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TAS Validation Report

Applicant Name: **SAMSUNG Electronics Co., Ltd.** 129, Samsung-ro, Yeongtong-gu, Suwon-Si, Gyeonggi-do, 16677 Rep. of Korea	**Date of Issue:** Jan.12, 2022 **Test Report No.:** HCT-SR-2201-FC008 **Test Site: HCT CO., LTD.**

FCC ID: A3LSMA536V

Equipment Type:	**Mobile Phone**
Application Type:	**Certification**
FCC Rule Part(s):	**CFR §2.1093**
Model name:	**SM-A536V**
Date of Test:	**Jan. 03, 2022 ~ Jan. 11, 2022**
Results:	**Pass**

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

Tested By	Reviewed By
Jin-Young, Choi Test Engineer SAR Team Certification Division	Yun-Ieang, Heo Technical Manager SAR Team Certification Division

REVISION HISTORY

The revision history for this test report is shown in table.

Revision No.	Date of Issue	Description
0	Jan.12, 2022	Initial Release

This test results were applied only to the test methods required by the standard.

The above Test Report is not related to the accredited test result by (KS Q) ISO/IEC 17025 and KOLAS(Korea Laboratory Accreditation Scheme), which signed the ILAC-MRA.

Table of Contents

1. Introduction

This Process of TAS Validation is to demonstrate that the DUT complies with FCC RF exposure compliance requirement under varying Tx power transmission scenarios, thus validation the Samsung S.LSI TAS algorithm feature for FCC equipment authorization of the mobile phone.
The value of Plimit used in this report per scenarios are determined in SAR_PD Char.Report.

FCC RF exposure limits are comprised of SAR (Specific Absorption Rate) and PD (Power Density) limits depending on frequency of operation. Both SAR and PD regulatory specifications are defined over certain measurement duration allowing for time-averaging. The Samsung S.LSI proprietary 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.

1.1 RF Exposure Limits for Frequencies < 6 GHz

HUMAN EXPOSURE	UNCONTROLLED ENVIRONMENT General Population (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT Occupational (W/kg) or (mW/g)
SPATIAL PEAK SAR * (Partial Body)	1.6	8.0
SPATIAL AVERAGE SAR ** (Whole Body)	0.08	0.4
SPATIAL PEAK SAR *** (Hands / Feet / Ankle / Wrist)	4.0	20.0

NOTES:

* The Spatial Peak value of the SAR averaged over any 1 g of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

** The Spatial Average value of the SAR averaged over the whole-body.

******* The Spatial Peak value of the SAR averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

1.2 RF Exposure Limits for Frequencies > 6 GHz

Per §1.1310 (d)(3), the MPE limits are applied for frequencies above 6 GHz. Power Density is expressed in units of W/m^2 or mW/cm^2.
Peak Spatially Averaged Power Density was evaluated over a circular area of 4 cm2 per interim FCC Guidance for near-field power density evaluations per October 2018 TCB Workshop notes

Frequency range (MHz)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposure		
1,500-100,000	5	6
(B) Limits for General Population/Uncontrolled Exposure		
1,500-100,000	1	30

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

1.3 T Interim Guidance for Time Averaging

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

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

2.Tx Varying Transmission Test Cases and Test Proposal.

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

As described in SAR_PD Char.Report, the RF exposure is proportional to the Tx power for both FR1 and FR2. Thus, we rely on conducted power measurements (FR1) and radiated power measurements (FR2) 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 $TxPower(t)$, and radiated power EIRP(FR2)over time, denoted $EIRP(t)$, with time index t
2. Convert measured powers to RF exposure values using linear relationship shown below. In below expression, $P_{limit,FR1}$ would be the measured power at which FR1 technology meets measured SAR level of SAR_design_target as described in SAR_PD Char Report .Similarly, $Plimit,FR2$ would be the measured EIRP at which FR2 technology meets measured PD level of PD $\_design\_target$ as described in SAR_PD Char Report.

$$SAR(t) = \frac{TxPower(t)}{P_{limit,FR1}} \times SAR\_design\_target$$

Eqn. (1)

$$PD(t) = \frac{EIRP(t)}{P_{limit,FR2}} \times PD\_design\_target$$

Eqn. (2)

3. Compute the average RF exposure over the most recent measurement duration which are denoted as TSAR and TPD for FR1 and FR2, respectively. These durations are as specified by FCC. This measurement duration interval is then given by $[t - T$SAR , $t]$ and $[t - T$PD, $t]$ for FR1 and FR2, respectively

4. Divide the RF exposure for FR1 and FR2 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 and FR2 radios in general denoted by LSAR and LPD.

For sub 6 transmission only:

$$\sum_{lSAR=0}^{LSAR-1} \frac{SARavr, lSAR}{FCC\ SAR} \leq 1$$

For sub 6 and mmWave:

$$\sum_{lSAR=0}^{LSAR-1} \frac{SARavr, lSAR}{FCC\ SAR} + \sum_{lPD=0}^{LPD-1} \frac{PDavr, lPD}{FCC\ PDlimit} \leq 1$$

3. Time Averaging Validation Test Procedures for Sub 6

Test Plan and test procedure for validating Samsung S.LSI TAS algorithm for sub-6 scenarios.

3.1 Test sequence determination for validation

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

1. Test Sequence A is generated with two power levels. One is maximum power level Pmax and the other is lower power level. The lower power level is defined as 3dB lower value than maximum power level. At first, maximum power level is applied for 120 seconds ($1.2 * T_{SAR}$). After this, lower power level is used until this test is finished.
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 for Validation TAS

This section provides general guidance for selecting test cases in TAS algorithm validation.

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 as determined in SAR Char Report and PD Char Report. Essentially, we need to pick this combination such that Plimit is less than Pmax so that the TAS algorithm will enforce power restriction.

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 among all bands. 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. However, to show the performance of the TAS algorithm in this document, the case of low Plimit is considered, which is shown in SAR Char Report and PD Char Report.

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 from SAR_PD Char. Report such that Plimit is less than Pmax for both states.
However, to show the performance of the TAS algorithm in this document, the case of low Plimit is considered, which is shown in Table 6.2.1.

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 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.

3.3 Test procedures for conducted power measurements

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

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.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.

3.3.1.1 Test procedure

1. Using the Pmax and Plimit obtained in Table 6.2.1, 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

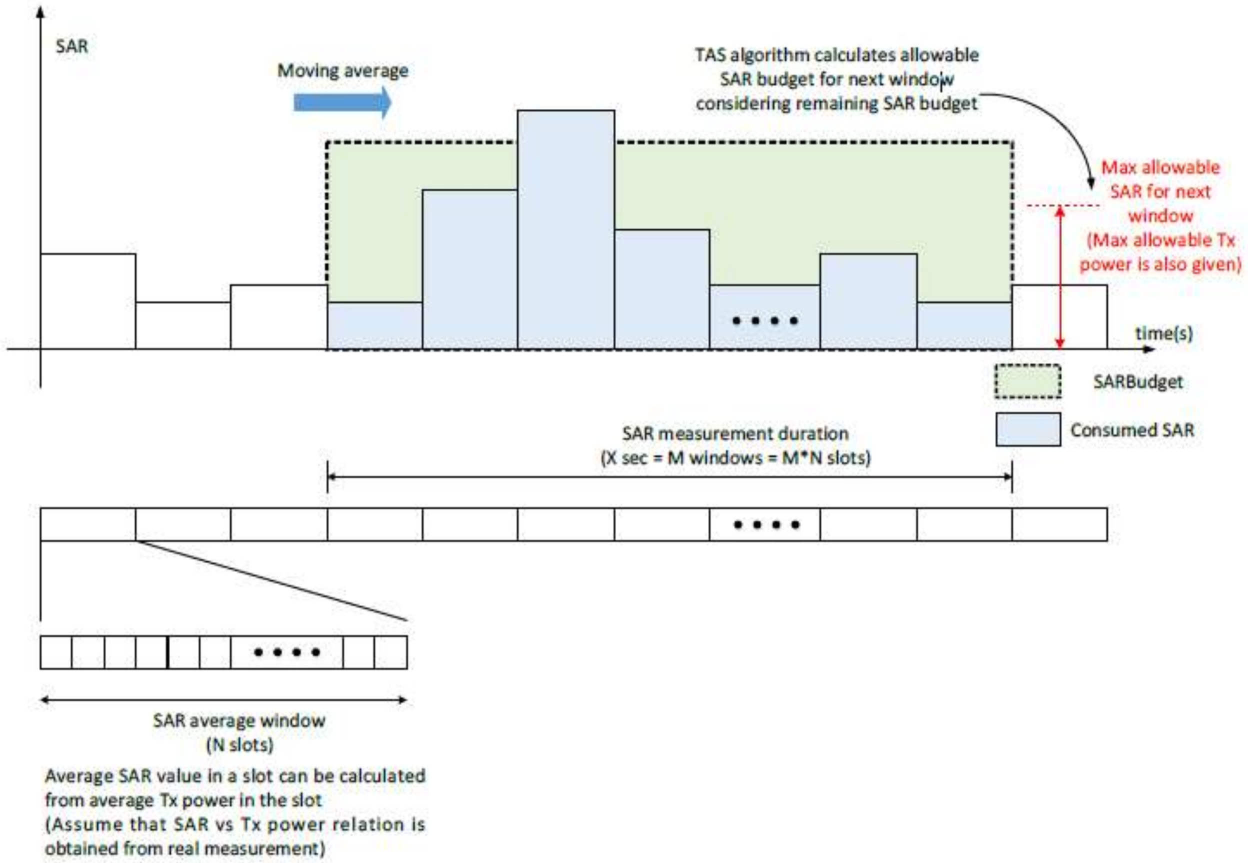

Figure 3.3-1 SAR measurement from Tx power using block-wise processing

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 in Table 6.2.1(Pmax Plimit Table)
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.

3.3.2.1 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 command to bring the Tx power to Pmax level again.
6. Continue LTE transmission at Pmax level for another 110s.
7. Release LTE connection.
8. 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
9. 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.

