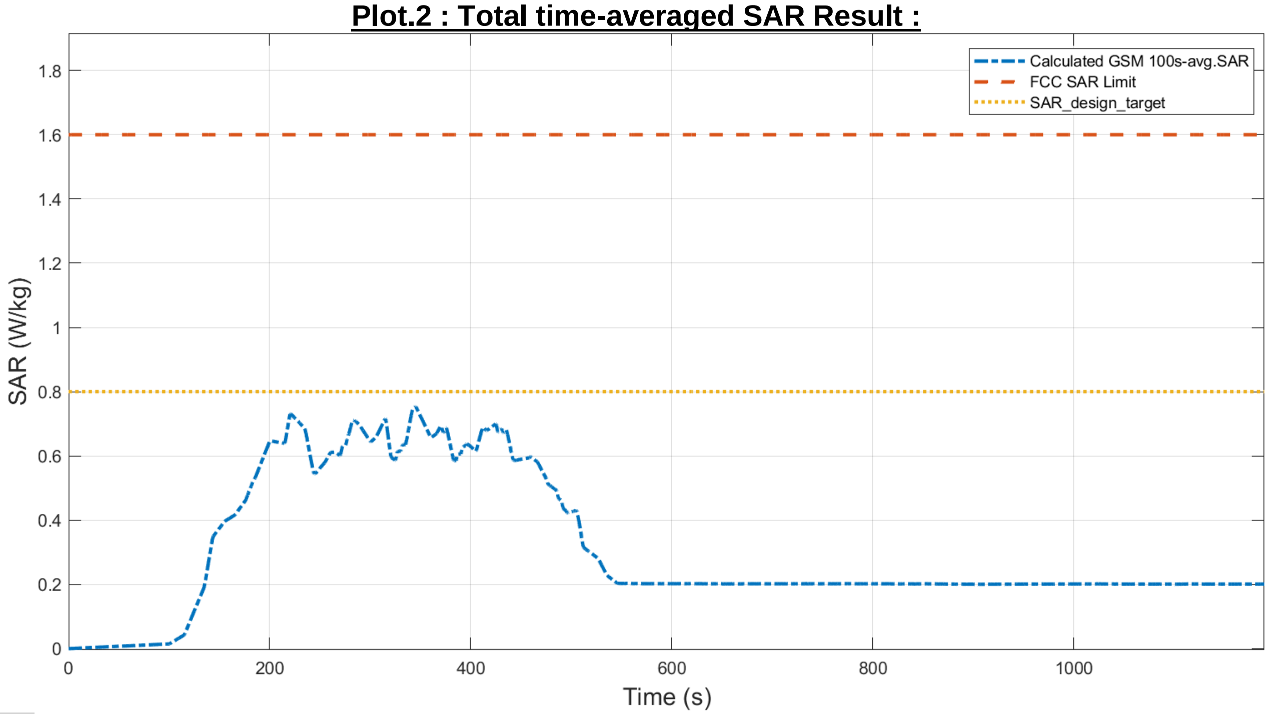
(TC22: GSM _Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



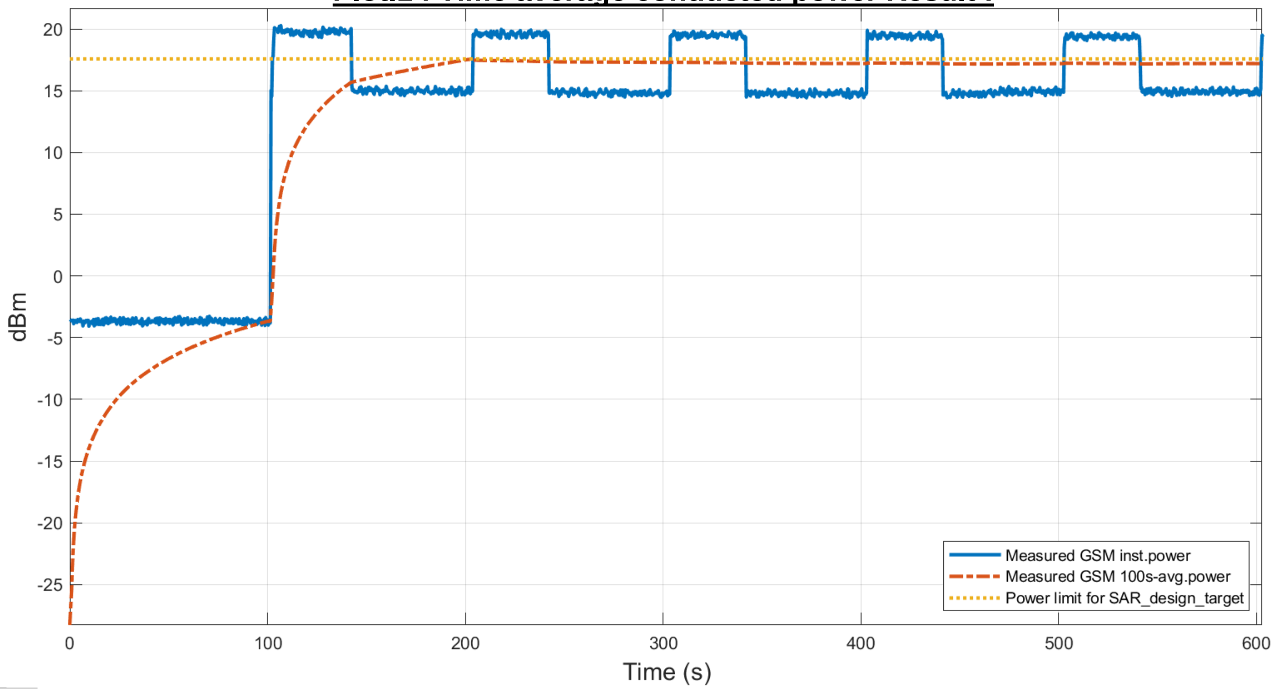
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.753**	W/kg
Device uncertainty	**1.0**	dB

5.3.8 GSM 1900

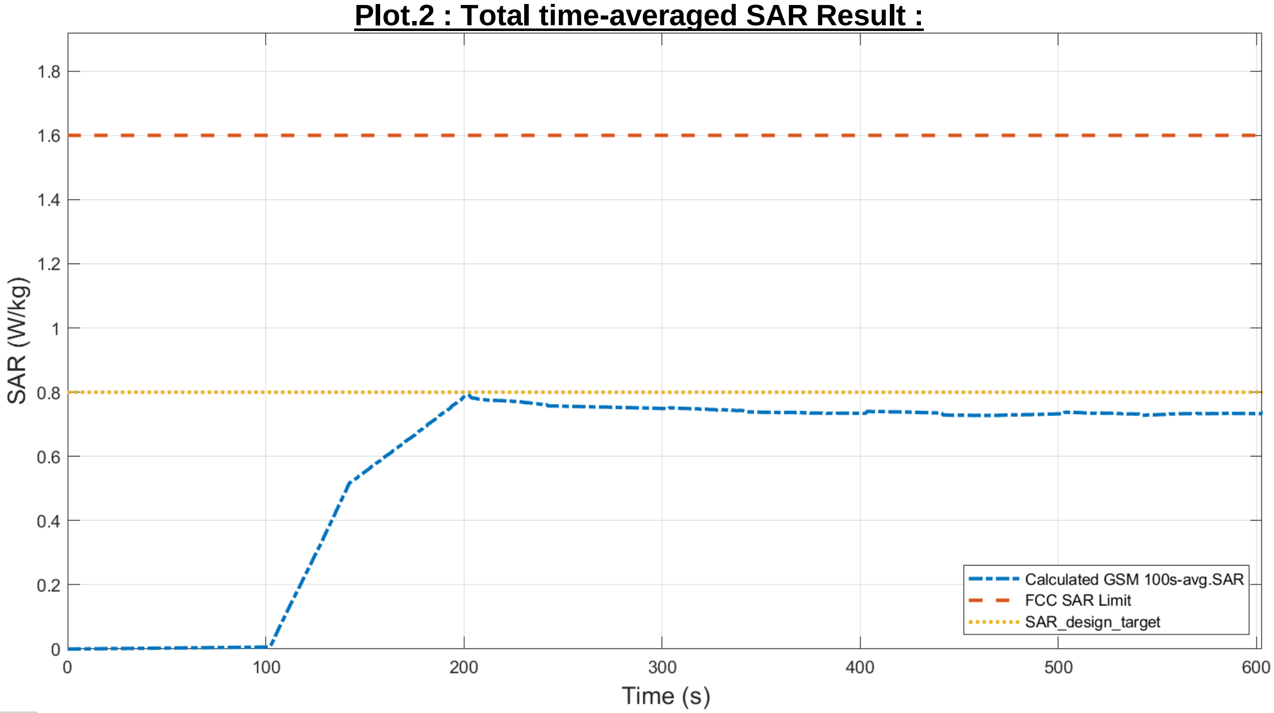
(TC21: GSM_Time_Varying_Tx_Power_Case_1)

Plot.1 : Time average conducted power Result :



Plot.1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. As shown in Plot.1, it is confirmed for time average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is smaller than the target power, and it will saturate to target power with little margin.

Plot.2 : Total time-averaged SAR Result :

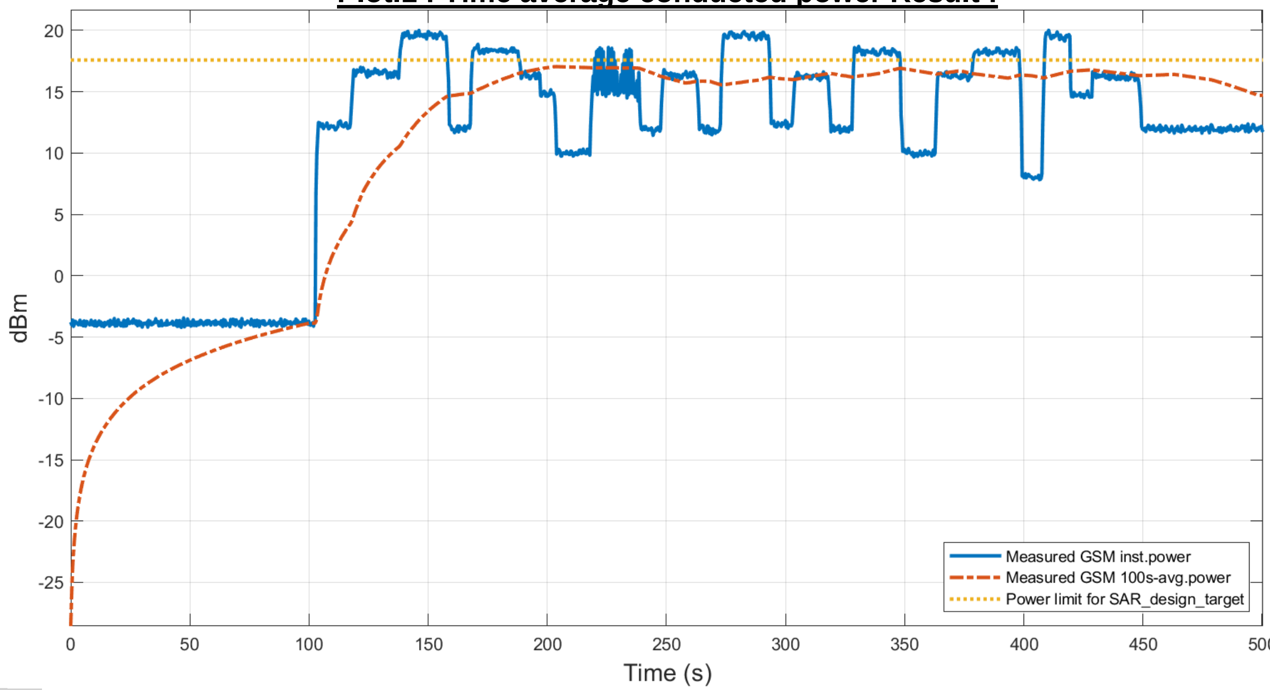


Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.792**	W/kg
Device uncertainty	**1.0**	dB

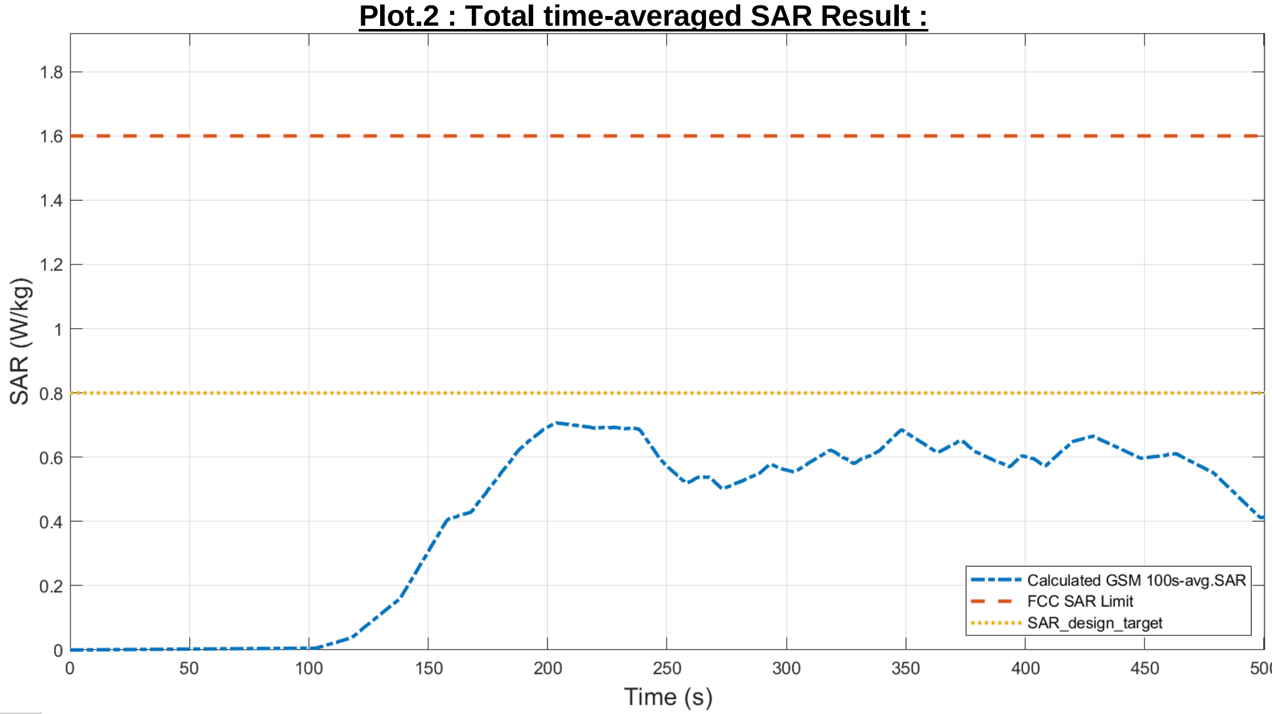
(TC22: GSM _Time_Varying_Tx_Power_Case_2)

Plot.1 : Time average conducted power Result :



Plot.1 shows the instantaneous and time-averaged Tx power with test sequence B.