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

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

where $P_{limit,1,FR1}$ would correspond to measured power at which first technology/band meets measured SAR level of $SAR\_design\_target_1$ as described in Table 6.2.1 with time-averaging duration of $T_{1,SAR}$. Similarly, $P_{limit,FR2}$ would be the measured EIRP at which FR2 technology meets measured PD level of PD$_design_target$ as described in Table 6.2.1. Similarly, the quantities $P_{limit,2,FR1}$, $SAR\_design\_target_2$, $T_{2,SAR}$ are defined for the second technology/band. When first band is chosen below 3GHz, we would have

$T_{1,SAR}$ = 100s, and by choosing second band to be above 3GHz, we would use $T_{2,SAR}$ = 60s. On the other hand, when first band is chosen above 3GHz and second band below 3GHz, we would use $T_{1,SAR}$ = 60s and $T_{1,SAR}$ = 100s.

3.3.3.1 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 which has 100s averaging duration.
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 105s.
4. Change band from band A to another LTE band B , 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 60s
5. Change band from band Bback to the first band A(B2) and continue call at maximum power for at least 100s.
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 below equations and (c) FCC 1gSAR limit of 1.6W/kg.

$$SAR_1(t) = \frac{TxPower_1(t)}{P_{limit,1,FR1}} * SAR\_design\_target_1$$
$$SAR_2(t) = \frac{TxPower_2(t)}{P_{limit,2,FR1}} * SAR\_design\_target_2$$

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.

3.3.3.2 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 which has 60s averaging duration.
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 65s.
4. Change band from band B to another LTE band A , 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 100s

5. Change band from band A back to the first band B and continue call at maximum power for at least 60s.
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 below equations, and (c) FCC 1gSAR limit of 1.6W/kg.

$$SAR_1(t) = \frac{TxPower_1(t)}{P_{limit,1,FR1}} * SAR\_design\_target_1$$
$$SAR_2(t) = \frac{TxPower_2(t)}{P_{limit,2,FR1}} * SAR\_design\_target_2$$

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.

3.3.4 Change in RSI

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 = 3, the head exposure can be distinguished through audio receiver mode, represented as RSI = 1; similarly, the body worn with 10mm distance exposure is represented as RSI = 0; the other exposure would be updated and defined as other RSI numbers.

3.3.4.1 Test procedure for change in RSI

1. Establish radio connection of DUT with call box.
2. Configure DUT to send at low Tx power of 0 dBm for 110s and set the RSI index corresponding to Plimit
3. Configure call box to send “ALL UP” power control commands and continue SA FR1 transmission from DUT so that maximum power of Pmax is achieved. Continue the transmission for 390s.
4. Change the RSI index corresponding to lower value of 3dB and continue the transmission for another 390s
5. Release the SA FR1 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. Test Configurations

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.

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 UP” power control commands. This would correspond to NR dominant SAR scenario and continue this stage for about 110s.
3. In the second part of test, configure the LTE 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 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.

4 PD Time Averaging Validation Test Procedures

In this section, we cover the test plan and test procedure for validating Samsung S.LSI TAS feature for FR2 scenarios. For this DUT, FR2 transmissions are only in non-standalone mode, so it requires LTE as an anchor, and both SAR for LTE and PD for FR2 will be accounted.

4.1 Test sequence determination for validation

In FR2 transmissions, the test sequence for validation is with the callbox requested maximum power for FR2 at all time.

4.2 Test configuration selection criteria for validating TAS

4.2.1 Test configuration selection for time-varying Tx power transmission

Since the TAS feature is independent of band and beams for a given technology, demonstration with one band will be sufficient.

4.2.2 Test configuration selection for SAR vs PD exposure switch during transmission

The TAS feature works for both types of exposure (SAR or PD) and ensures total time-averaged exposure ratio meets the FCC limit of 1. One scenarios of LTE band and FR2 band is sufficient, while exposure condition can be varied between SAR dominant, SAR+PD scenario and PD dominant scenarios for demonstration.

4.2.3 Test configuration selection for change of beam

Since the TAS feature is independent of band and beams for a given technology, demonstration with one pair of beams for switching between them will be sufficient.

4.3 Test procedures for FR2 radiated power measurements

For FR2 testing, we need to perform conducted power measurements for LTE and radiated power measurements for FR2. This section provides general procedures for test setup to validate the compliance in dynamic scenarios outline in Section 2

4.3.1 FR2 max power transmission

4.3.1.1 Test procedure

1. Set the phone in an anechoic chamber for FR2 radiated transmission. In a non-signaling transmission mode for FR2 at maximum target EIRP, adjust the position of the DUT via rotation within the chamber to obtain the maximum measured radiated EIRP using the fixed test antenna. Keep the DUT in this fixed position for the remainder of the test.
2. Reset the DUT state to normal signaling mode and establish both LTE and FR2 connections with the call box.
3. Immediately send “ALL DOWN” power control commands from LTE call box to send LTE to the lowest transmission power. Next, configure the FR2 call box to send “ALL UP” power control commands to send FR2 radio to maximum EIRP condition. In this case, the FR2 radio will comprise the dominant exposure condition using PD metric.
4. After 120s, configure LTE call box to send “ALL UP” power control commands and continue transmission.
5. Record the conducted power of LTE and radiated EIRP of FR2 radio at all times during the test.
6. After 200s, release LTE and FR2 connection.
7. After the end of the test, convert the instantaneous LTE Tx power into 1gSAR value using Plimit and Eqn (1), and then divide by FCC limit of 1.6W/Kg to obtain normalized SAR versus time. Perform 100s time averaging to determine normalized average 1gSAR versus time.
8. Similar to Step 7, convert the instantaneous radiated FR2 EIRP into PD value using Plimit and Eqn (2), and then divide by FCC limit of 10W/m^2 for 4cm^2 spatial averaging to obtain instantaneous normalized PD versus time. Perform 4s time averaging to determine normalized average PD versus time.
9. Make one plot containing (a) Instantaneous conducted power for LTE, (b) computed 100s time averaged power for LTE, (c) Instantaneous EIRP for FR2, (d) computed 4s time averaged EIRP for FR2 and (e) Plimit for each of LTE and FR2
10. Make a second plot containing (a) normalized 100s time-averaged SAR for LTE computed in Step 7 (b) normalized 4s time-averaged PD for FR2, (c) TER (Total Exposure Ratio) corresponding total normalized time-averaged RF exposure (using sum of 10(a) and 10(b)) versus time
    Pass condition is to demonstrate that TER is kept under 1.0 throughout the test. This ensures that criteria defined in is met at all times.

4.3.2 SAR vs PD exposure switch during transmission

This test is to ensure that Samsung S.LSI TAS feature works for any nature of exposure (SAR or PD) and accurately accounts for switching among SAR dominant, SAR+PD, and PD dominant scenarios, and ensured total time-averaged RF exposure compliance at all times.

4.3.2.1 Test procedure

1. Set the phone in an anechoic chamber for FR2 radiated transmission. In a non-signaling transmission mode for FR2 at maximum target EIRP, adjust the position of the DUT via rotation within the chamber to obtain the maximum measured radiated EIRP using the fixed test antenna. Keep the DUT in this fixed position for the remainder of the test.
2. Reset the DUT state to normal signaling mode and establish both LTE and FR2 connections with the call box.
3. Immediately send “ALL DOWN” power control commands from LTE call box to send LTE to the lowest transmission power. Next, configure the FR2 call box to send “ALL UP” power control commands to send FR2 radio to maximum EIRP condition. In this case, the FR2 radio will comprise the dominant exposure condition using PD metric.
4. After 120s, configure LTE call box to send “ALL UP” power control commands and continue transmission. Now, the RF exposure margin for FR2 should begin to reduce and could cause reduction in EIRP or stopping of FR2 transmissions.
5. After 120s, configure LTE call box to send “ALL DOWN” power control commands and continue transmission. Now, the FR2 radio should begin to obtain more RF exposure margin and start its transmission at higher power again.
6. Record the conducted power of LTE and radiated EIRP of FR2 radio at all times during the test.
7. Release LTE and FR2 connection.
8. After the end of the test, convert the instantaneous LTE Tx power into 1gSAR value using Plimit and Eqn.(1), and then divide by FCC limit of 1.6W/Kg to obtain normalized SAR versus time. Perform 100s time averaging to determine normalized average 1gSAR versus time.
9. Similar to Step 7, convert the instantaneous radiated FR2 EIRP into PD value using Plimit and Eqn (2), and then divide by FCC limit of 10W/m^2 for 4cm^2 spatial averaging to obtain instantaneous normalized PD versus time. Perform 4s time averaging to determine normalized average PD versus time.
10. Make one plot containing (a) Instantaneous conducted power for LTE, (b) computed 100s time averaged power for LTE, (c) Instantaneous EIRP for FR2, (d) computed 4s time averaged EIRP for FR2 and (e) Plimit for each of LTE and FR2
11. Make a second plot containing (a) normalized 100s time-averaged SAR for LTE computed in Step 7 (b) normalized 4s time-averaged PD for FR2, (c) TER (Total Exposure Ratio) corresponding total normalized time-averaged RF exposure (using sum of 10(a) and 10(b)) versus time
    Pass condition is to demonstrate that TER is kept under 1.0 throughout the test. This ensures that criteria defined in is met at all times.

4.3.3 Change of beam

This test is to demonstrate that Samsung S.LSI TAS feature can account for change of beam in FR2 and still meet total RF exposure compliance.