Plot.2 : Total time-averaged SAR Result :



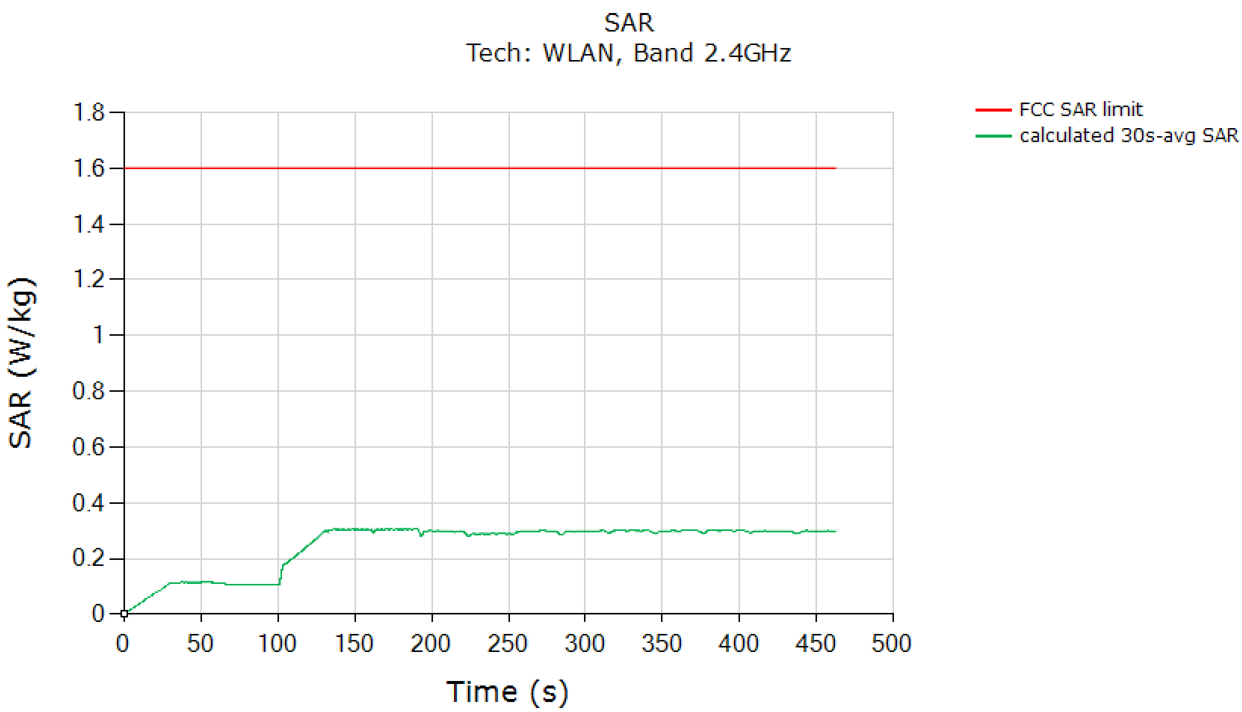
Plot.2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.707**	W/kg
Device uncertainty	**1.0**	dB

5.3.9 2.4GHz SISO (802.11b)

Test result for test sequence #1:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (4a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):

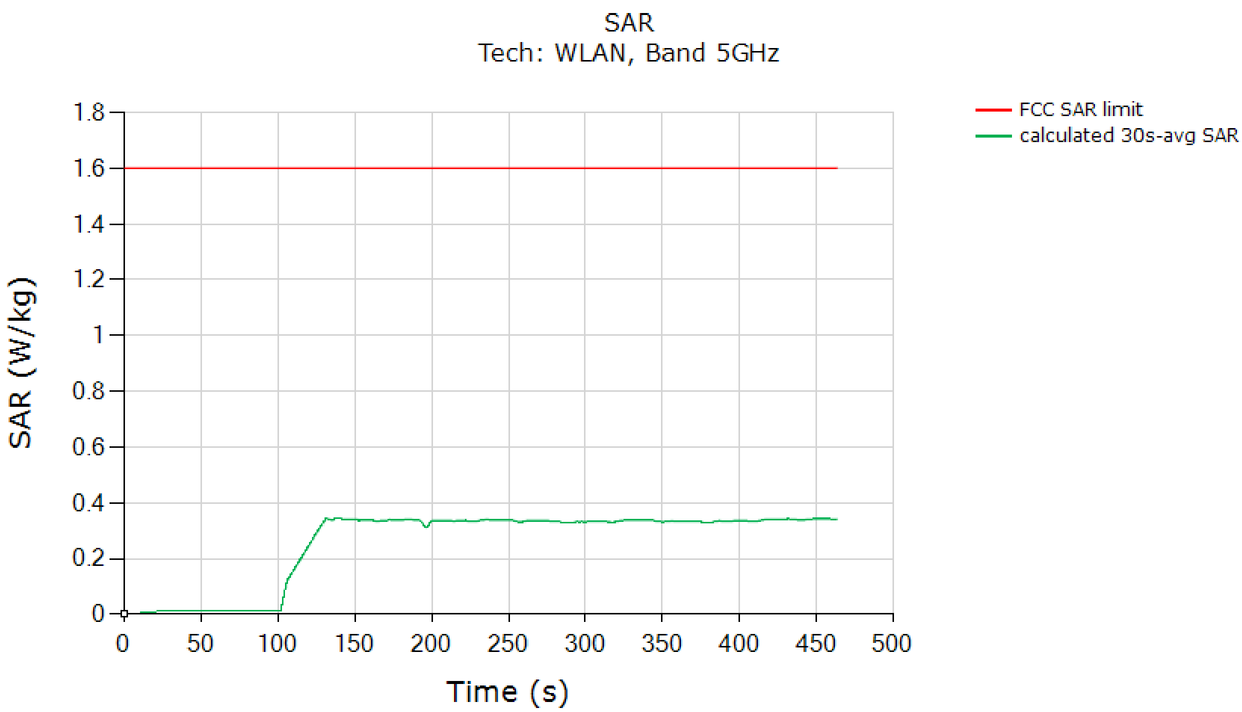


	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged 1gSAR (green curve)	0.304
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5.2.1).	

5.3.10 5GHz SISO (802.11a)

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

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (4a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):

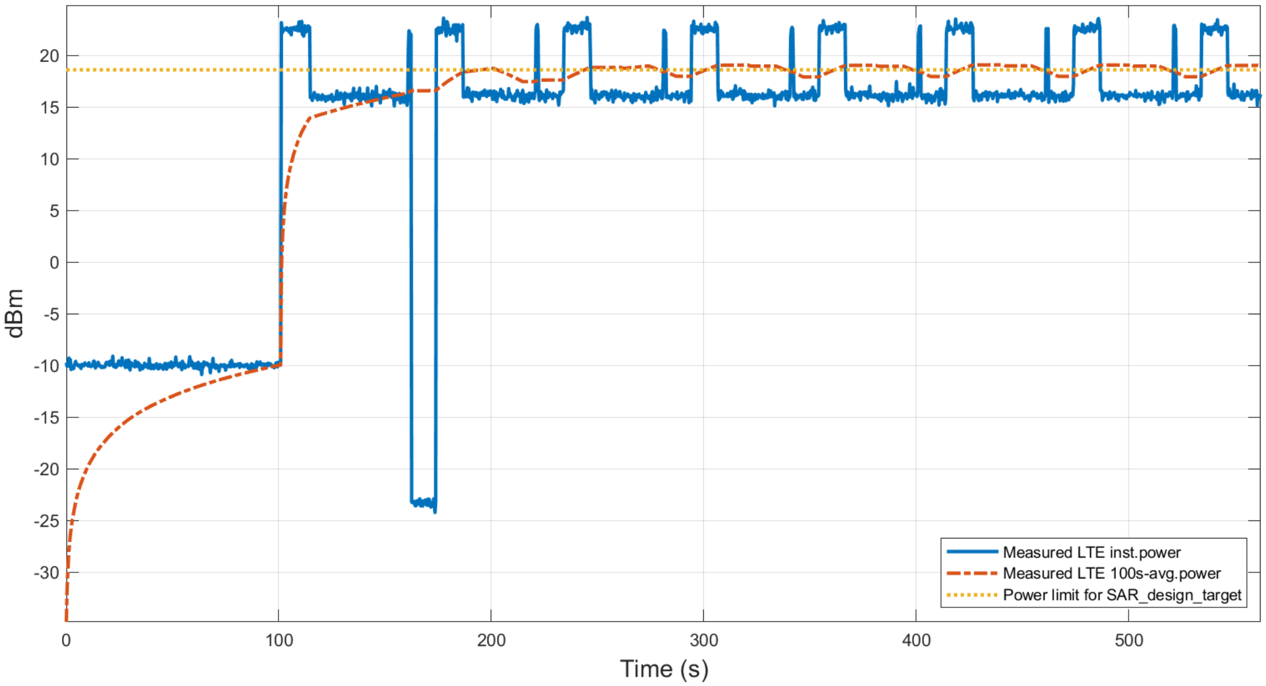


	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged 1gSAR (green curve)	0.346
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5.2.1).	

5.4 Change in call test results

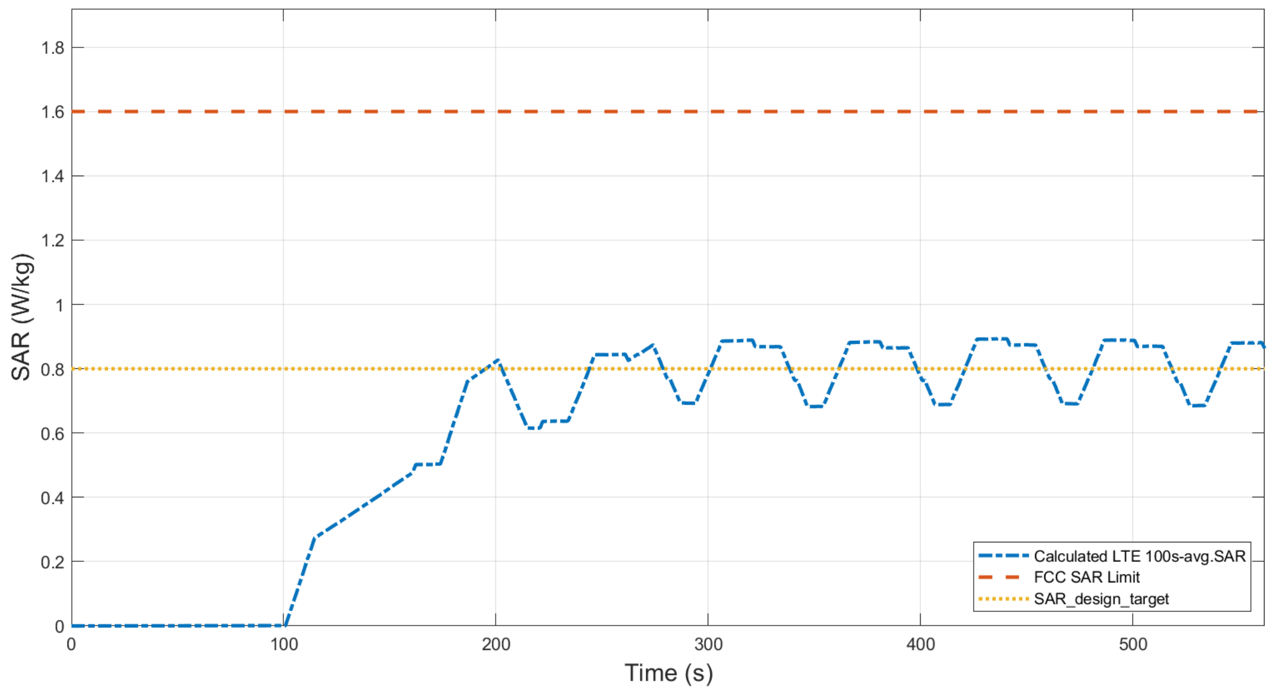
The test results in this section are obtained following the procedure in Section 3.3.2. The test case corresponds to TC05 in Table 5.1.2.

Plot.1 : Conducted Tx power in Call_Disconnect_Re-establishment :



Plot.1 shows the instantaneous and time-averaged Tx power for this test. The call disconnected around 160s and resumed after 10s. It is confirmed for time-average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is lower than the value of Plimit.

Plot.2 : Total time-averaged SAR Result :



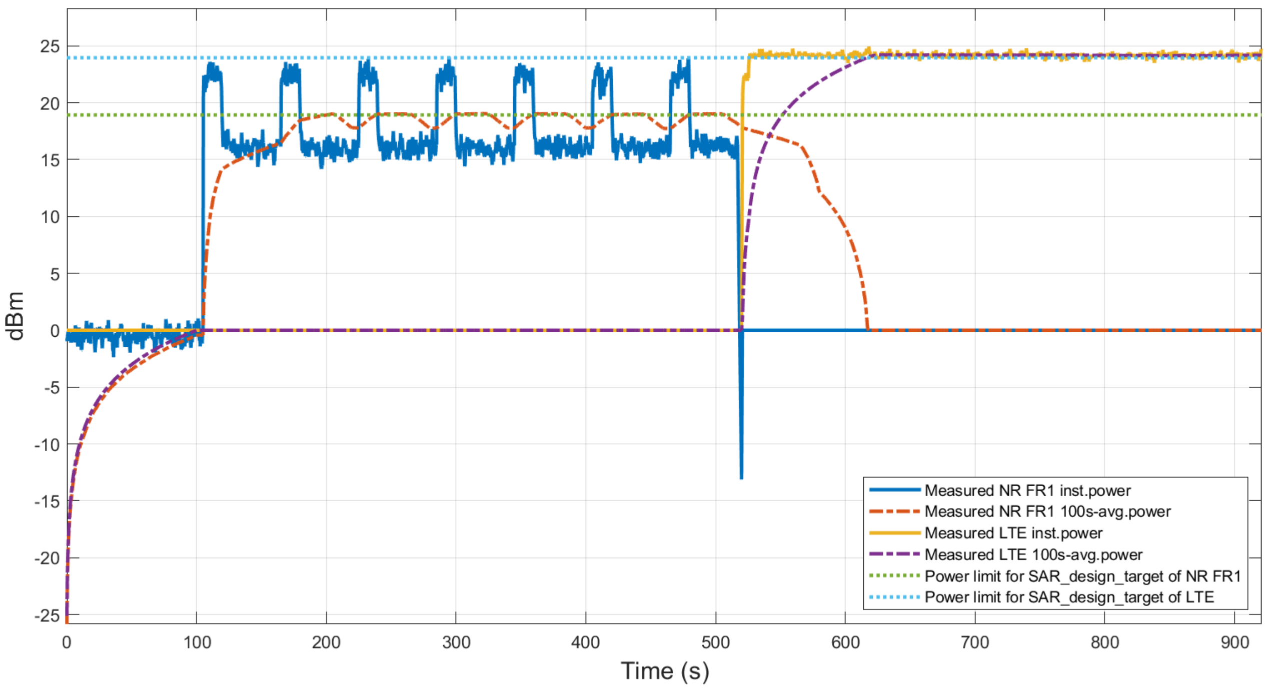
Plot.2 shows calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg. Looking at the results, it can be seen that even if transmission is stopped due to a call drop, the SAR value measured for a period of time window is stored in the window section and is continuously checked.

FCC1g SAR limit	**1.6** W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.893** W/kg
Device uncertainty	**1.0** dB

5.5 Re-selection in call test results

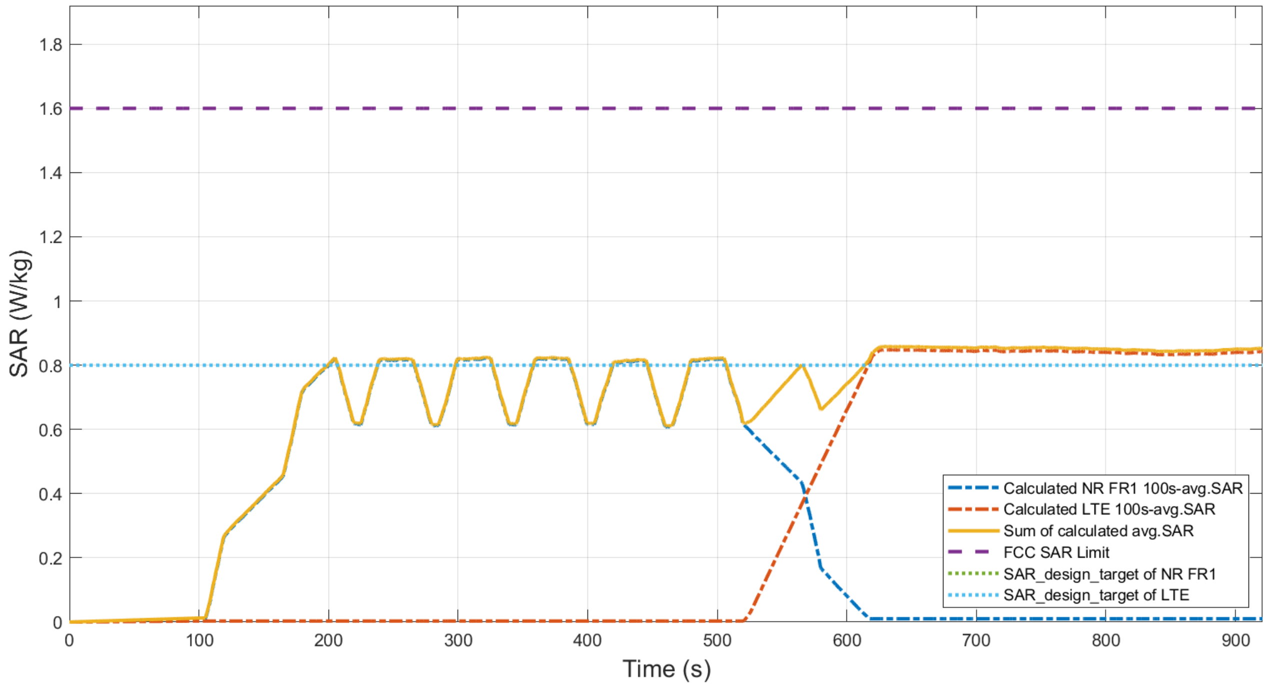
The test results in this section are obtained following the procedure in Section 3.3.3. The test cases correspond to TC06 in Table 5.1.2.

Plot.1 : Conducted Tx power for SAR IRAT re-selection :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band and NR FR1 Band for the duration of the test. Around time stamp of ~510s, a RAT re-selection from LTE Band to NR FR1 Band was executed, resulting in reduction of time-averaged power of LTE Band and simultaneous increase in time-averaged power of NR FR1 Band.

Plot.2 : Total time-averaged SAR Result :



Plot.2 shows the time-averaged 1gSAR value for each of LTE Band and NR FR1 Band, as well as the total SAR value. We can see that the total 1gSAR is higher during the band transitions, but is always under the total FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6** W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.858** W/kg
Device uncertainty	**1.0** dB

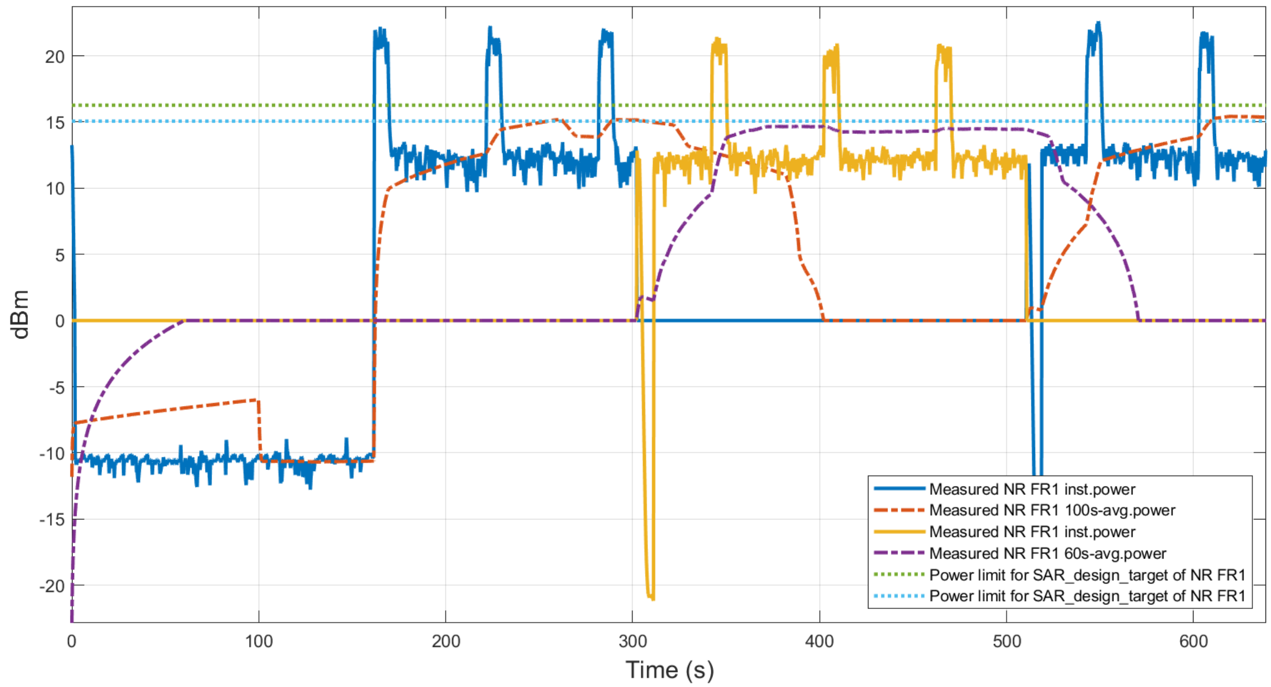
5.6 Change in band/time-window/antenna test results

5.6.1 Change in band/time-window test results of WWAN

Test Case.1) 100s-60s-100s

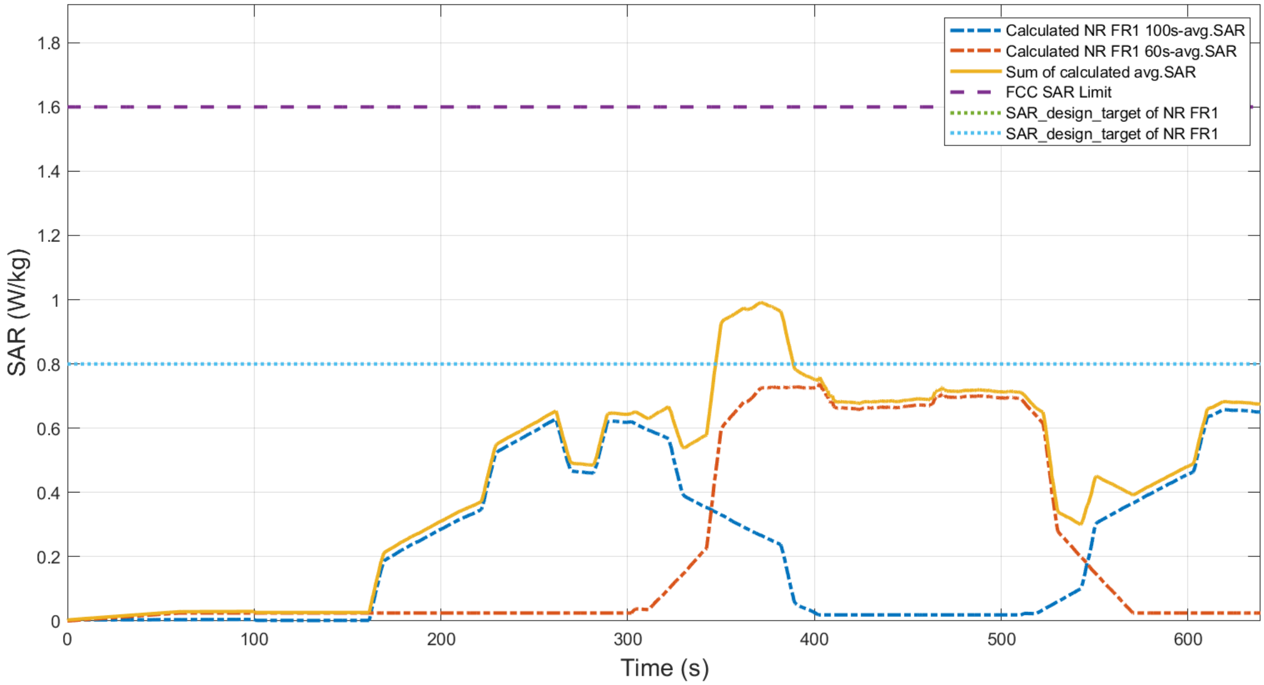
The test results in this section are obtained following the procedure in Section 3.3.3. The test cases correspond to TC07 in Table 5.1.2.

Plot.1 : Conducted Tx power for SAR window change :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for both NR FR1 Bands for the duration of the test. Around time stamp of ~300s, a handover from Band (100s) to Band (60s) was executed, resulting in reduction of time-averaged power of Band (100s) and simultaneous increase in time-averaged power of Band (60s). Around time stamp of ~500s, handover back to Band (100s) was executed, resulting in reduction of time-averaged power of Band (60s) and increase of time-averaged power of Band (100s). It can be seen that transition time of time-averaged values for Band (100s) is longer than Band (60s), which is the consequence of 100s time averaging for Band (100s) versus shorter 60s averaging for Band (60s).