4.3.3.1 Test procedure

1. Set the phone in an anechoic chamber for FR2 radiated transmission. In a non-signaling transmission mode for FR2 at maximum target EIRP with beam 1, adjust the position of the DUT via rotation within the chamber to obtain the maximum measured radiated EIRP using the fixed test antenna.
2. Reset the DUT state to normal signaling mode and establish both LTE and FR2 connections with the call box.
3. Immediately send “ALL DOWN” power control commands from LTE call box to send LTE to the lowest transmission power. Next, configure the FR2 call box to send “ALL UP” power control commands to send FR2 radio to maximum EIRP condition. In this case, the FR2 radio will comprise the dominant exposure condition using PD metric.
4. After 20s, the test equipment turns the DUT by 90 degrees (horizontal=90, vertical=0) to change best module and correspondingly a beam change.
5. After 20s, the test equipment turns the DUT by 90 degrees (horizontal=270, vertical=0) to change best module again and correspondingly a beam change.
6. Continue the LTE and FR2 transmissions for another 20s
7. Record the conducted power of LTE and radiated EIRP of FR2 radio and per beam at all times during the test.
8. Release LTE and FR2 connection.
9. After the end of the test, convert the instantaneous LTE Tx power into 1gSAR value using Plimit and Eqn (1), and then divide by FCC limit of 1.6W/Kg to obtain normalized SAR versus time. Perform 100s time averaging to determine normalized average 1gSAR versus time.
10. Similar to Step 9, convert the instantaneous radiated FR2 EIRP into PD value using Plimit and Eqn (2), and then divide by FCC limit of 10W/m^2 for 4cm^2 spatial averaging to obtain instantaneous normalized PD versus time for each beam. Perform 4s time averaging to determine normalized average PD versus time. Note that for each beam, we have to use the corresponding Plimit values before converting to the PD values.
11. Make one plot containing (a) Instantaneous conducted power for LTE, (b) computed 100s time averaged power for LTE, (c) Instantaneous EIRP for FR2 per beam, (d) computed 4s time averaged EIRP for FR2 per beam and (e) Plimit for each of LTE and FR2
12. Make a second plot containing (a) normalized 100s time-averaged SAR for LTE computed in Step 7 (b) normalized 4s time-averaged PD for FR2 per beam, (c) TER (Total Exposure Ratio) corresponding total normalized time-averaged RF exposure (using sum of 12(a) and 12(b)) versus time as computed in left hand side of equation below –

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} SAR(t')dt'}{FCC\ \ SAR_{limit}} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} PD_1(t')dt'}{FCC\ \ PD_{limit}} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} PD_2(t')dt'}{FCC\ \ PD_{limit}} \le 1$$

Equation (3)

Pass condition is to demonstrate time-averaged 1gSAR value and 4cm$_2$ PD versus time does not exceed the

FCC limits of 1.6 W/kg and 10W/m2 throughout the test duration. And TER (Total Exposure Ratio) as in Eqn (3) should be kept under 1.0 throughout the test. It is required to check if power limiting enforcement is operated as expected during the test.

5 Test Configurations

5.1 Test case list for sub-6GHz transmissions

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 Scenario	Test case	Test configuration
TC01	Time-varying Tx power transmission	LTE_Time_Varying_Tx_Power_Case_1	LTE Band 7, 66, Test Seq. A
TC02		SA_FR1_Time_Varying_Tx_Power_Case_1	NR Band n66 Test Seq. A
TC03		LTE_Time_Varying_Tx_Power_Case_2	LTE Band 7, 66, Test Seq. B
TC04		SA_FR1_Time_Varying_Tx_Power_Case_2	NR Band n66, Test Seq. B
TC05	Change in call	LTE_Call_Disconnect_Reestablishment	LTE Band 7, 66
TC06	Re-selection in call	SA_FR1_to_LTE_RAT_Re-selection	NR Band n66 to LTE Band 7
TC07	Change in band/time window	LTE_Averaging_Time_Window_Change	LTE Band 7 to LTE Band 48 LTE Band 66 to LTE Band 48
TC08		LTE_Averaging_Time_Window_Change2	LTE Band 48 to LTE Band 7 LTE Band 48 to LTE Band 66
TC09	SAR exposure switch	NSA_FR1_Dominant_Power_Switching	LTE Band 48 and NR Band n66
TC13	Change in RSI	SA_FR1_RF_SAR_Index_Change	NR Band n66
TC14	TAS to nonTAS H.O.	LTE_to_WCDMA_H.O.	LTE Band 7 and WCDMA Band2 LTE Band 66 and WCDMA Band2

5.2 Test case list for LTE+FR2 transmissions

To validate TAS algorithm in scenarios including FR2, the chosen TC (Test Case) list is defined as in Table5.2.1

Table 5.2.1 LTE+FR2 TAS validation test case list

No.	Test Scenario	Test case	Test Configuration
TC10	Time-varying Tx power transmission	mmWave_Max_Tx_Power	LTE Band 66, NR Band n260,261
TC11	SAR exposure switch	mmWave_Dominant_Power_Switching	LTE Band 66, NR Band n260,261
TC12	Change of beam	mmWave_Module_Beam_Change	LTE Band 66, NR Band n260,261 FR2 Module 0 Beam switch

6 Conducted Power Test Results for Sub-6 TAS validation

6.1 Measurement set-up

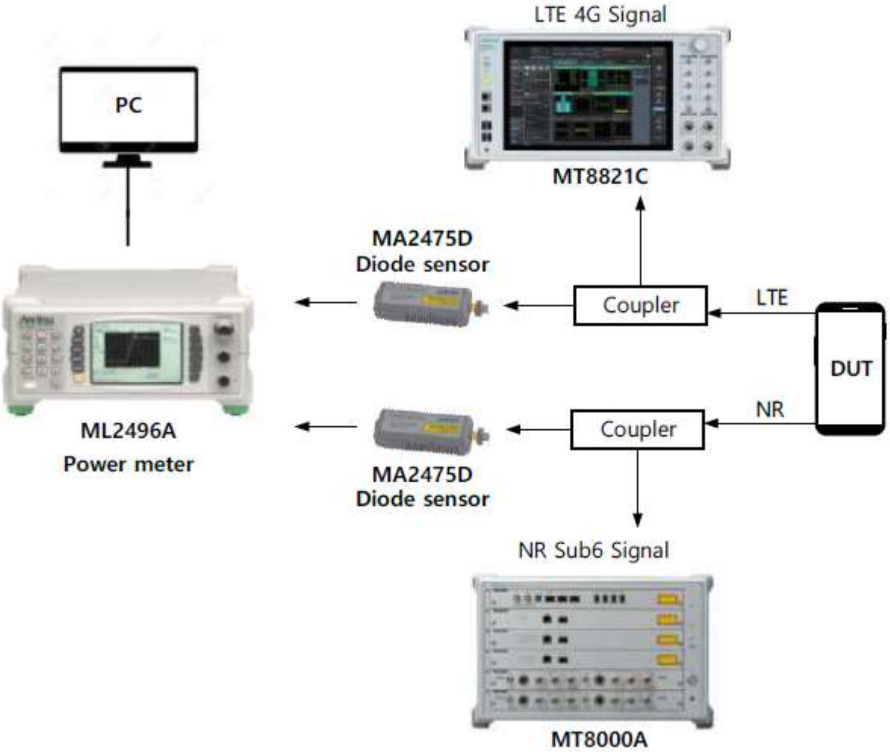

Figure 6.1-1 Test set-up for legacy and sub 6GHz

The test setup for TAS validation with sub-6GHz RATs only is shown in Figure 6.1-1. Normally, a power sensor would measure total power in the entire frequency of its specification e.g. 10MHz to 50GHz for the MA2475D 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 post processing 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 3.1 and Section 4.1. 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 post processing 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.

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

The measured P_{limit} for all the selected radio configurations are listed in Table 6.2.1. P_{max} 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 6.2.1 is not actual Plimit corresponding to 1W/Kg SAR, but our measured averaged power when forcing Plimit in our SW based on Table 6.2.1.

TC#	Test scenario	Tech	Band	RSI	RB/offset/BW	Mode	Congfiguration	Plimit setting (dBm)	Pmax setting (dBm)	measured Plimit (dBm)	measured Pmax (dBm)
1	Time varying Tx power case	LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
			B66	2	1/99/20MHz	QPSK	1g/10mm/Hotspot	19.0	23.3	18.90	23.78
2		SA/FR1	n66	2	50/56/20MHz	DFT-s QPSK	1g/10mm/Hotspot	19.0	23.0	19.93	23.89
3		LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
			B66	2	1/99/20MHz	QPSK	1g/10mm/Hotspot	19.0	23.3	18.90	23.78
4		SA/FR1	n66	2	1/0/20MHz	DFT-s QPSK	1g/10mm/Hotspot	19.0	23.0	19.93	23.89
5	Disconnect reestablishment	LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
			B66	2	1/99/20MHz	QPSK	1g/10mm/Hotspot	19.0	23.3	18.90	23.78
6	FR1 to LTE IRAT Reselection	LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
		SA/FR1	B66	2	50/56/20MHz	DFT-s QPSK	1g/10mm/Hotspot	19.0	23.0	19.93	23.89
7	Window change case 1	LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
			B48	2	50/25/20MHz	QPSK	1g/10mm/Hotspot	18.0	22.5	18.41	22.34
8	Window change case 2	LTE	B48	2	50/25/20MHz	QPSK	1g/10mm/Hotspot	18.0	22.5	18.41	22.34
			B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
9	FR1 dominant power change	LTE	B48	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	18.0	22.5	18.41	22.34
		NSA/FR1	B66	2	1/0/20MHz	DFT-s QPSK	1g/10mm/Hotspot	19.0	23.0	19.93	23.89
10	mmWave Max Tx power	LTE	B66	2	1/0/10MHz	QPSK	1g/10mm/Hotspot	19	23.3	18.90	23.78
		FR2	n260		66/0/100MHz	DFT-s QPSK	V+H / 3,10	10.7	-	10.31	-
			n261				V+H / 2, 9	8.8	-	10.48	-
11	mmWave Dominant Power Switching	LTE	B66	2	1/0/10MHz	QPSK	1g/10mm/Hotspot	19	23.3	18.90	23.78
		FR2	n260		66/0/100MHz	DFT-s QPSK	V+H / 3,10	10.7	-	9.63	-
			n261				V+H / 2, 9	8.8	-	11.04	-
12	mmWave Module Beam change	LTE	B66	2	1/0/10MHz	QPSK	1g/10mm/Hotspot	19	23.3	18.90	23.78
		FR2	n260		66/0/100MHz	DFT-s QPSK	V+H / 3,10	10.7	-	8.21	-
			n261				V+H / 3,10	9.2	-	10.42	-
13	RSI change	SA FR1	B66	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	19.0	23.0	19.93	23.89
14	TAS to NonTAS	LTE	B7	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	20.0	23.0	20.56	22.62
			B66	2	1/0/20MHz	QPSK	1g/10mm/Hotspot	19.0	23.3	18.90	23.78
		WCDMA	B2	2	-	RMC	1g/10mm/Hotspot	21.0	24.0	21.41	24.65

Table 6.2.1.

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

6.3 Time-varying Tx power measurement results

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 1g SAR while the red line shows the corresponding FCC limit of 1.6W/Kg. Time-varying Tx power measurements were conducted for TC #1-4 in Table 6.2.1 by generating the test sequence A or B given in Appendix.

TC01: LTE_Time_Varying_Tx_Power_Case_1 [LTE B7]

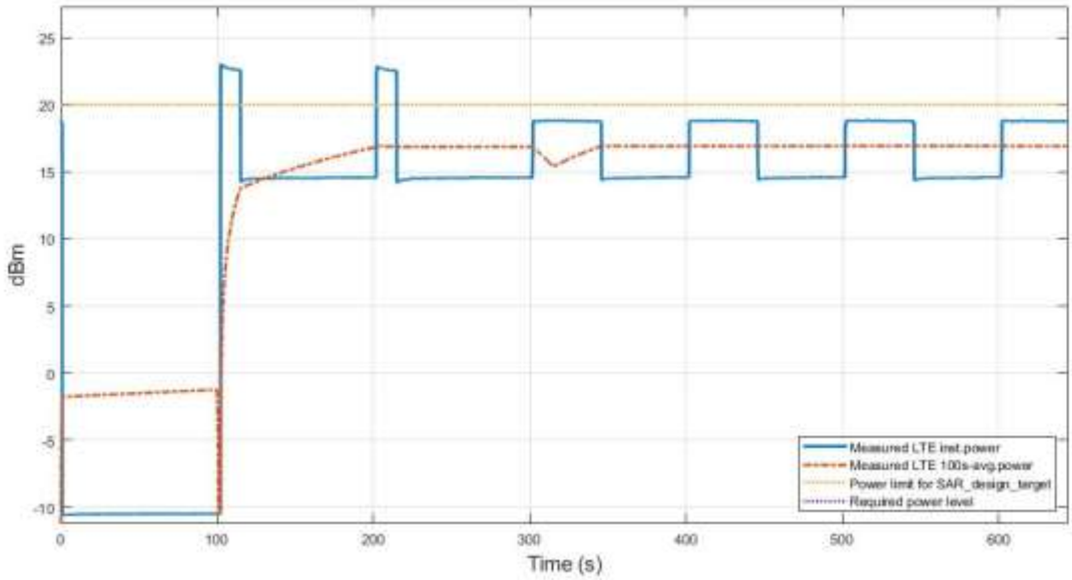

Figure 6.3-1 Time average conducted power of LTE B7 in TC01

Figure 6.3-1 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 Figure 6.3-1, 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. Figure 6.3-2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

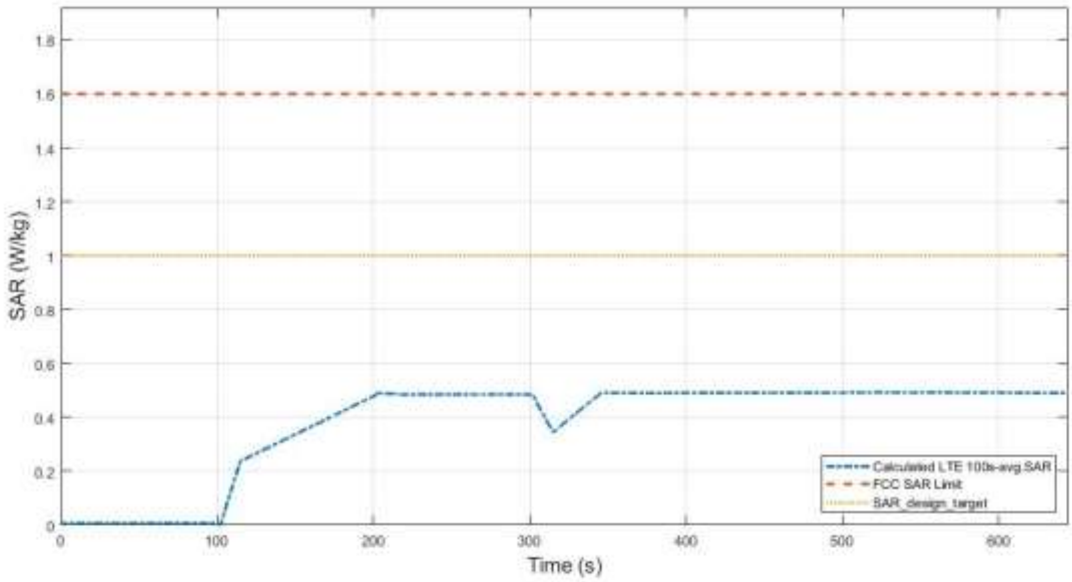

Figure 6.3-2 Total time-averaged SAR in TC01

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.493 W/kg
Device uncertainty	1 dB

TC01: LTE_Time_Varying_Tx_Power_Case_1 [LTE B66]

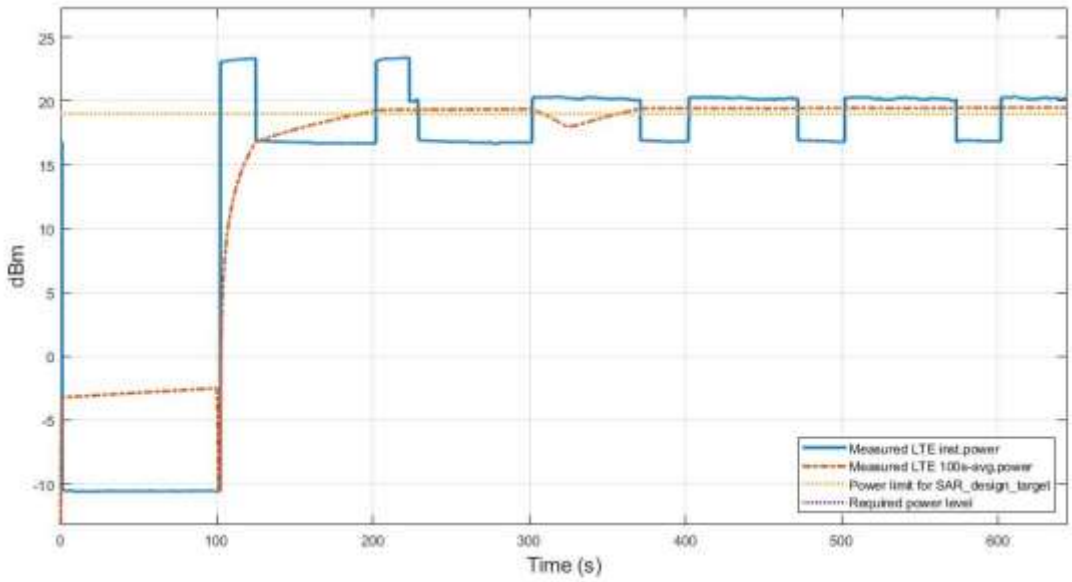

Figure 6.3-3 Time average conducted power of LTE B66 in TC01

Figure 6.3-3 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 Figure 6.3-3, it is confirmed for timeaverage 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. Figure 6.3-4 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

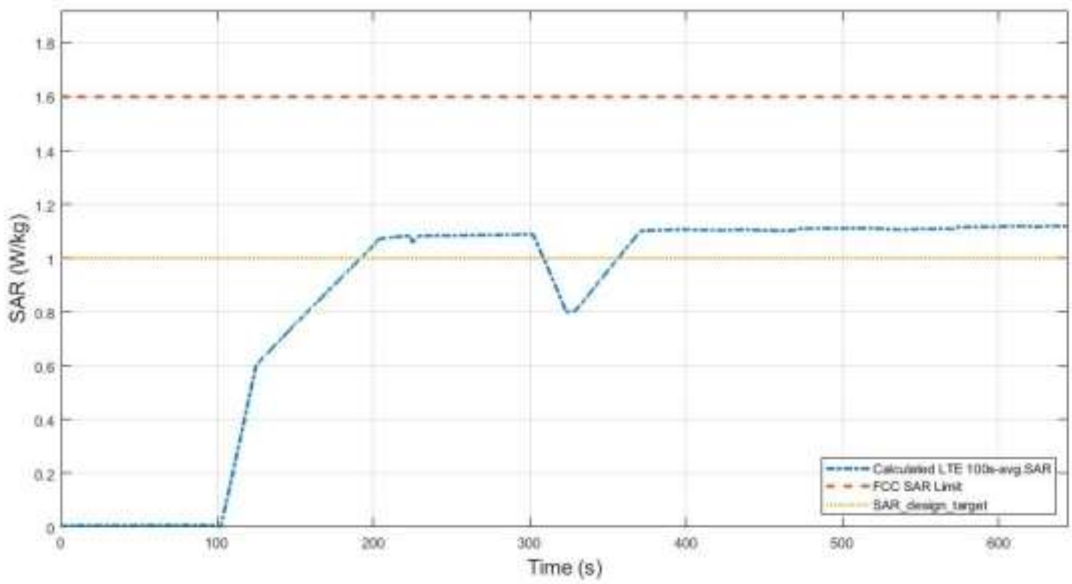

Figure 6.3-4 Total time-averaged SAR in TC01

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.12 W/kg
Device uncertainty	1 dB

TC02: SA_FR1_Time_Varying_Tx_Power_Case_1 [n66]

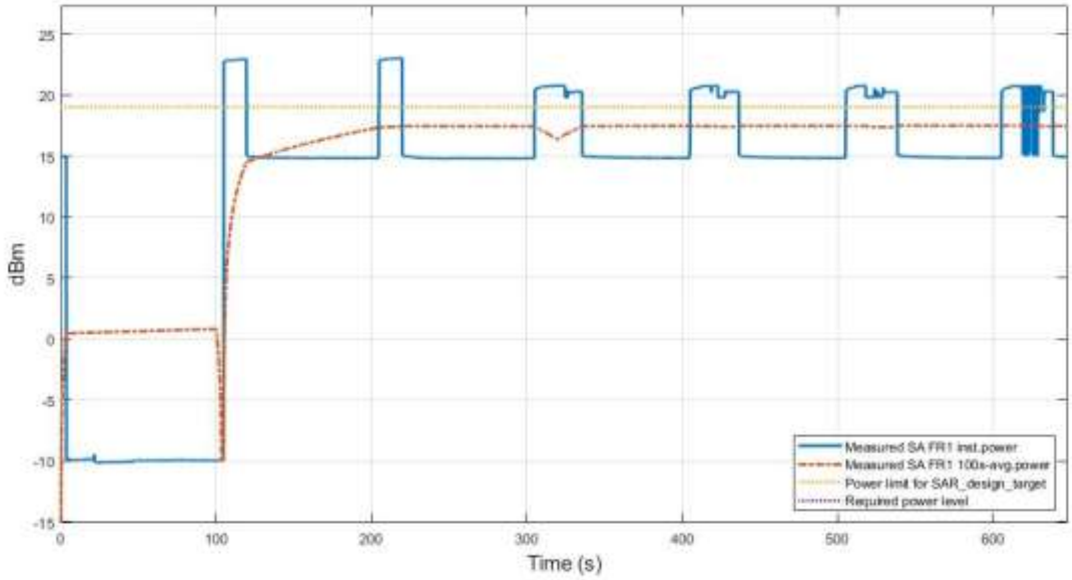

Figure 6.3-5 Time-average conducted power of SA FR1 n66 in TC02
Figure 6.3-5 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 6.3-5, it is confirmed for time-average Tx power that the FCC limit was not exceeded, and that the averaged Tx power is lower than the value of Plimit. Figure 6.3-6 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