Plot.2 : Total time-averaged SAR Result :



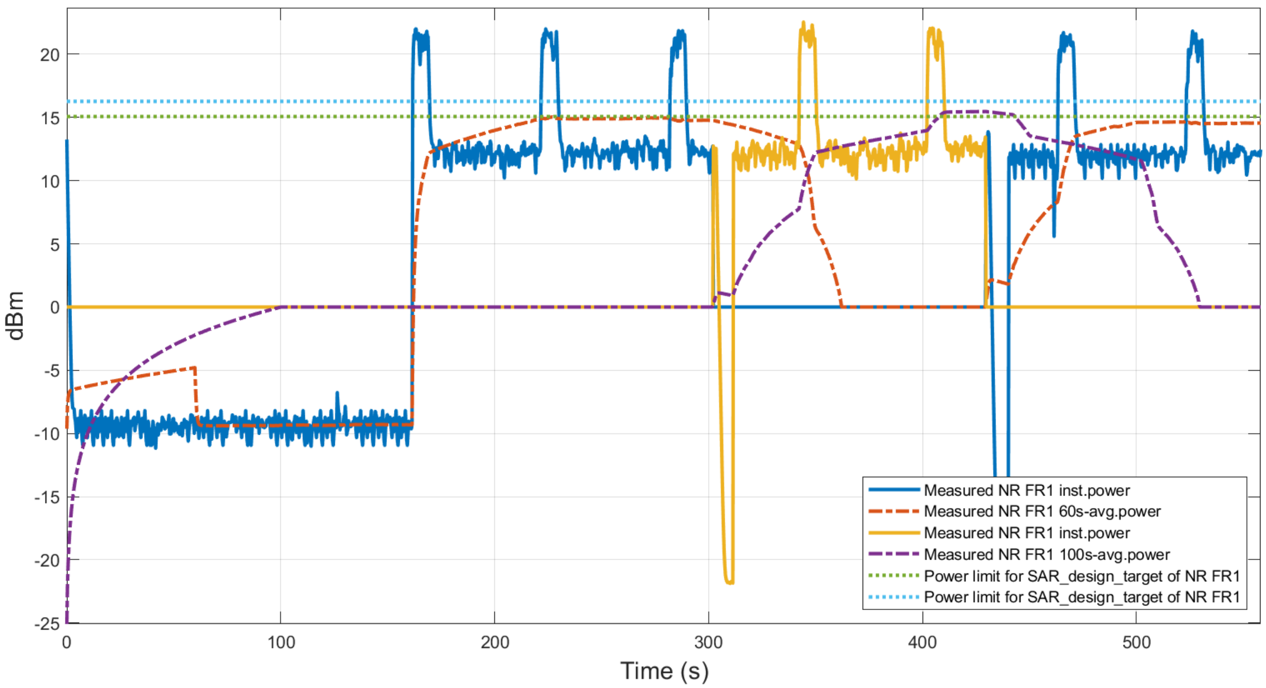
Plot.2 shows the time-averaged 1gSAR value for each of Band (100s) and Band (60s), as well as the total SAR value. We can see that the total 1gSAR is higher during the band transitions, but is always under the total FCC limit of 1.6W/Kg.

FCC1g SAR limit	**1.6** W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.992** W/kg
Device uncertainty	**1.0** dB

Test Case.2) 60s-100s-60s

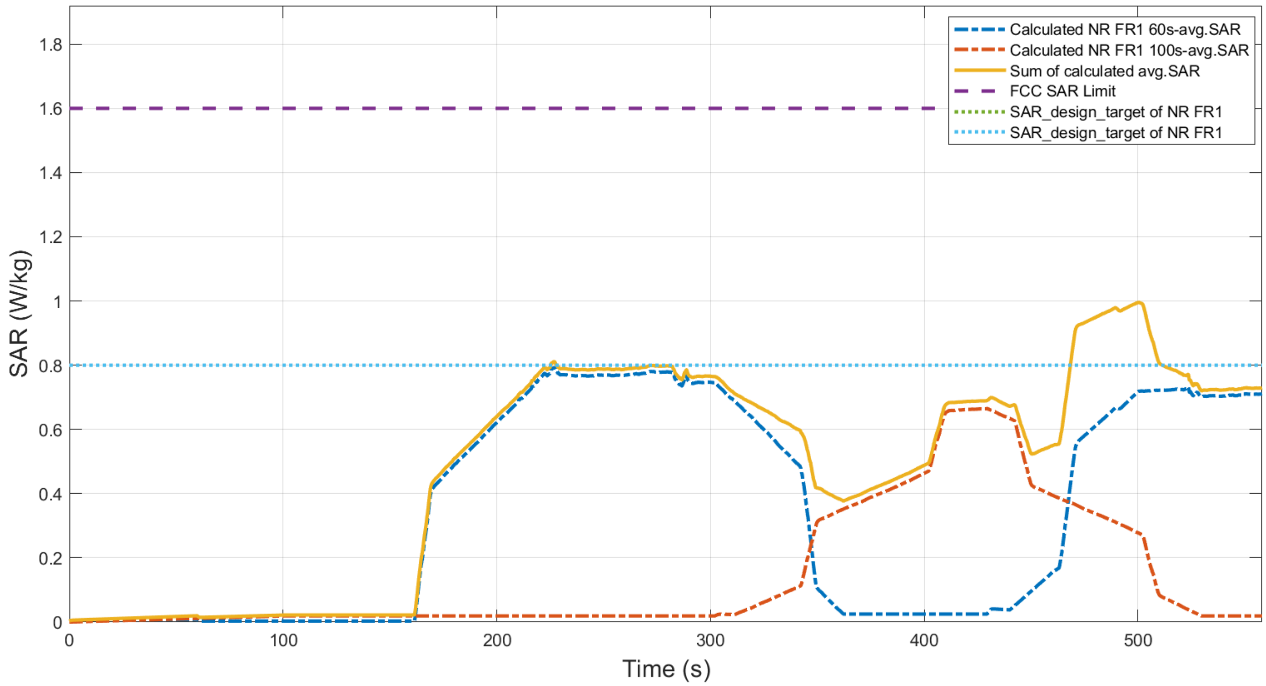
The test results in this section are obtained following the procedure in Section 3.3.3. The test cases correspond to TC08 in Table 5.1.2.

Plot.1 : Conducted Tx power for SAR window change :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for both NR FR1 Bands for the duration of the test. Around time stamp of ~300s, a handover from Band (60s) to Band (100s) was executed, resulting in reduction of time-averaged power of Band (60s) and simultaneous increase in time-averaged power of Band (100s). Around time stamp of ~420s, handover back to Band (60s) executed, resulting in reduction of time-averaged power of Band (100s) and increase of time-averaged power of Band (60s). It can be seen that transition time of time-averaged values for Band (100s) is longer than Band (60s), which is the consequence of 100s time averaging for Band (100s) versus shorter 60s averaging for Band (60s).

Plot.2 : Total time-averaged SAR Result :



Plot.2 shows the time-averaged 1gSAR value for each of Band (100s) and Band (60s), as well as the total SAR value. We can see that the total 1gSAR is higher during the band transitions, but is always under the total FCC limit of 1.6W/Kg.

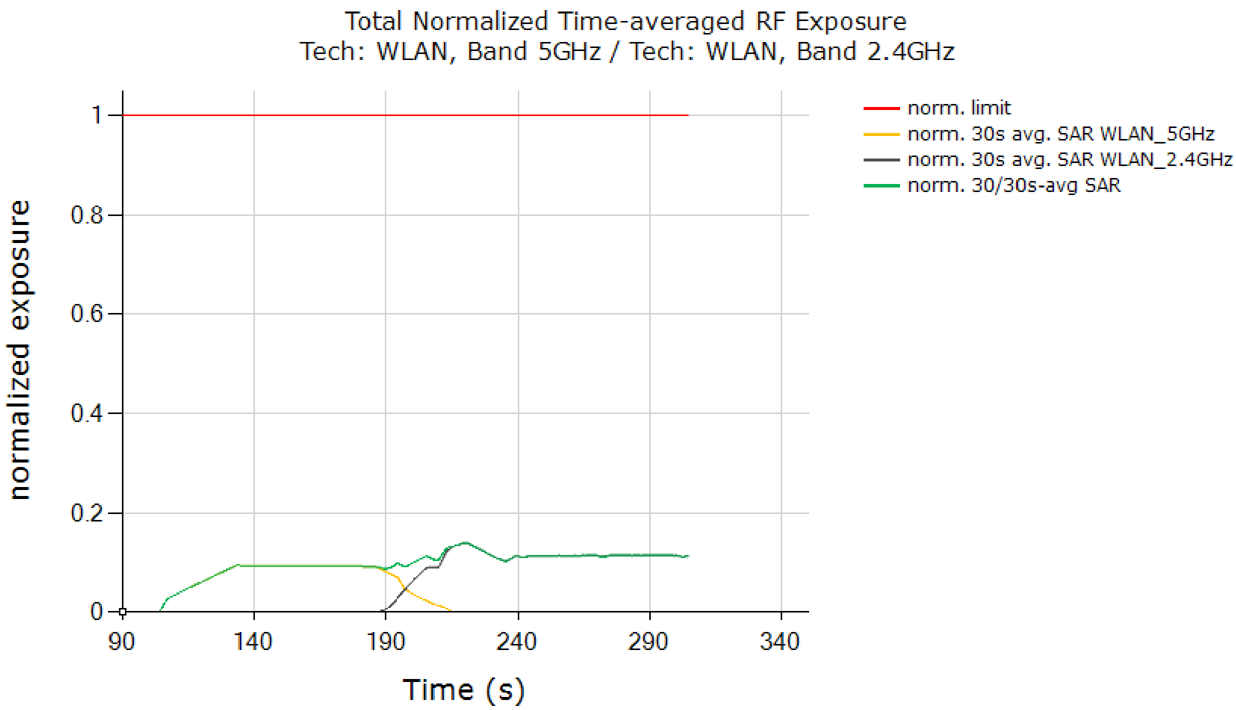
FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.996**	W/kg
Device uncertainty	**1.0**	dB

5.6.2 Change in band/Antenna test results of WLAN

This test was conducted with callbox requesting maximum power, and with technology switch from 2.4GHz SISO(802.11ax), Ant.1, DSI =1 to 5GHz SISO(802.11ac_VHT20), Ant.2, DSI = 1. Following procedure detailed in Section 4.2, the band/Antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region). Please refer to test case 2 in Table 5.2.1.

<u>Test result for change in technology/band:</u>

Time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (4a), (4b) and (4c), and plotted below to demonstrate that the time-average normalized SAR versus time does not exceed the normalized FCC limit of 1.0:



	(W/kg)
FCC normalized SAR limit	1.0
Max 30s-time averaged normalized SAR (green curve)	0.139
Validated	

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

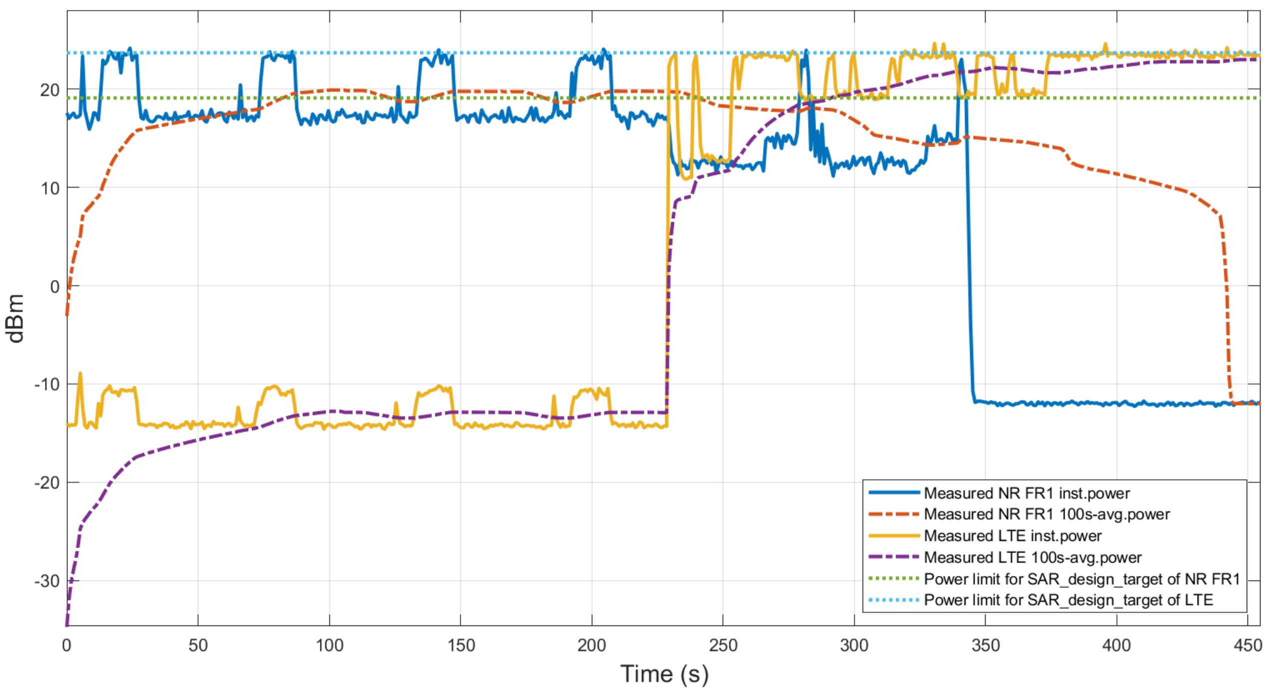
5.7 Switch in SAR exposure test results

5.7.1 Switch in SAR exposure test results of WWAN(NSA)

The test results in this section are obtained following the procedure in Section 3.3.5. The test cases correspond to TC09 in Table 5.1.2.