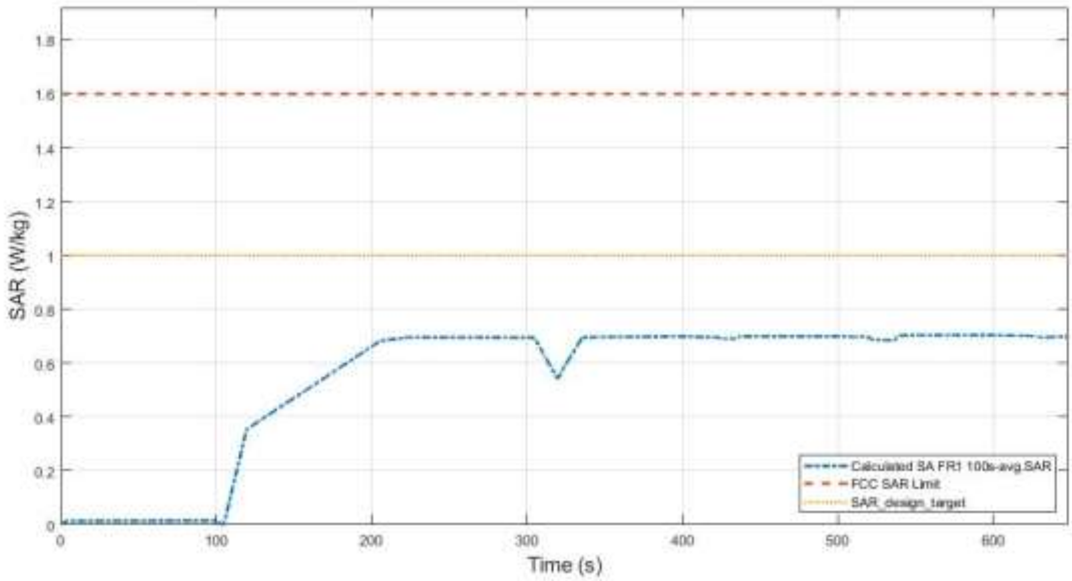

Figure 6.3-6 Total time-averaged SAR in TC02

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.705 W/kg
Device uncertainty	1 dB

TC03: LTE_Time_Varying_Tx_Power_Case_2 [LTE B7]

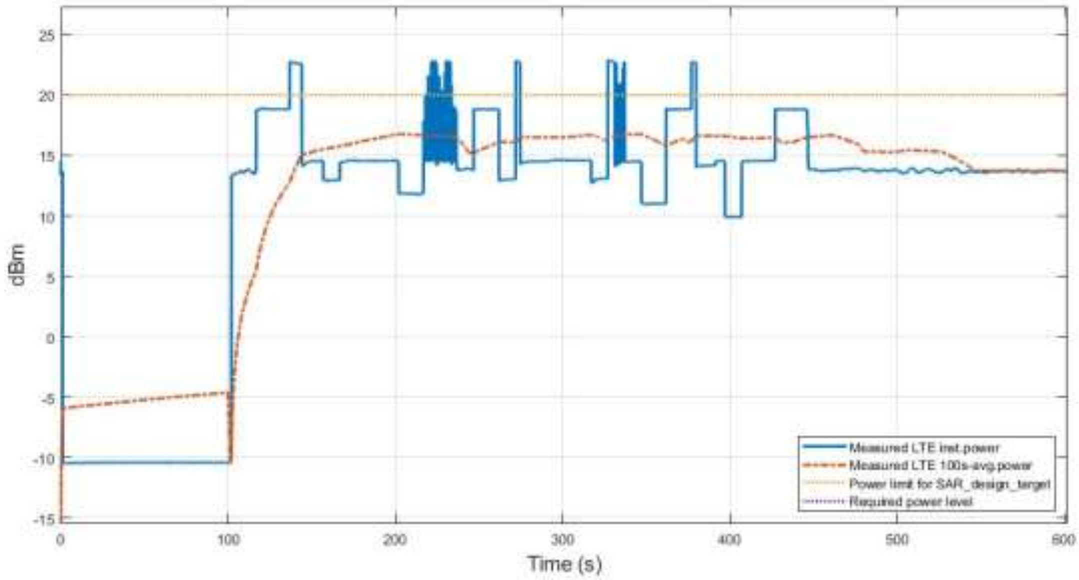

Figure 6.3-9 Conducted Tx power of LTE B7 in TC03

Figure 6.3-9 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 6.3-9, 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. Figure 6.3-10 shows the plot of calculated time-averaged 1gSAR for this test

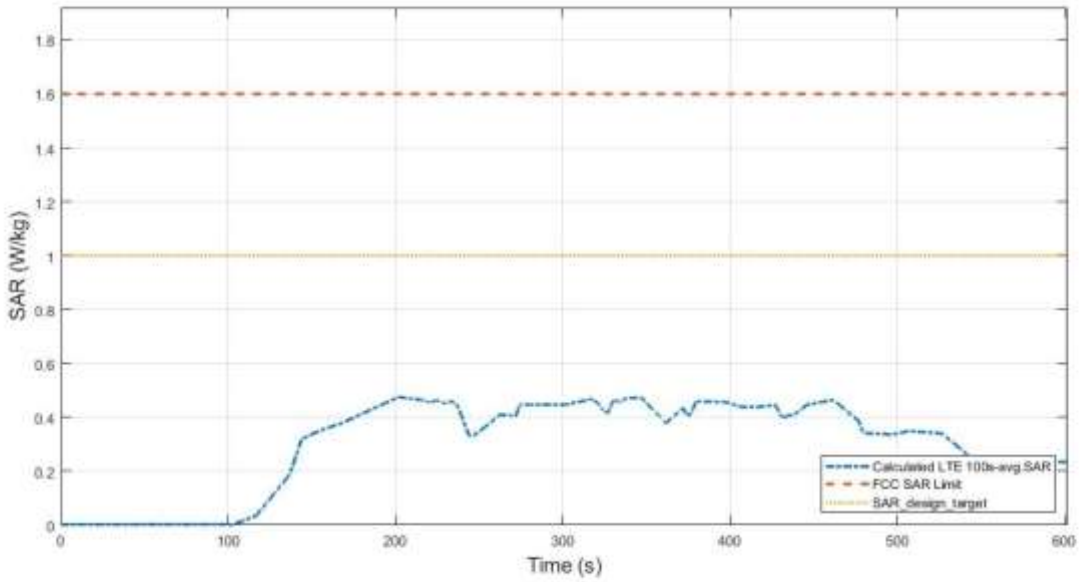

Figure 6.3-10 Total time-averaged SAR in TC03

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.475W/kg
Device uncertainty	1 dB

TC03: LTE_Time_Varying_Tx_Power_Case_2 [LTE B66]

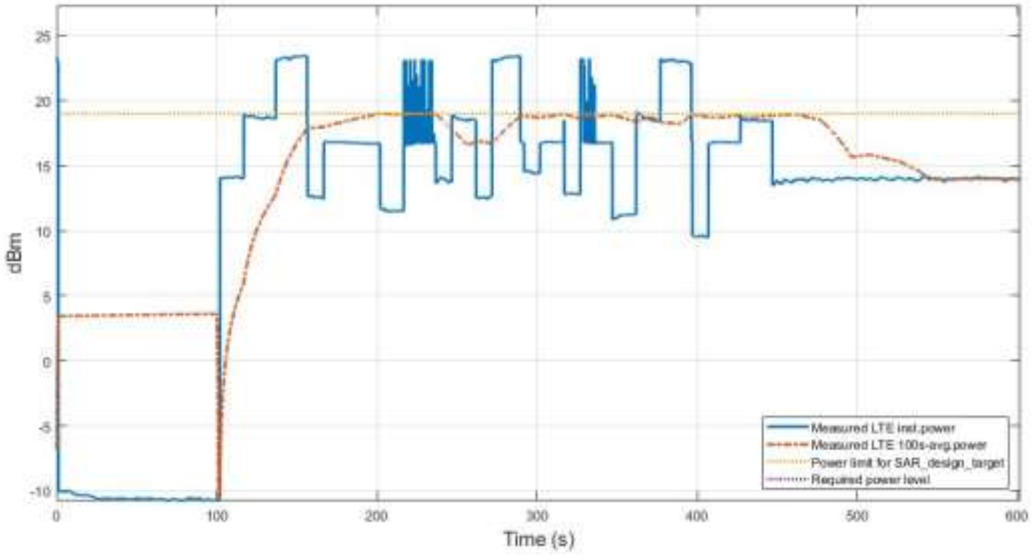

Figure 6.3-11 Conducted Tx power of LTE B66 in TC03

Figure 6.3-11 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 6.3-11, 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. Figure 6.3-12 shows the plot of calculated time-averaged 1gSAR for this test

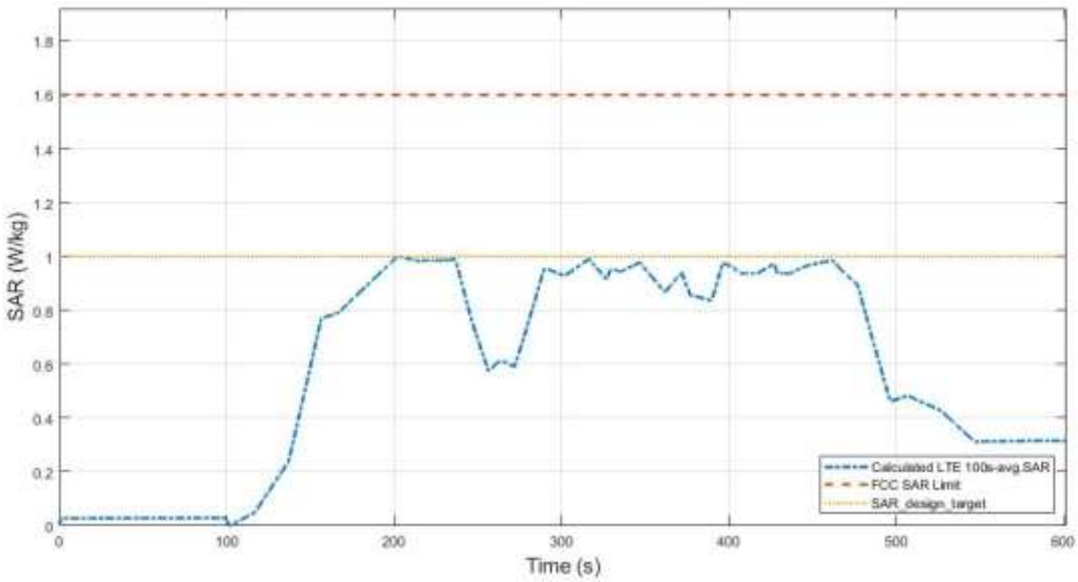

Figure 6.3-12 Total time-averaged SAR in TC03

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.0 W/kg
Device uncertainty	1 dB

TC04: SA_FR1_Time_Varying_Tx_Power_Case_2 [n66]

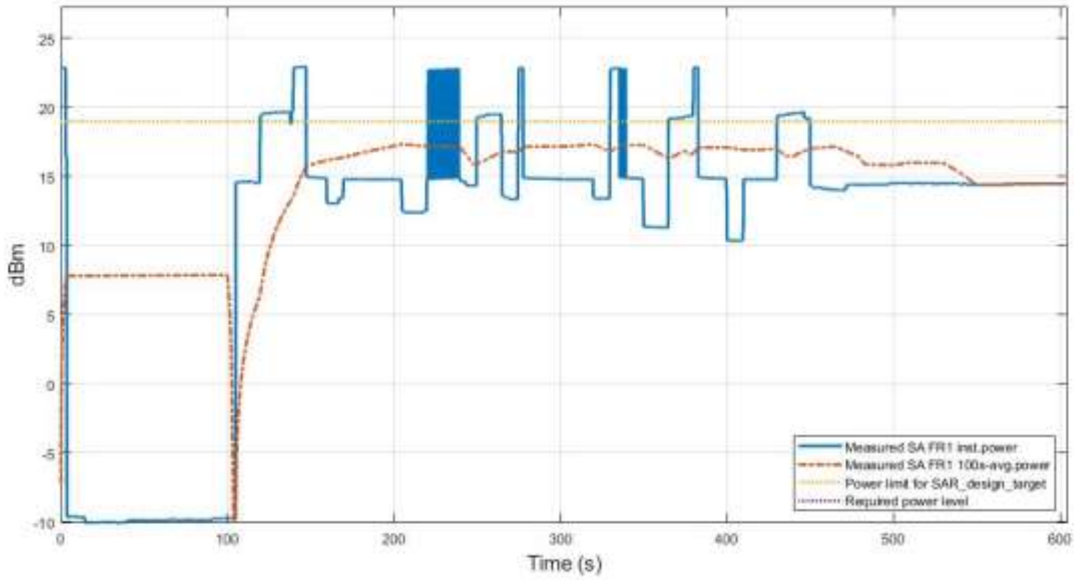

Figure 6.3-13 Conducted Tx power for SA FR1 n66 in TC04

Figure 6.3-13 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 6.3-13, 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. Figure 6.3-14 shows the plot of calculated time-averaged 1gSAR for this test

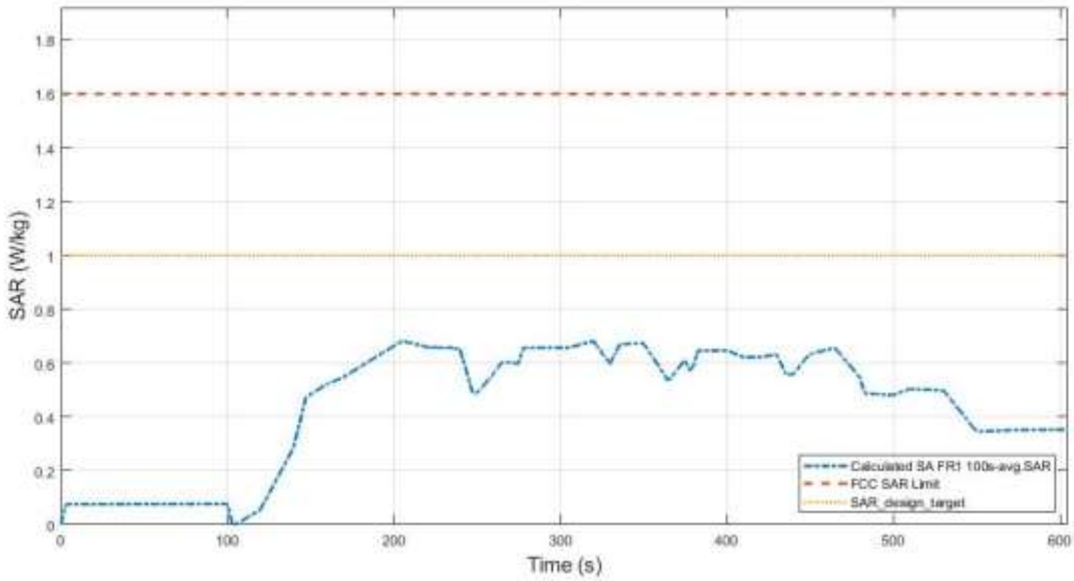

Figure 6.3-14 Total time-averaged SAR in TC04

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.682W/kg
Device uncertainty	1 dB

6.4 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 TC#5 in Table 6.2.1.

TC05: LTE_Call_Disconnect_Reestablishment

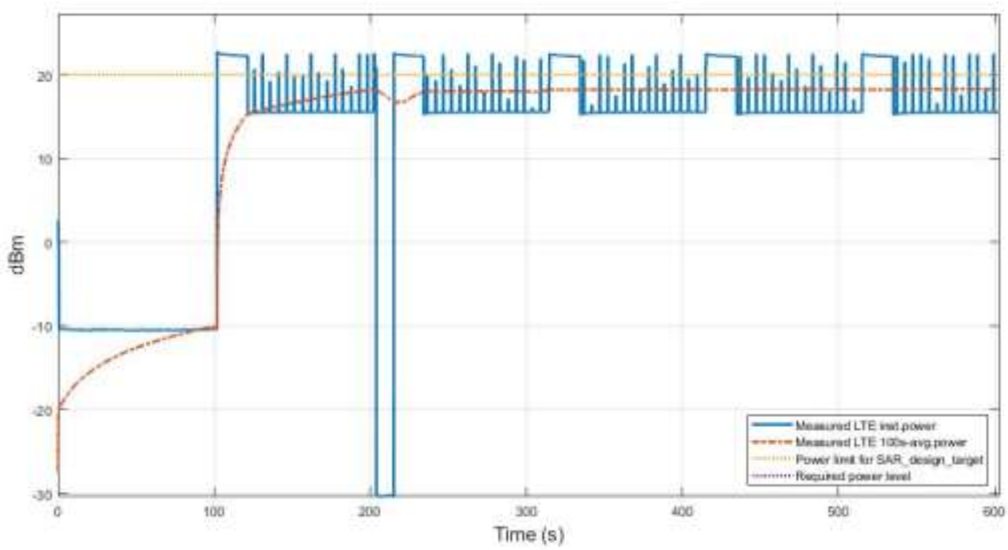

Figure 6.4-1 Conducted Tx power in Call_Disconnect_Reestablishment LTE Band 7 case TC05

Figure 6.4-1 shows the instantaneous and time-averaged Tx power for this test. The call disconnected around 200s 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. Figure 6.4-2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg. 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.

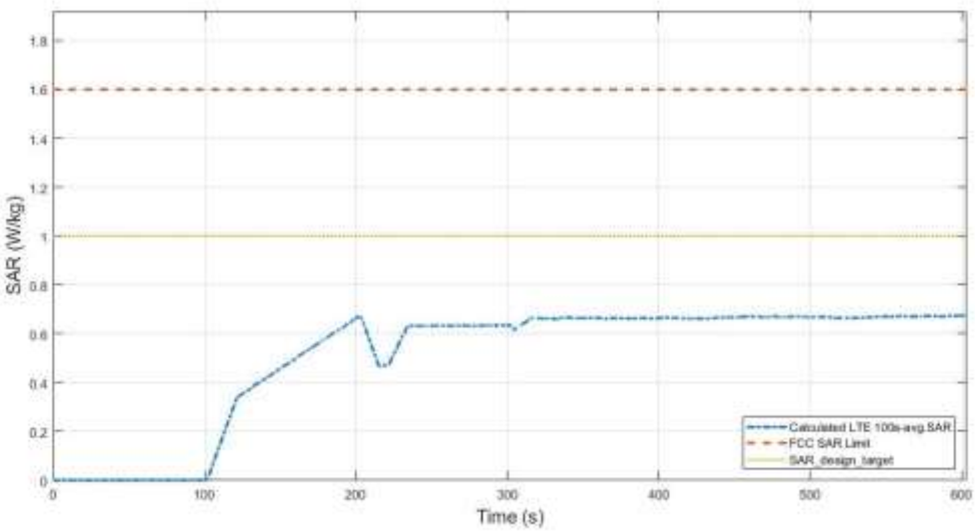

Figure 6.4-2 Conducted Tx power in Call_Disconnect_Reestablishment LTE Band 7 case TC05

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.675 W/kg
Device uncertainty	1 dB

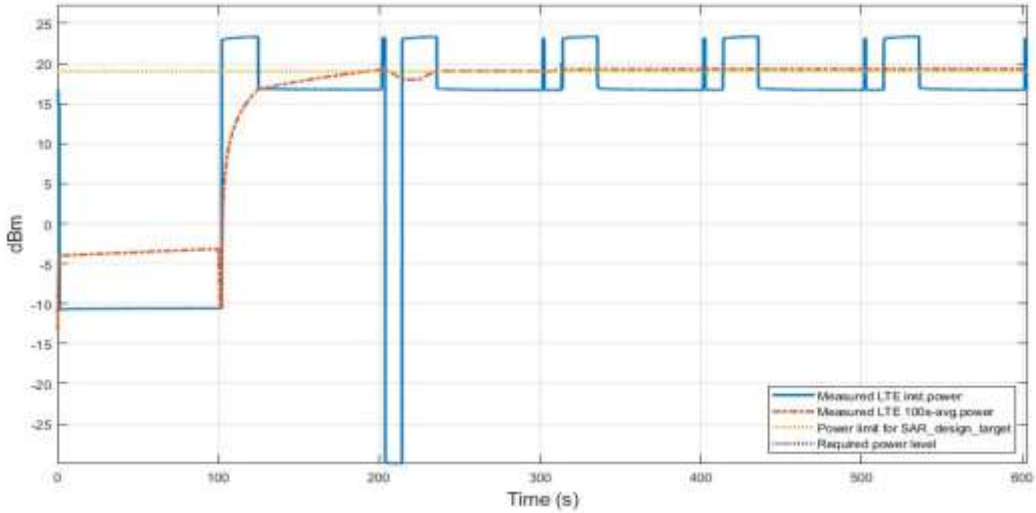

Figure 6.4-3 Conducted Tx power in Call_Disconnect_Reestablishment LTE Band 66 case TC05

Figure 6.4-3 shows the instantaneous and time-averaged Tx power for this test. The call disconnected around 200s 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. Figure 6.4-4 shows the plot of 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.