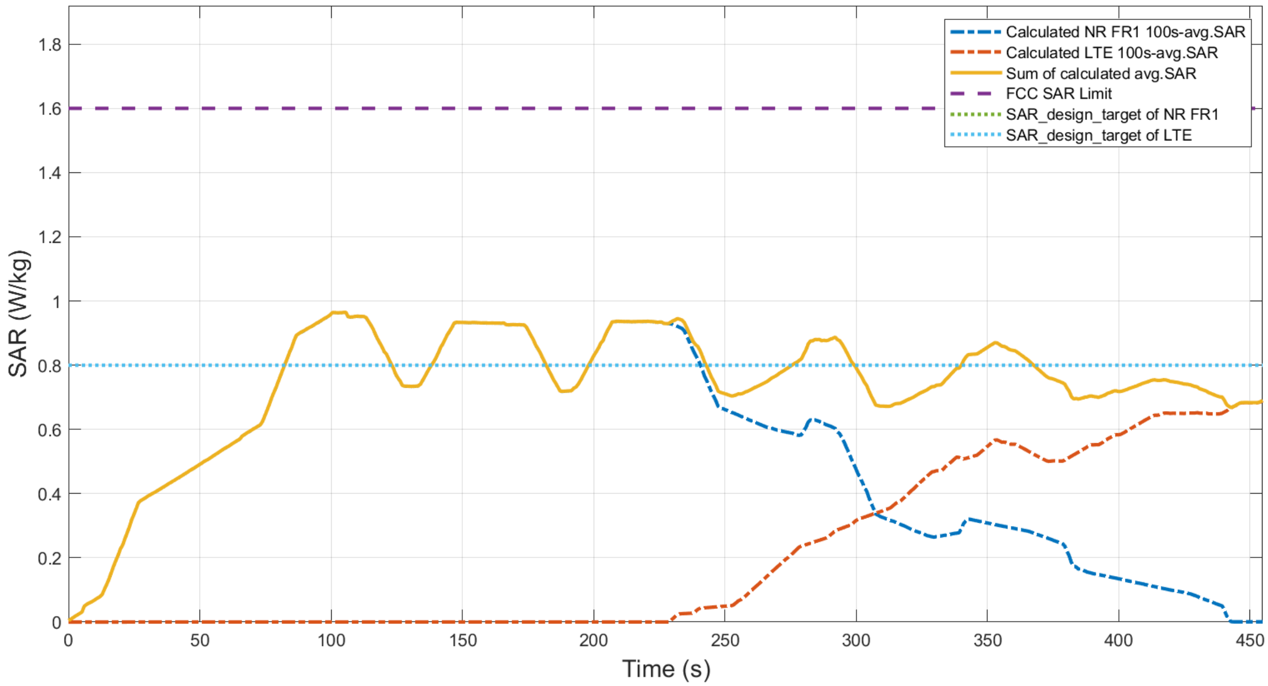
In this LTE+FR1 NSA scenario, we first establish LTE and NR call. In the first part of test, LTE is sent to lowest transmit power using “ALL DOWN” power control commands from call box while NR is sent to maximum power using “ALL UP” power control commands from call box. This would correspond to FR1 dominant SAR scenario and lasts about 220s. In the second part of test, LTE is sent “ALL UP” commands and transmissions are continued, resulting in LTE+FR1 SAR scenario lasting another 110s. In the third part of test, NR is sent “ALL DOWN” power control commands so that it becomes an FR1 dominant SAR scenario for 110s. Finally, both LTE and NR connections are released.

Plot.1 :Time average SAR of LTE and FR1 in NSA case :



Plot.1 shows the instantaneous and time-averaged Tx power for both LTE band and NR FR1 band versus time. When both LTE and FR1 operate, the SAR value was the highest instantaneously, but it can be seen that sum of average power in LTE and FR1 decreases again as soon as it is turned off. Plot.2 shows the computed time-averaged SAR value for LTE and FR1 as well as the sum. It was confirmed that algorithm operated under the total SAR design target limit of 0.8W/Kg, while also being under the FCC limit of 1.6W/Kg at all times. After the operation of FR1 is turned off, it can also be seen that the average power of LTE increases.

Plot.2 : Total time-averaged SAR Result :

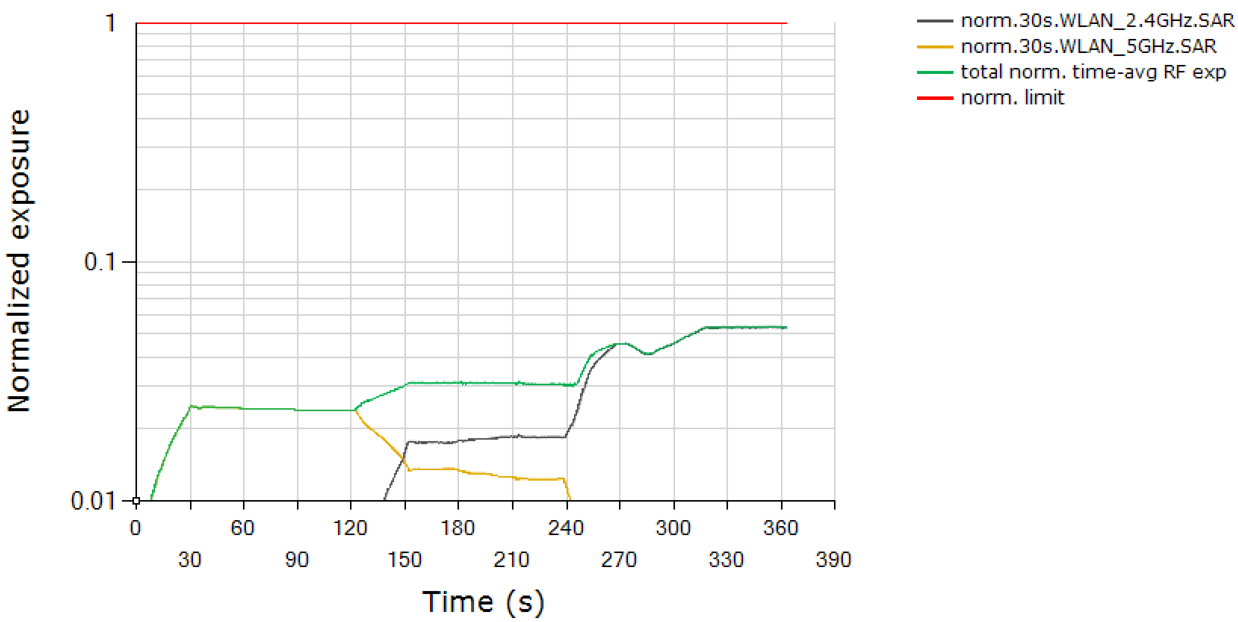


Plot.2 shows the computed time-averaged SAR value for LTE and FR1 as well as the sum. It was confirmed that algorithm operated under the total SAR design target limit of 0.8W/Kg, while also being under the FCC limit of 1.6W/Kg at all times. After the operation of FR1 is turned off, it can also be seen that the average power of LTE increases.

FCC1g SAR limit	**1.6** W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.965** W/kg
Device uncertainty	**1.0** dB

5.7.2 Switch in SAR exposure test results of WLAN(DBS)

This test was conducted with callbox requesting maximum power, and with the EUT in 2.4GHz SISO(802.11b) + 5GHz SISO(802.11ac_VHT20) call. Following procedure detailed in Section 4.2 and 2.4GHz SISO(Ant.2) and 5GHz SISO(Ant.2) are sharing the different antenna port, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (4a), (4b) and (4c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1.0 unit. Equation (4a) is used to convert the WLAN Tx power of device to obtain 30s-averaged normalized SAR in 2.4GHz SISO(802.11b) as show in black curve. Similarly, equation (1b) is used to obtain 30s-averaged normalized SAR in 5GHz SISO(802.11ac_VHT20) as shown in orange curve. Equation (4b) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves). Please refer to test case 4 in Table 5.2.1.



	(W/kg)
FCC normalized total exposure limit	1.0
Max 100s-time averaged normalized SAR (green curve)	0.053
Validated	

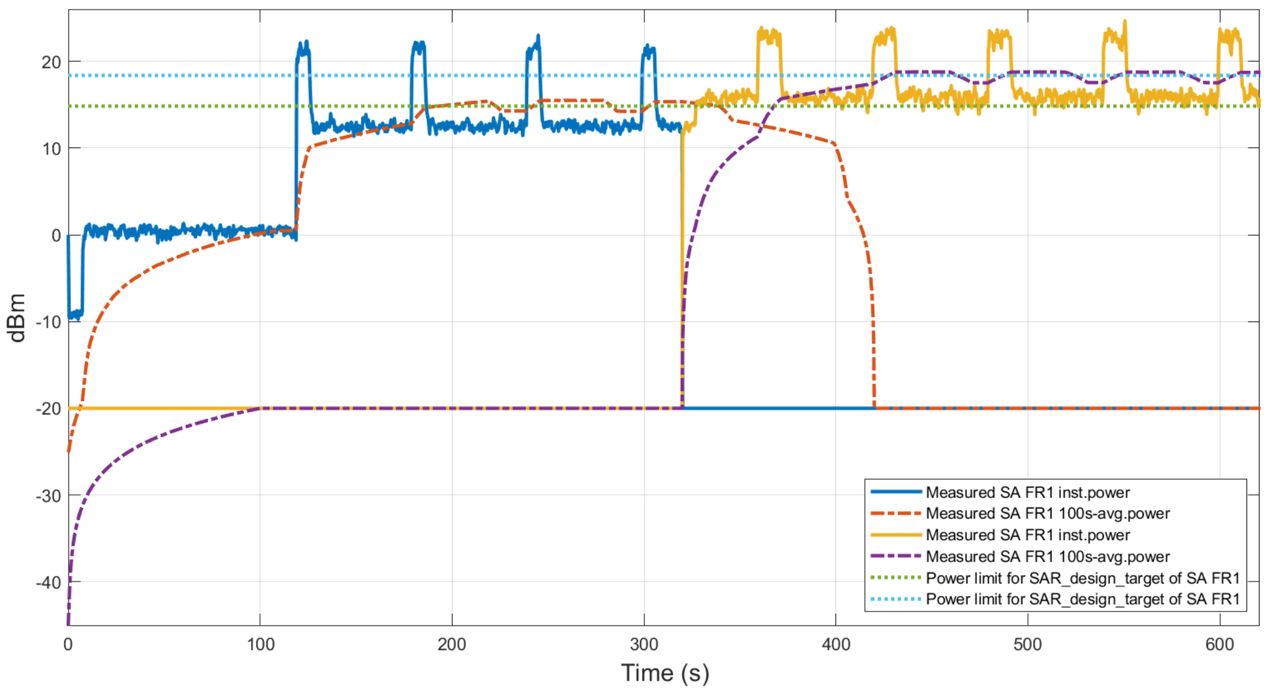
Plot Notes: Device starts predominantly in 5GHz SISO(802.11ac_VHT20) SAR exposure scenario between 0s and 120s, and 2.4GHz SISO(802.11b) + 5GHz MIMO(802.11ac_VHT20) SAR exposure scenario between 120s and 240s, and in predominantly in 2.4GHz SISO(802.11b) exposure scenario after t=240s, in SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1.0dB device uncertainty. In this test, with a maximum normalized SAR of 0.053 being ≤ 0.314 (= 0.4/1.6 + 1.0dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

5.8 Change in RSI(Radio SAR Index)/DSI(Device State Index) value results

5.8.1 Change in RSI value results of WWAN

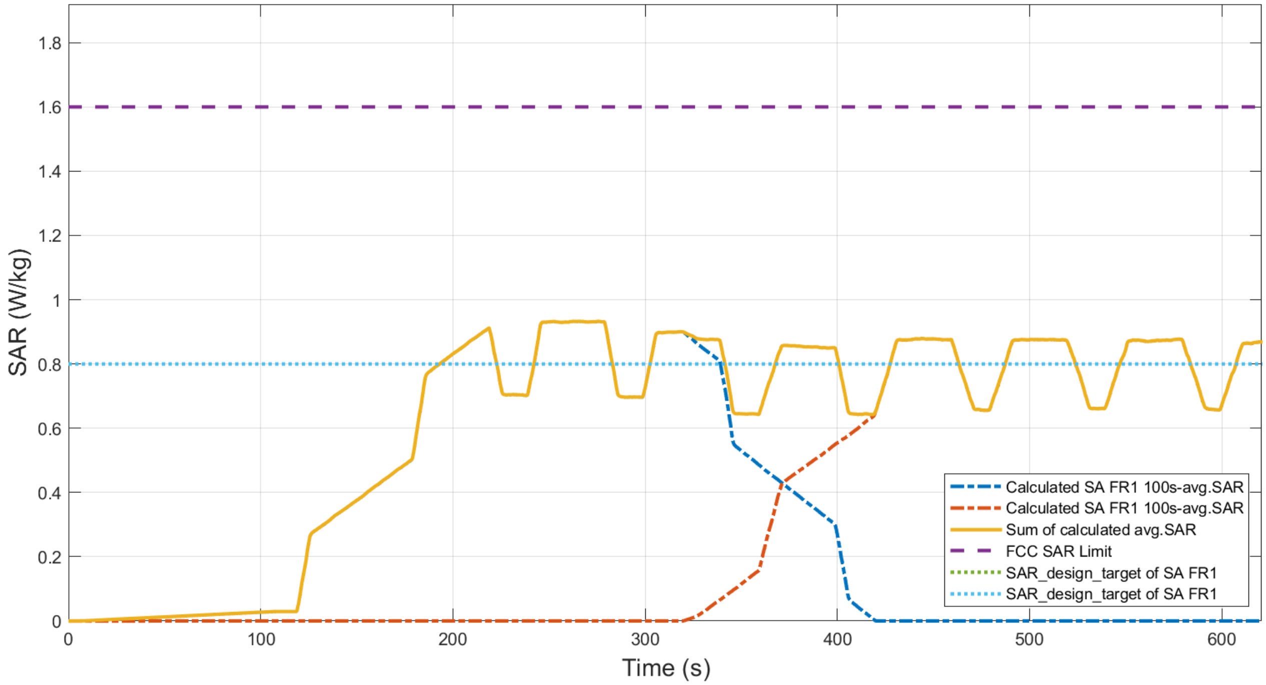
The test results in this section are obtained following the procedure in Section 3.3.4. The test cases correspond to TC13 in Table 5.1.2.

Plot.1 : Conducted Tx power for SAR RSI change :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for both SA FR1 Band n25 for the duration of the test. Around time stamp of ~310s, the RSI value is changed from RSI=RCV to RSI=Free, resulting in reduction of target time-averaged power of SA FR1 Band n25. It can be seen that Plimit value of RSI=RCV is lower than that of RSI=Free, so in RSI=Free region, more Tx power is limited compared to RSI=RCV region. Figure 8.8-2 shows the time-averaged 1gSAR value for each of RSI value, as well as the total SAR value. We can see that the total 1gSAR is higher during the band transitions, but is always under the total FCC limit of 1.6W/Kg.

Plot.2 : Total time-averaged SAR Result :



Plot.2 shows the time-averaged 1gSAR value for each of low and high RSI value, as well as the total SAR value. We can see that the total 1gSAR is higher during the band transitions, but is always under the total FCC limit of 1.6W/Kg.