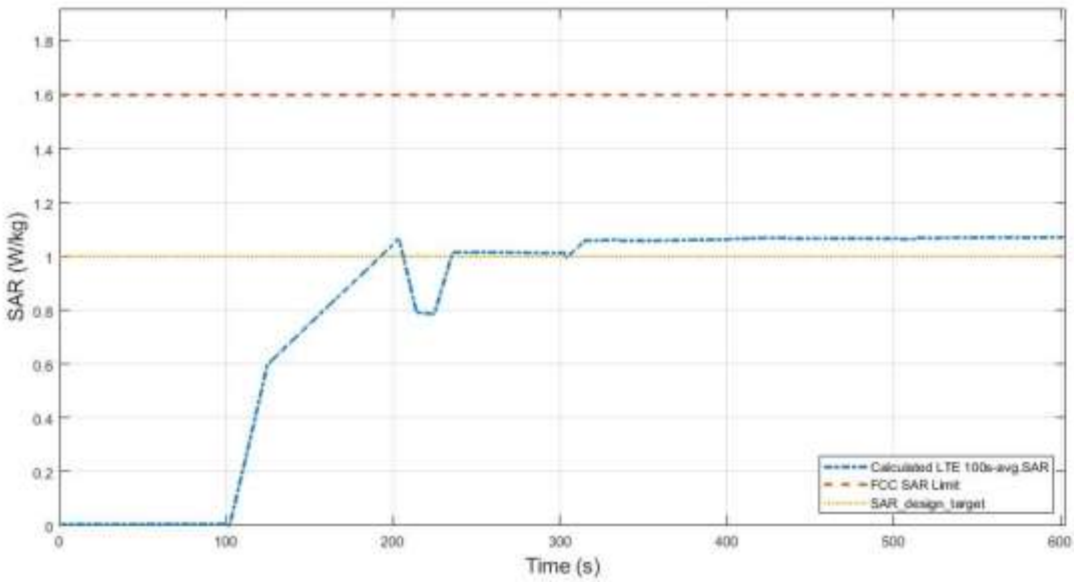

Figure 6.4-4 Conducted Tx power in Call_Disconnect_Reestablishment LTE Band 66 case TC05

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.074 W/kg
Device uncertainty	1 dB

6.5 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 TC#6 in Table 6.2.1.

TC06: FR1 to LTE IRAT Re-selection

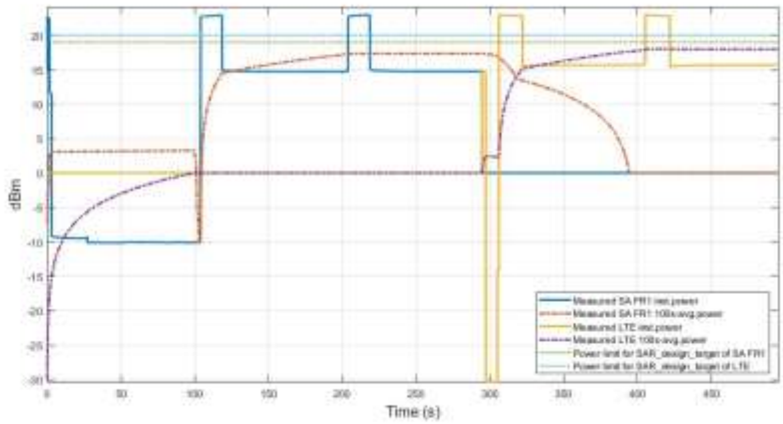

Figure 6.5-1 Conducted Tx power for SAR IRAT re-selection in test TC06

Figure 6.5-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 7 and NR FR1 Band n66 for the duration of the test. Around time stamp of ~310s, a RAT re-selection from NR Band 66 to LTE Band 7 was executed, resulting in reduction of time-averaged power of Band 7 and simultaneous increase in time-averaged power of Band n66. Figure 6.5-2 shows the time-averaged 1gSAR value for each of LTE Band 5 and NR FR1 Band n2, 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.

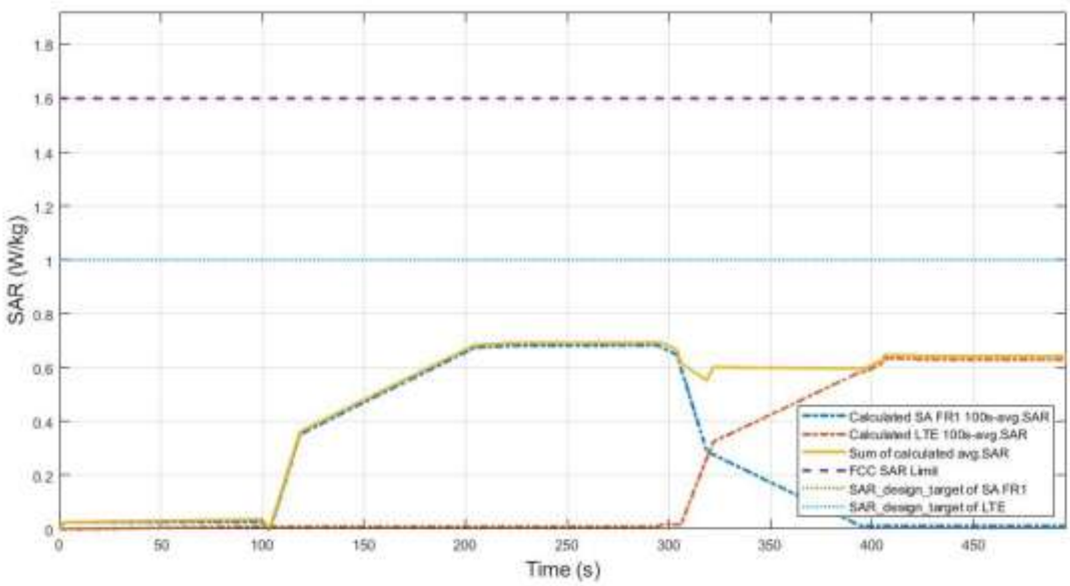

Figure 6.5-2 Conducted Tx power for SAR IRAT re-selection in test TC06

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.693 W/kg
Device uncertainty	1 dB

6.6 Change in band/time-window test results

The test results in this section are obtained following the procedure in Section 3.3.3. The test cases correspond to TC#7-8 in Table 6.2.1.

TC07: LTE_Averaging_Time_Window_Change_1

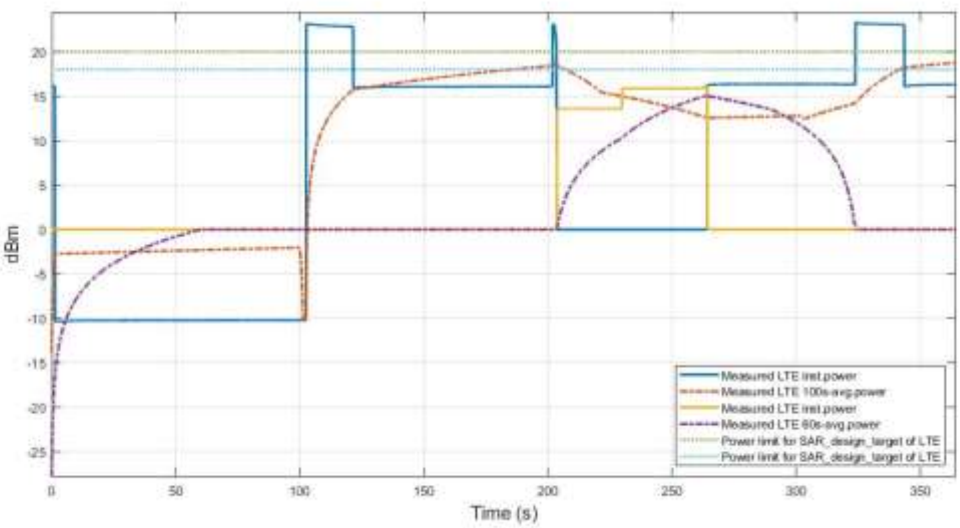

Figure 6.6-1 Conducted Tx power for SAR window change in test TC07

Figure 6.6-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 7 and Band 48 for the duration of the test. Around time stamp of ~210s, a handover from Band 7 to Band 48 was executed, resulting in reduction of time-averaged power of Band 7 and simultaneous increase in time-averaged power of Band 48. Around time stamp of ~280s, handover back to Band 7 was executed, resulting in reduction of time-averaged power of Band 48 and increase of time-averaged power of Band 7. It can be seen that transition time of time-averaged values for Band 7 is longer than Band 48, which is the consequence of 100s time averaging for Band 7 versus shorter 60s averaging for Band 48. Figure 6.6-2 shows the time-averaged 1gSAR value for each of Band 7 and Band 48, 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.