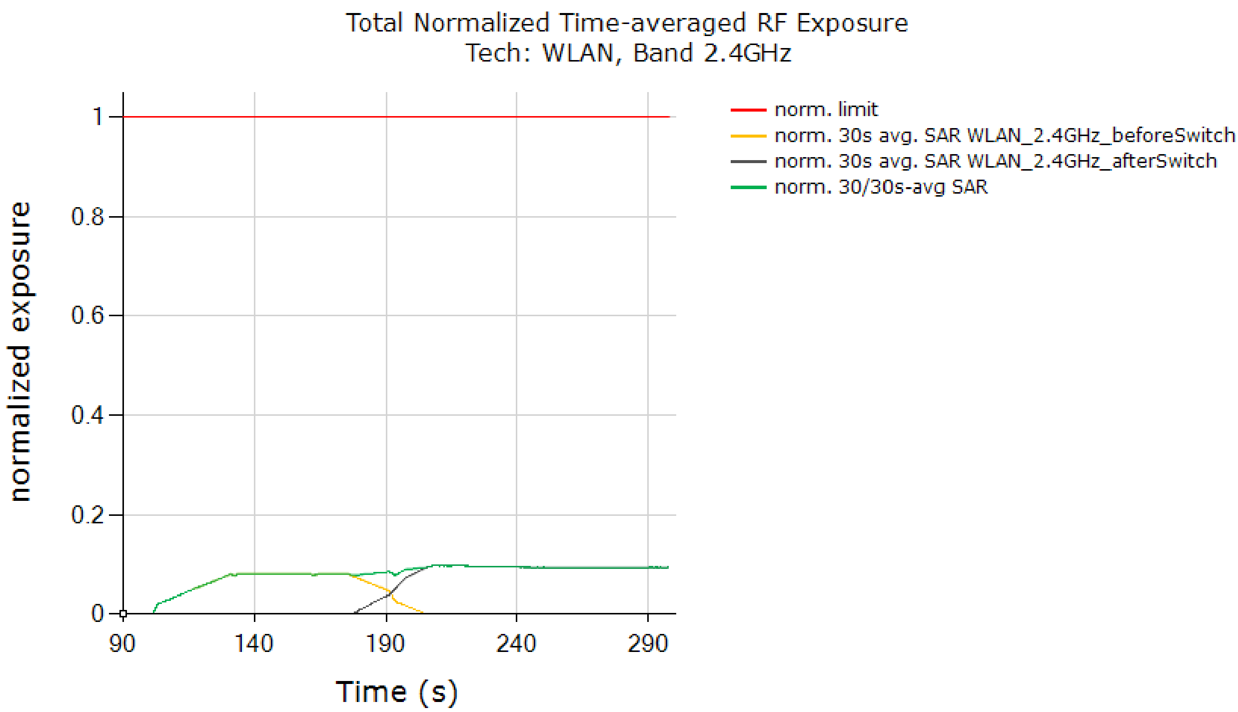
FCC1g SAR limit	**1.6**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	**0.933**	W/kg
Device uncertainty	**1.0**	dB

5.8.2 Change in DSI value results of WLAN

This test was conducted with callbox requesting maximum power, and with DSI switch from 2.4GHz SISO(802.11b) Ant.1 DSI = 1 to DSI = 0. Following procedure detailed in Section 4.2, the DSI switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black circle). Please refer to test case 3 in Table 5.2.1.

<u>Test result for change in DSI:</u>

All the time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (4a), (4b) and (4c), and plotted below to demonstrate that the time-average normalized SAR versus time does not exceed the normalized FCC limit of 1.0 unit.



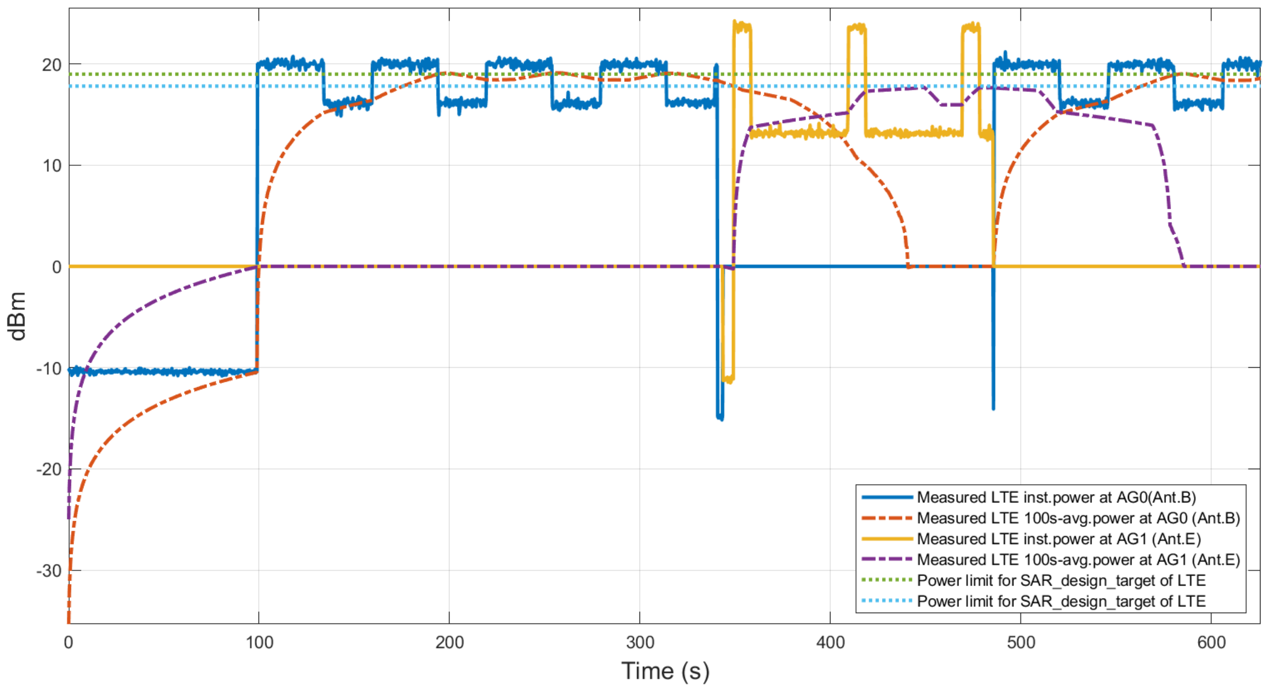
	(W/kg)
FCC normalized SAR limit	1.0
Max 30s-time averaged normalized SAR (green curve)	0.098
Validated	

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

5.9 Antenna switching with spatial TAS test results

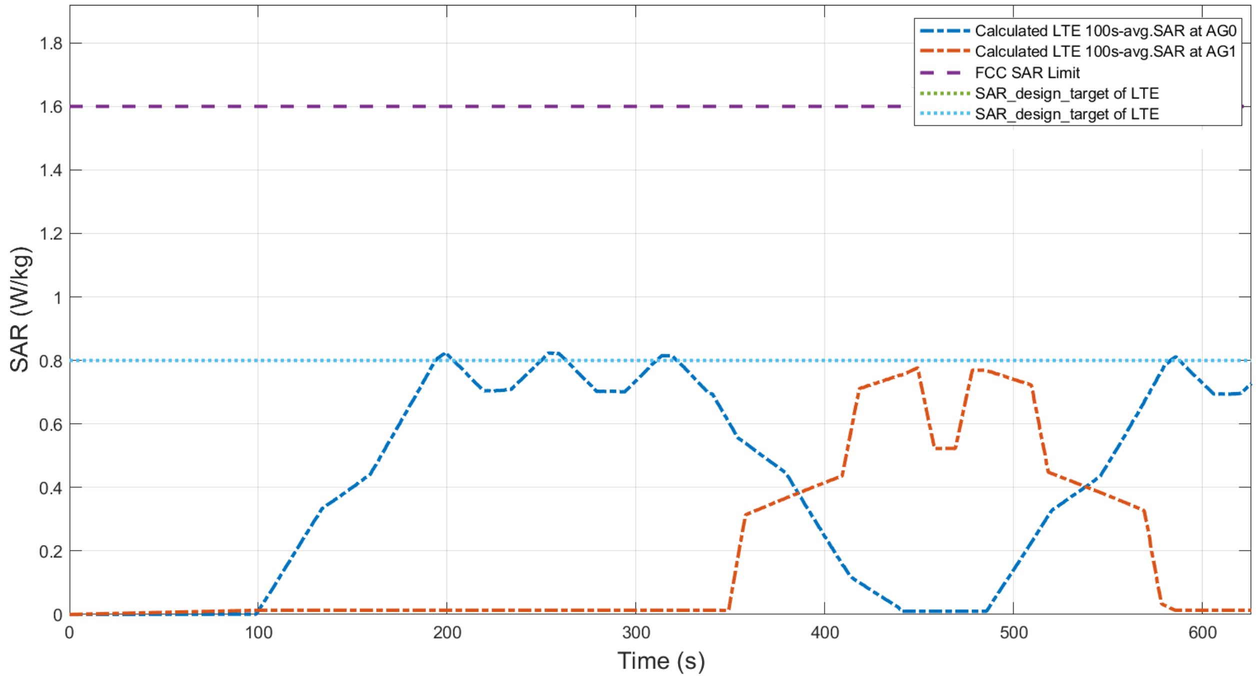
The test results in this section are obtained following the procedure in Section 3.3.8. The test cases correspond to TC23 in Table 5.1.2.

Plot.1 : Conducted Tx power for LTE :



Plot.1 shows the instantaneous and time-averaged conducted Tx power at each different antenna groups. Transmission is initialized on AG0 where it was set for very low power for ~100s. After that, a maximum power is requested and the TAS starts to cycle. After ~140s a band change happens to other band witch operates at AG1 and an average maximum power is requested. Since the coupling between AG0 and AG1 is 0, then transmission at AG1 will start from maximum power regardless of the transmission at AG0 and will continue transmission for ~90s. Next, another band change is done to the first band and so an antenna switching to AG0 happens where a maximum power is request which yields a transmission at Pmax.

Plot.2 : Total time-averaged SAR Result :



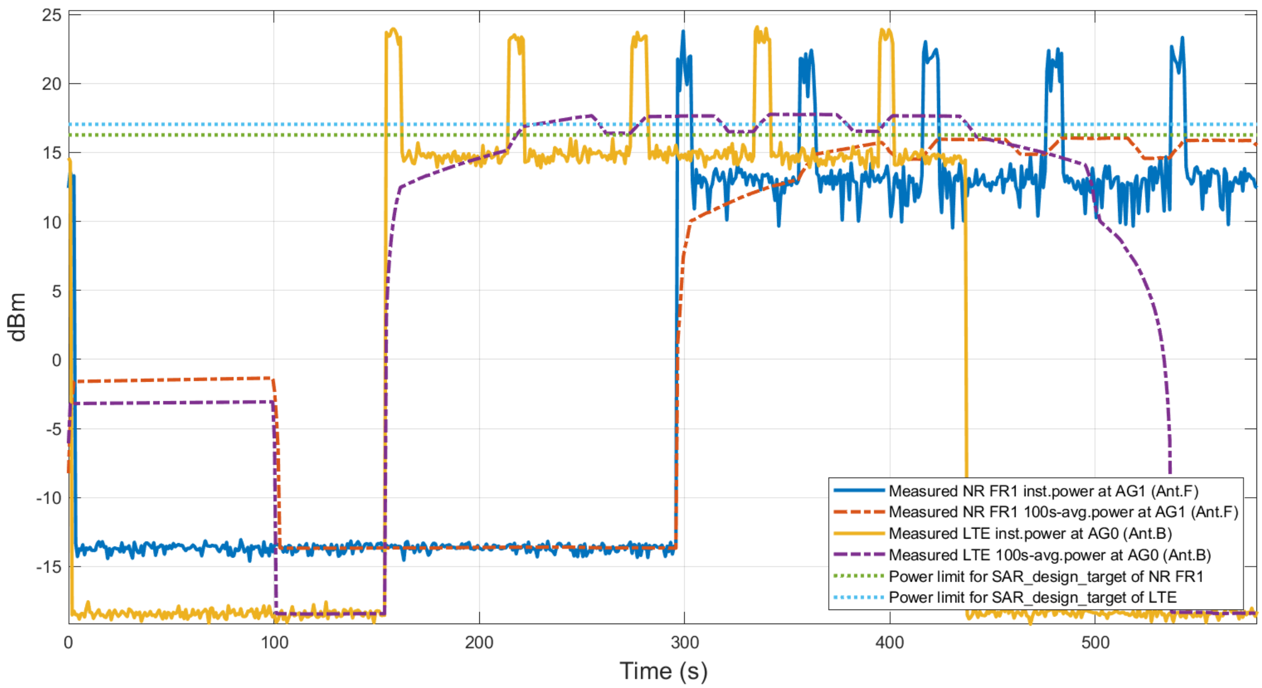
Plot.2 shows consequently the average SAR is below 0.8W/kg which is below the FCC limit of 1.6 W/kg.

FCC1g SAR limit	**1.6** W/kg	
Max 100s-time averaged 1gSAR (blue curve)	AG0(Ant.B)	**0.822** W/kg
Max 100s-time averaged 1gSAR (orange curve)	AG1(Ant.E)	**0.777** W/kg
Device uncertainty	**1.0** dB	

5.10 NSA(EN-DC) with spatial TAS test results

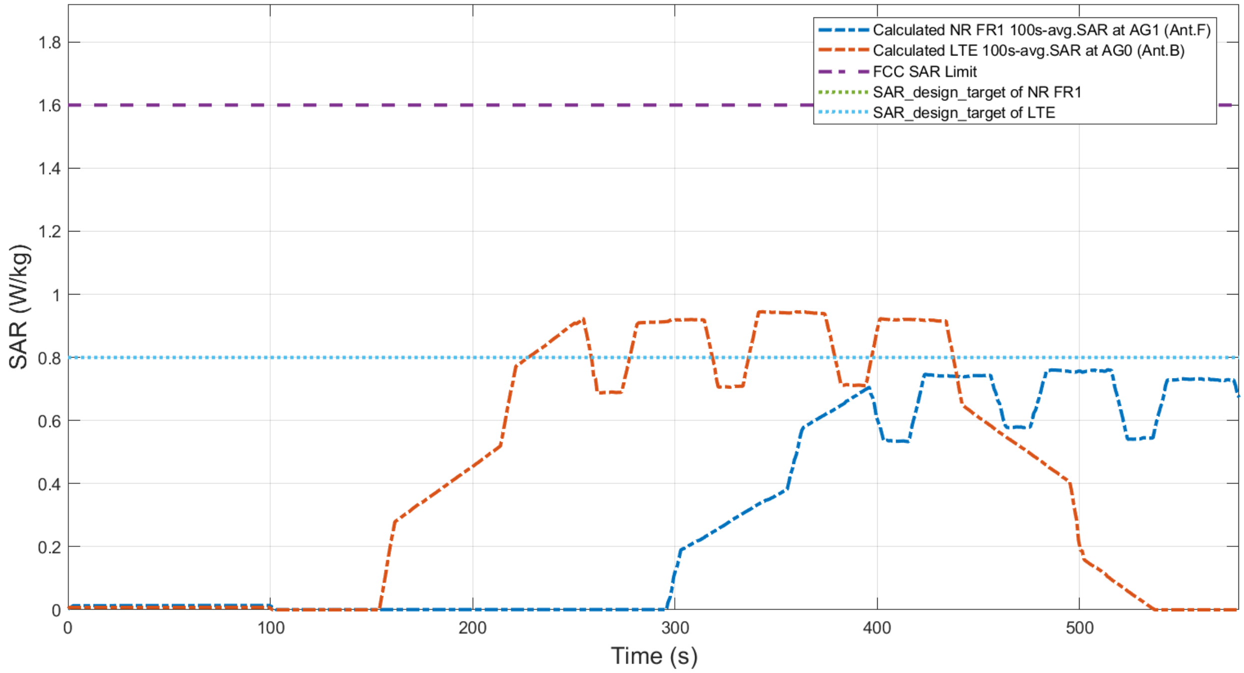
The test results in this section are obtained following the procedure in Section 3.3.8. The test cases correspond to TC25 in Table 5.1.2.

Plot.1 : Conducted Tx power for LTE and NR :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for a NSA operation where LTE is transmitting at AG0's antennas and NR FR1 at antennas of AG1. After EN-DC(NAS) connection establishment, Both LTE and NR FR1 are set to no transmission for ~150s. Next, a transmission starts with LTE requesting full max power and no transmission for NR FR1 and continue for ~140. After that, a maximum power is requested for NR FR1 and transmission is done on AG1's antennas and continue for ~140s. Since both AGs are fully uncoupled, each RAT will operate with full Plimit, where average power of LTE and average power of NR FR1 are closed to Plimit. Next, the LTE transmission is down while NR FR1 continue transmission.

Plot.2 : Total time-averaged SAR Result :



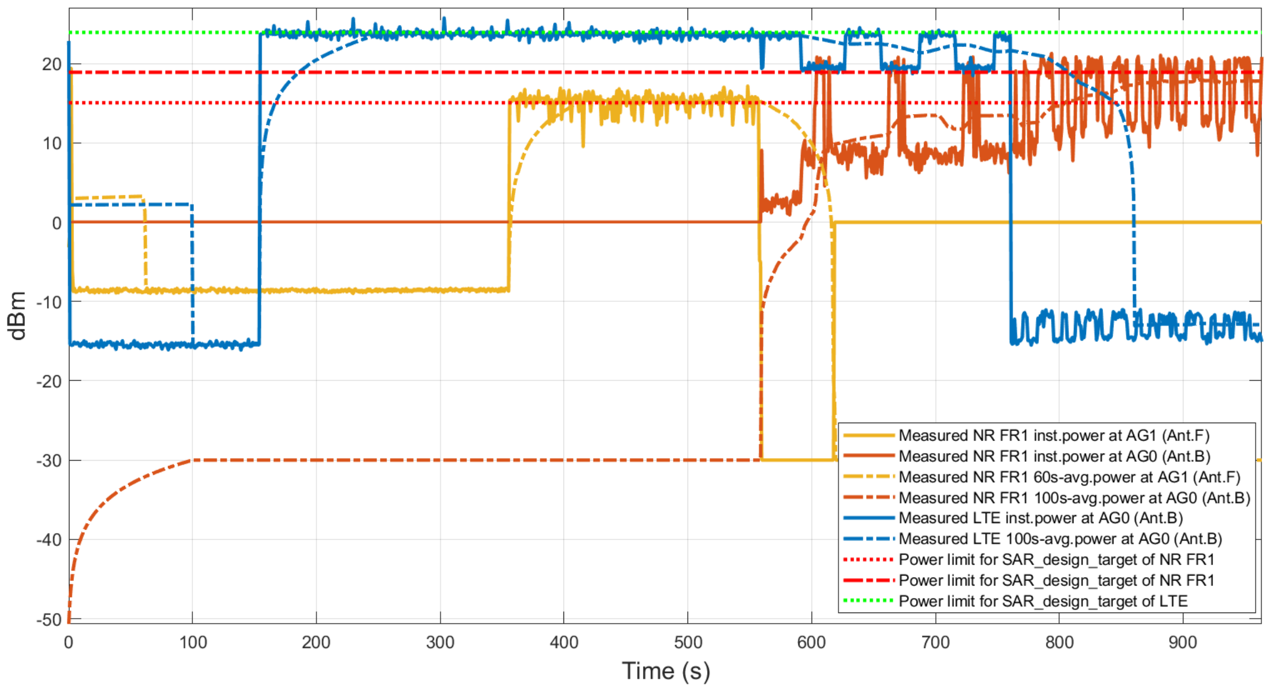
Plot.2 shows consequently the average SAR is below 0.8W/kg which is below the FCC limit of 1.6 W/kg.

FCC1g SAR limit	**1.6** W/kg	
Max 100s-time averaged 1gSAR (orange curve)	AG0(Ant.A)	**0.944** W/kg
Max 100s-time averaged 1gSAR (blue curve)	AG1(Ant.F)	**0.759** W/kg
Device uncertainty	**1.0** dB	

5.11 NSA(EN-DC) antenna switching with spatial TAS test results

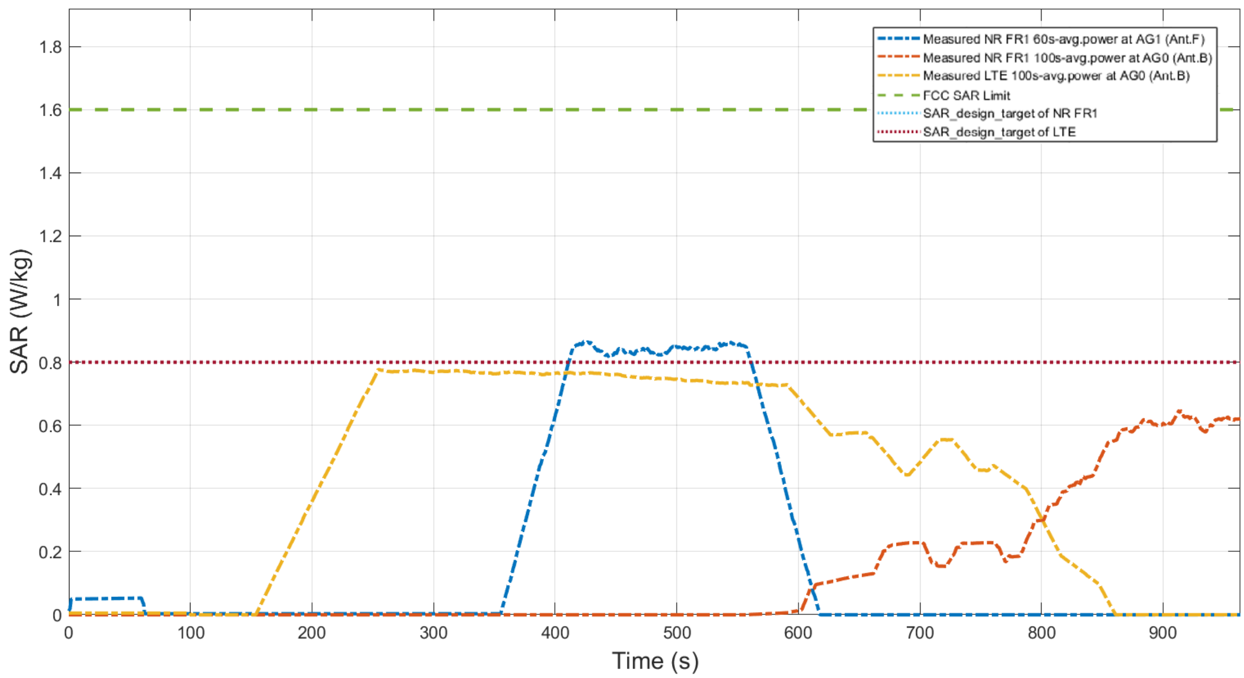
The test results in this section are obtained following the procedure in Section 3.3.8. The test cases correspond to TC26 in Table 5.1.2.

Plot.1 : Conducted Tx power for LTE and NR :



Plot.1 shows the instantaneous and time-averaged conducted Tx power for a NSA operation where LTE is transmitting at AG0's antennas and NR FR1 at AG0's antennas and AG1's antennas. After the EN-DC connection establishment, Both LTE and NR FR1 are set to no transmission for ~150s. Next, a transmission starts with LTE requesting full max power and no transmission for NR FR1 and continue for ~200s. After that, a maximum power is requested for NR FR1 band and transmission is done on AG1's antennas and continue for ~200s. Since AG0 and AG1 are fully uncoupled, each RAT will operate with full Plimit, where the average power of each RATs is close to Plimit. Next, FR1 will switch to other NR FR1 band which will require and antenna switch to AG0's antennas where NR FR1 requests maximum power and transmission continues for ~200s. Next, The LTE transmission is down while NR FR1 continues transmission.

Plot.2 : Total time-averaged SAR Result :



Plot.2 shows consequently the average SAR is below 0.8W/kg which is below the FCC limit of 1.6 W/kg.

FCC1g SAR limit	**1.6**		W/kg
Max 100s-time averaged 1gSAR (orange curve)	AG0(Ant.A)-LTE	**0.777**	W/kg
Max 100s-time averaged 1gSAR (blue curve)	AG1(Ant.F)-NR	**0.865**	W/kg
Max 100s-time averaged 1gSAR (red curve)	AG0(Ant.A)-NR	**0.646**	W/kg
Device uncertainty	**1.0**		dB

6 SAR Test Configurations & Test Results

Point SAR measurement is required for Qualcomm FastConnect TAS.

6.1 Dielectric Property Measurements & System Check

Please detail of explain refer to Sec.8 in SAR report.

6.1.1 Dielectric Property Measurements

Dielectric Property Measurements Results:

SAR 8 Room

Date	Freq. (MHz)	Liquid Parameters			Measured	Target	Delta (%)	Limit ±(%)
10-19-2023	Head 2450	e'	38.5300	Relative Permittivity (ϵ_r):	38.53	39.20	-1.71	5
		e''	12.9400	Conductivity (σ):	1.76	1.80	-2.07	5
	Head 2400	e'	38.6200	Relative Permittivity (ϵ_r):	38.62	39.30	-1.72	5
		e''	12.9500	Conductivity (σ):	1.73	1.75	-1.34	5
	Head 2480	e'	38.4900	Relative Permittivity (ϵ_r):	38.49	39.16	-1.72	5
		e''	12.9300	Conductivity (σ):	1.78	1.83	-2.70	5
10-19-2023	Head 5200	e'	37.7400	Relative Permittivity (ϵ_r):	37.74	35.99	4.86	5
		e''	15.5900	Conductivity (σ):	4.51	4.65	-3.08	5
	Head 5250	e'	37.6300	Relative Permittivity (ϵ_r):	37.63	35.93	4.72	5
		e''	15.6200	Conductivity (σ):	4.56	4.70	-3.03	5
	Head 5600	e'	36.9000	Relative Permittivity (ϵ_r):	36.90	35.53	3.84	5
		e''	15.8300	Conductivity (σ):	4.93	5.06	-2.59	5
	Head 5750	e'	36.6100	Relative Permittivity (ϵ_r):	36.61	35.36	3.53	5
		e''	15.9600	Conductivity (σ):	5.10	5.21	-2.13	5
	Head 5800	e'	36.5400	Relative Permittivity (ϵ_r):	36.54	35.30	3.51	5
		e''	15.9900	Conductivity (σ):	5.16	5.27	-2.15	5
	Head 5925	e'	36.3500	Relative Permittivity (ϵ_r):	36.35	35.20	3.27	5
		e''	16.0900	Conductivity (σ):	5.30	5.40	-1.84	5

6.1.2 SAR system check

Reference Target SAR Values

The reference SAR values can be obtained from the calibration certificate of system validation dipoles.

System Dipole	Serial No.	Cal. Date	Cal. Due.Date	Freq. (MHz)	Target SAR Values (W/kg)	
					1g/10g	Head
D2450V2	939	7-19-2023	7-19-2024	2450	1g	52.30
					10g	24.70
D5GHzV2	1325	4-21-2023	4-21-2024	5600	1g	83.90
					10g	23.80

System Check Results

The 1-g and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within 10% of the manufacturer calibrated dipole SAR target.

SAR 8 Room

Date Tested	System Dipole		T.S. Liquid		Measured Results		Target (Ref. Value)	Delta ±10 %
	Type	Serial #			Zoom Scan to 100 mW	Normalize to 1 W		
10-19-2023	D2450V2	939	Head	1g	5.19	51.9	52.30	-0.76
				10g	2.47	24.7	24.70	0.00
10-19-2023	D5GHzV2	1325	Body	1g	8.26	82.6	83.90	-1.55
				10g	2.43	24.3	23.80	2.10

6.2 Measurement setup

This measurement setup is similar to normal SAR measurements. The difference in SAR measurement setup for time averaging feature validation is that the callbox is signaling in close loop power control mode (instead of requesting maximum power in open loop control mode) and callbox is connected to the PC using GPIB(or Ethernet) so that the test script executed on PC can send GPIB(or Ethernet) 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.
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 Sub6 NR (with LTE as anchor), "path loss" between callbox antenna and the EUT needs to be carefully calibrated for both LTE link as well as for Sub6 NR link.
The EUT is placed in Worst-case position against flat section of SAM Twin phantom as shown in Appendix A.

6.3 SAR measurement results for Change in request power scenario

Following Section 4.3 procedure, time-averaged SAR measurements are conducted using EX3DV4 probe at peak location of area scan over 800 seconds. cDASY6 system validation for SAR measurement is provided in Section 6.1.2, and the associated SPEAG certificates are attached in Appendix E(Probes) & F(Dipoles) in SAR report. 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):

http://www.speag.com/assets/downloads/servces/cs/UIDSummary 171205.pdf

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the number of points in 360s interval is determined from the scan duration setting in cDASY6 time-average pointSAR measurement by (360s / cDASY6_scan_duration * total number of pointSAR values recorded). Running average is performed over these number of points in excel spreadsheet to obtain 360s-averaged pointSAR.

Following Section 4.3, for each of selected technology/band (listed in Table 5.2.1):

1. 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}.

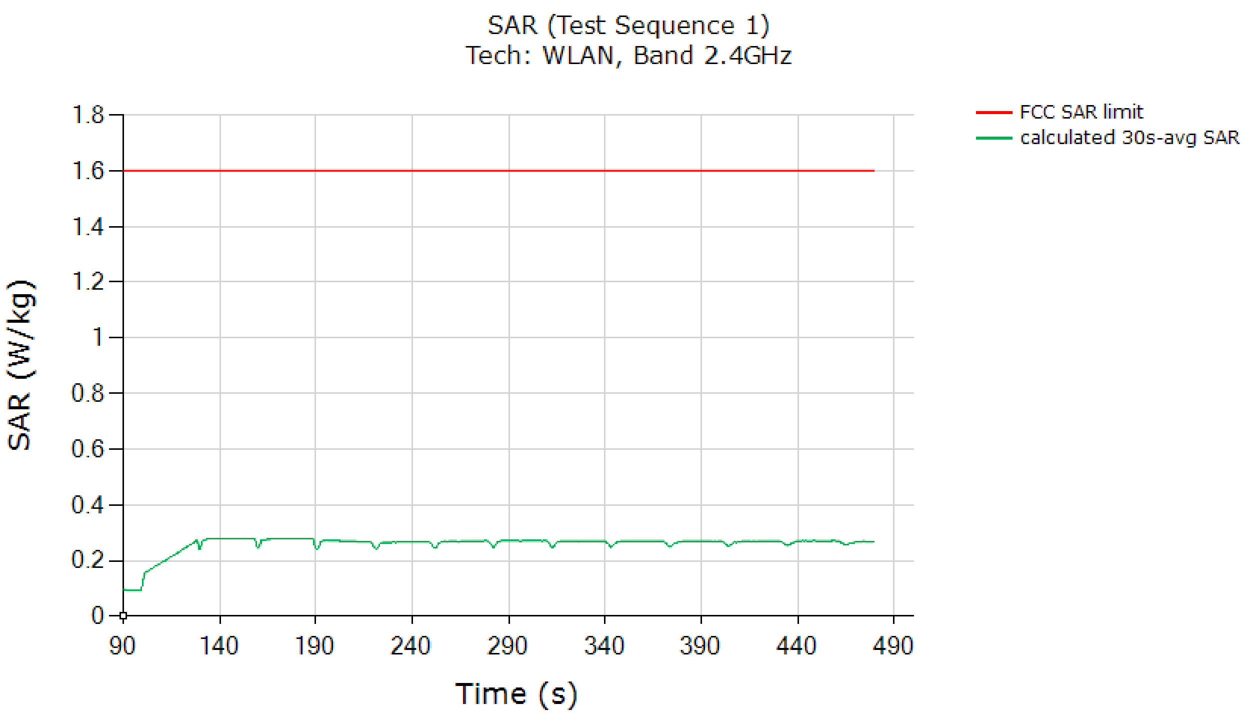
2. With *Reserve_power_margin* set to actual (intended) value, three more time-averaged pointSAR measurements are performed at the same peak location for test sequence. To demonstrate compliance, all the point SAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (5a), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (5a)$$

Where, *pointSAR(t)*, $pointSAR\_P_{limit}$, and $1g\_or\_10g\ SAR\_P_{limit}$ correspond to the measured instantaneous point SAR, measured point SAR at P_{limit} from above step 1 and 2, and measured *1gSAR or 10gSAR* values at P_{limit} obtained from SAR report and listed in Table 5.2.1 in Section 5.2.1.2 of this report.

6.3.1 2.4GHz SISO (802.11b)

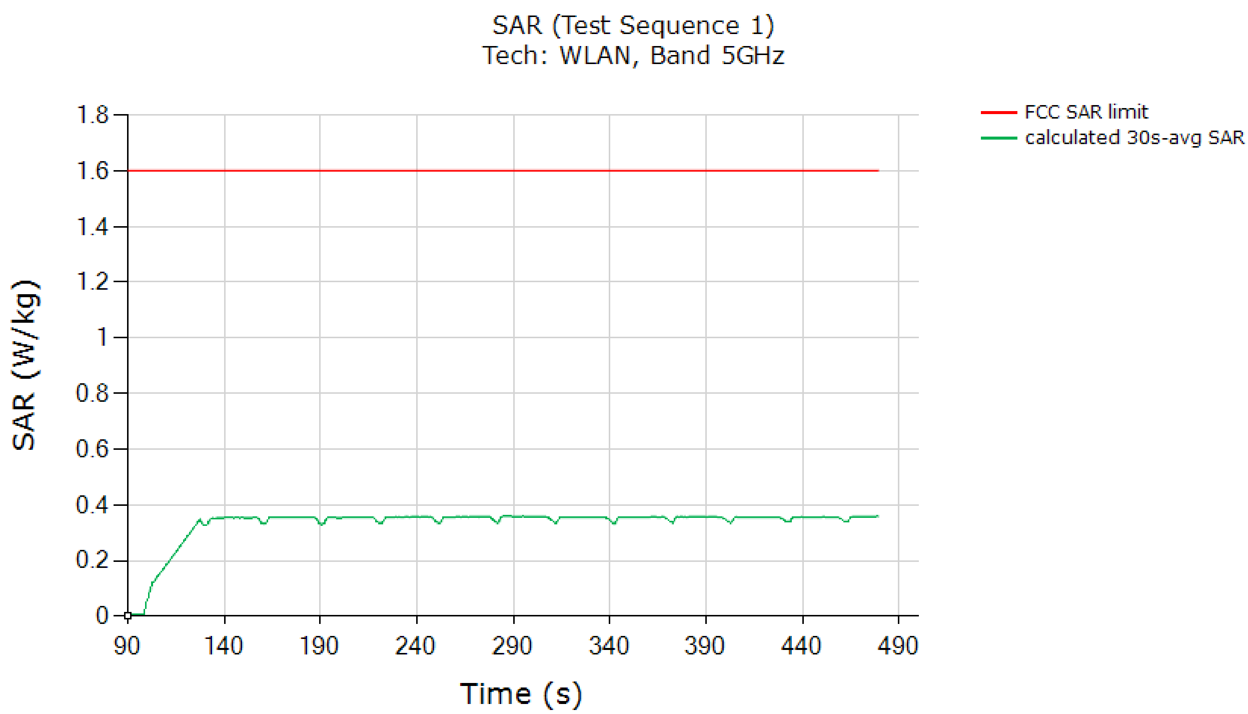
<u>Test result for test sequence:</u>



	Test sequence (W/kg)
ISED 1gSAR limit	1.6
Max 360s-time averaged 1gSAR (green curve)	0.278
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5.2.1).	

6.3.2 5GHz SISO (802.11a)

Test result for test sequence:



	Test sequence (W/kg)
ISED 1gSAR limit	1.6
Max 360s-time averaged 1gSAR (green curve)	0.359
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5.2.1).	

7. Test Equipment

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

Conducted test

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Power Sensor	Anritsu	MA2472D	2014271	10-18-2024
Power Sensor	Anritsu	MA2472D	2014291	10-18-2024
Power Meter	Anritsu	ML2438A	2212002	10-18-2024
Power Sensor	R & S	NRP8S	104520	7-26-2024
Power Sensor	R & S	NRP8S	104521	7-26-2024
Directional Coupler	MINI-CIRCUITS	ZUDC20-183+	N/A	7-24-2024
Directional Coupler	MINI-CIRCUITS	ZUDC20-183+	N/A	7-24-2024
Resistive Power Splitter	WEINSCHEL	1534	S0246	1-5-2024
Resistive Power Splitter	WEINSCHEL	1534	S0247	1-5-2024
Resistive Power Splitter	WEINSCHEL	1534	S0248	1-5-2024
Band Pass Filter	MINI-CIRCUITS	VBFZ-780-S+	S0234	1-6-2024
Band Pass Filter	MINI-CIRCUITS	VBFZ-2000-S+	S0238	1-6-2024
Band Pass Filter	MINI-CIRCUITS	VBFZ-2340-S+	S0240	1-6-2024
Band Pass Filter	MINI-CIRCUITS	VBFZ-3590-S+	S0243	1-6-2024
Radio Communication Test Station	Anritsu	MT8000A	6272466165	10-18-2024
Radio Communication Analyzer	Anritsu	MT8821C	6161094351	11-29-2023
Base Station Simulator	R & S	CMW500	169803	1-5-2024

SAR test

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Network Analyzer	ROHDE & SCHWARZ	ZNB 20	102256	7-24-2024
Dielectric Assessment Kit	SPEAG	DAK-3.5	1196	7-17-2024
Shorting block	SPEAG	DAK-3.5 Short	SM DAK 200 BA	N/A
Thermometer	LKM	DTM3000	3851	7-25-2024
MXG Analog Signal Generator	Keysight	N5173B	MY59101083	7-27-2024
Power Sensor	KEYSIGHT	U2000A	MY60180020	7-27-2024
Power Sensor	KEYSIGHT	U2000A	MY60490008	7-25-2024
Power Amplifier	EXODUS	AMP2027ADB	10002	1-6-2024
Directional Coupler	KRYTAR	100318010	215542	1-5-2024
Low Pass Filter	MINI-CIRCUITS	VLF-6000+	S0142	7-25-2024
Low Pass Filter	MINI-CIRCUITS	VLF-3000+	S0143	7-25-2024
Attenuator	KEYSIGHT	8491B/003	MY39272276	7-25-2024
Attenuator	KEYSIGHT	8491B/010	MY39271981	7-24-2024
Attenuator	KEYSIGHT	8491B/020	MY39272301	7-25-2024
E-Field Probe	SPEAG	EX3DV4	7314	5-23-2024
Data Acquisition Electronics	SPEAG	DAE4	1670	5-23-2024
System Validation Dipole	SPEAG	D2450V2	939	7-19-2024
System Validation Dipole	SPEAG	D5GHzV2	1325	4-21-2024
Thermometer	Lutron	MHB-382SD	AK.12102	7-31-2024
Base Station Simulator	R & S	CMW500	169803	1-5-2024

8. Conclusions

Both Samsung S.LSI TAS feature and Qualcomm FastConnect TAST feature employed in Samsung device has been validated through the conducted power/SAR measurement (as demonstrate in Section 5 and 6).
As demonstrated in this report, TAS feature limit the transmit power effectively and shows that SAR value does not exceed 1.6 W/Kg and the TER value does not exceed 1.0 for all the transmission scenarios described in Section 2.

Section A. Test Sequences

A.1 Test sequence is generated based on below parameters of the DUT :

1. Measured maximum power (P_{max})

2. Measured Tx power (P_{limit}) to satisfy SAR Compliance

3. Setup time to make SAR Remaining be full

4. Do test according to test sequence

A.2 WWAN's Test sequence A waveform :

Based on the parameters above, the Test Sequence A is generated with one or two power levels where one of the levels is maximum power level (Pmax) which is applied at least for 100s. Based on the second level this test sequence is sub-categorized into four different sequences used:

a. Test Sequence A.i where after Pmax, a second level of Plimit is requested till the end of the test

b. Test Sequence A.ii where after Pmax, a second level of Pmax-3dB is requested till the end of the test

c. Test Sequence A.iii where after Pmax, a second level of Plimit-3dB is requested till the end of the test

d. Test Sequence A.iv where only Pmax is requested till the end of the test

A.3 WLAN's Test sequence #1 waveform :

Request EUT to transmit maximum power for at least 30s with 100% duty cycle and 50% duty cycle for 60s to determine time-averaged 1gSAR versus time.

Time duration (seconds)	Duty Cycle (%)
30	100%
60	50%

A.4 WWAN's Test sequence B waveform :

Based on the parameters above, the Test Type B is generated with pre-defined power levels, which is described in Table A.3.1.

Table A.3.1 Table of test sequence B

Time duration (second)	Power level (dB)
15	P_{limit} - 5
20	P_{limit}
20	P_{limit} + 5
10	P_{limit} – 6
20	P_{max}
15	P_{limit}
15	P_{limit} -7
20	P_{max}
10	P_{limit}-5
15	P_{limit}
10	P_{limit}-6
20	P_{limit} + 5
10	P_{limit} – 4
15	P_{limit}
10	P_{limit} – 6
20	P_{max}
15	P_{limit}-8
15	P_{limit}
20	P_{max}
10	P_{limit} – 9
20	P_{limit} + 5
20	P_{limit}
15	P_{limit} – 5

Section B. References

The following documents contain reference in this technical document.

[1] 3GPP TR 37.815: Study on high power User Equipment (UE) (power class 2) for E-UTRA (Evolved Universal Terrestrial Radio Access) – NR Dual Connectivity (EN-DC) (1 LTE FDD band + 1 NR TDD band)

Appendixes

Refer to separated files for the following appendixes.

4790976555-S1 FCC Report TAS Validation_App A_Test setup photos

End OF REPORT