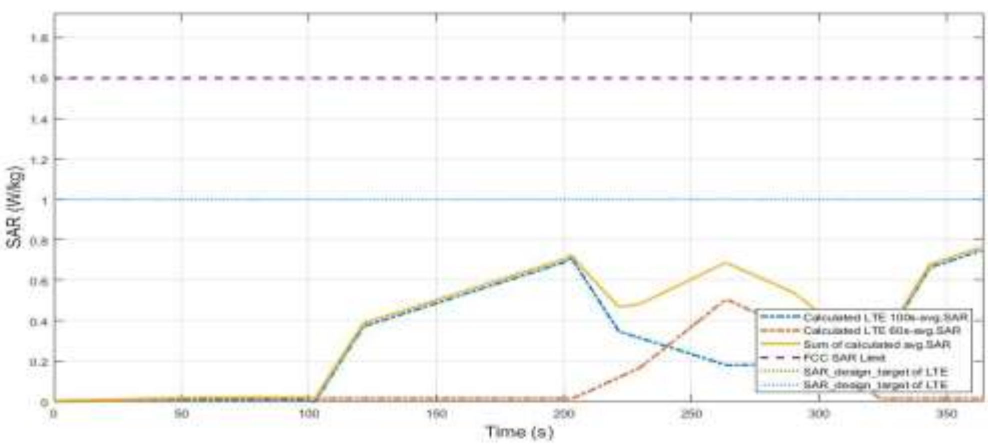

Figure 6.6-2 Conducted Tx power for SAR window change in test TC07

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.764 W/kg
Device uncertainty	1 dB

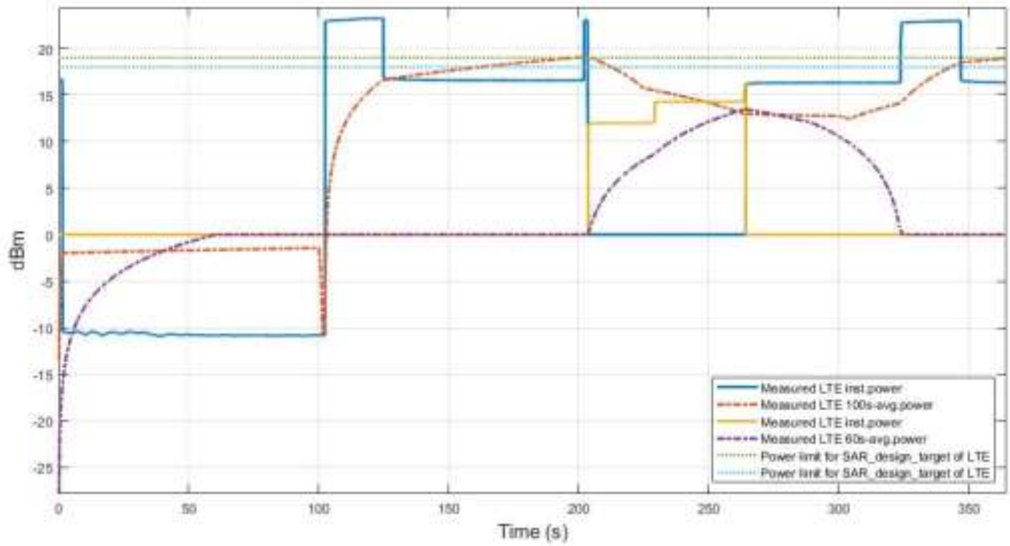

Figure 6.6-3 Conducted Tx power for SAR window change in test TC07

Figure 6.6-3 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 66 and Band 48 for the duration of the test. Around time stamp of ~210s, a handover from Band 66 to Band 48 was executed, resulting in reduction of time-averaged power of Band 66 and simultaneous increase in time-averaged power of Band 48. Around time stamp of ~280s, handover back to Band 66 was executed, resulting in reduction of time-averaged power of Band 48 and increase of time-averaged power of Band 66. It can be seen that transition time of time-averaged values for Band 66 is longer than Band 48, which is the consequence of 100s timeaveraging for Band 7 versus shorter 60s averaging for Band 48. Figure 6.6-4 shows the time-averaged 1gSAR value for each of Band 66 and Band 48, 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.

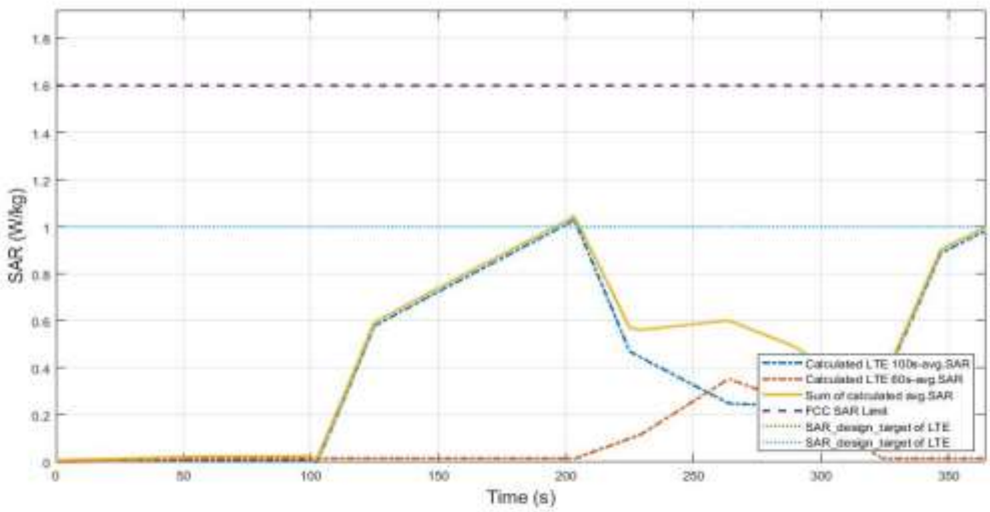

Figure 6.6-4 Conducted Tx power for SAR window change in test TC07

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.048 W/kg
Device uncertainty	1 dB

TC08: LTE_Averaging_Time_Window_Change_2

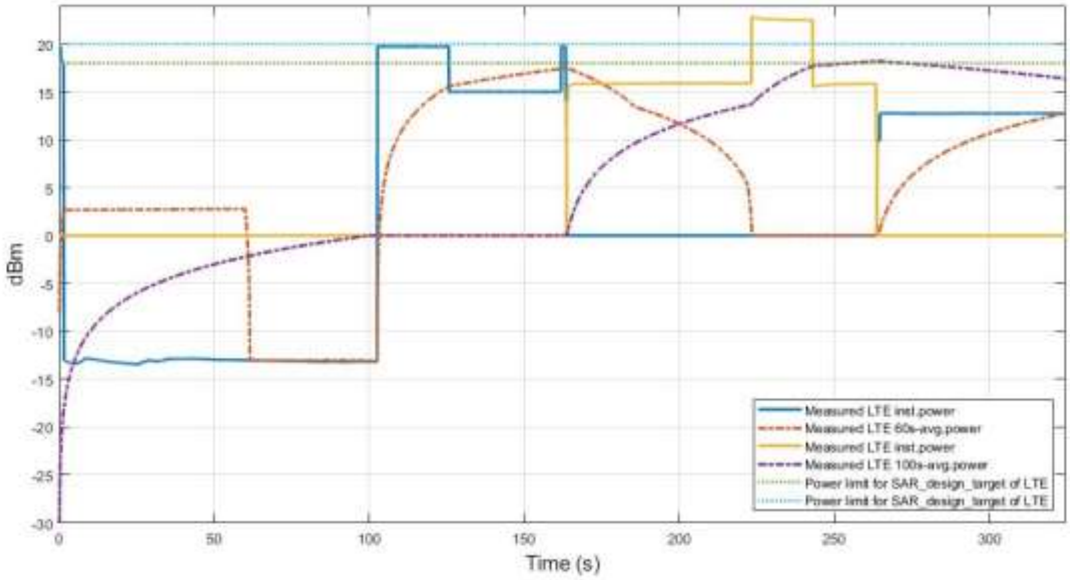

Figure 6.6-5 Conducted Tx Power in SAR Window Change test TC08

Figure 6.6-5 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 7 and Band 48 for the duration of the test. Around time stamp of ~170s, a handover from Band 48 to Band 7 was executed, resulting in reduction of time-averaged power of Band 48 and simultaneous increase in time-averaged power of Band 7. Around time stamp of ~270s, handover back to Band 48 was executed, resulting in reduction of time-averaged power of Band 7 and increase of time-averaged power of Band 48. It can be seen that transition time of time-averaged values for Band 7 is longer than Band 48, which is the consequence of 100s time averaging for Band 7 versus shorter 60s averaging for Band 48. Figure 6.6-6 shows the time-averaged 1gSAR value for each of Band 7 and Band 48, 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.

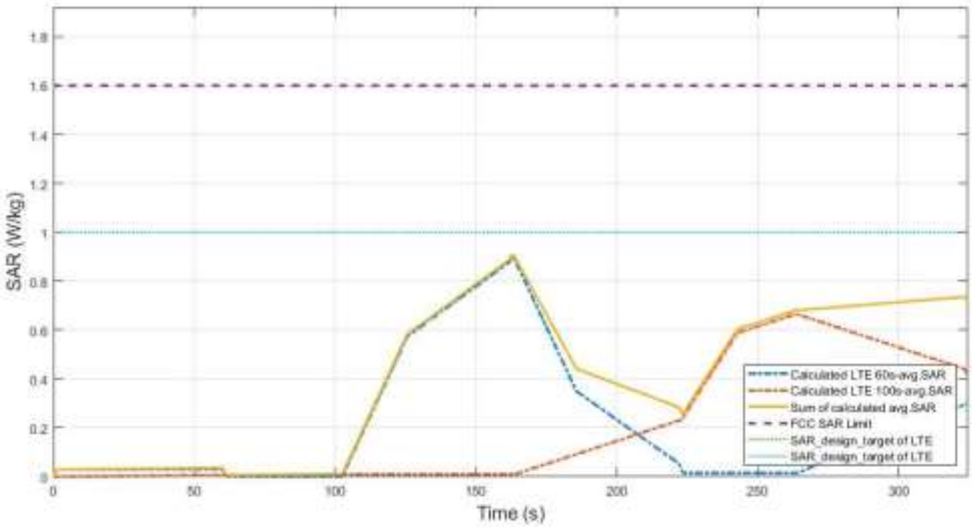

Figure 6.6-6 Total time-averaged SAR in TC08

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.907 W/kg
Device uncertainty	1 dB

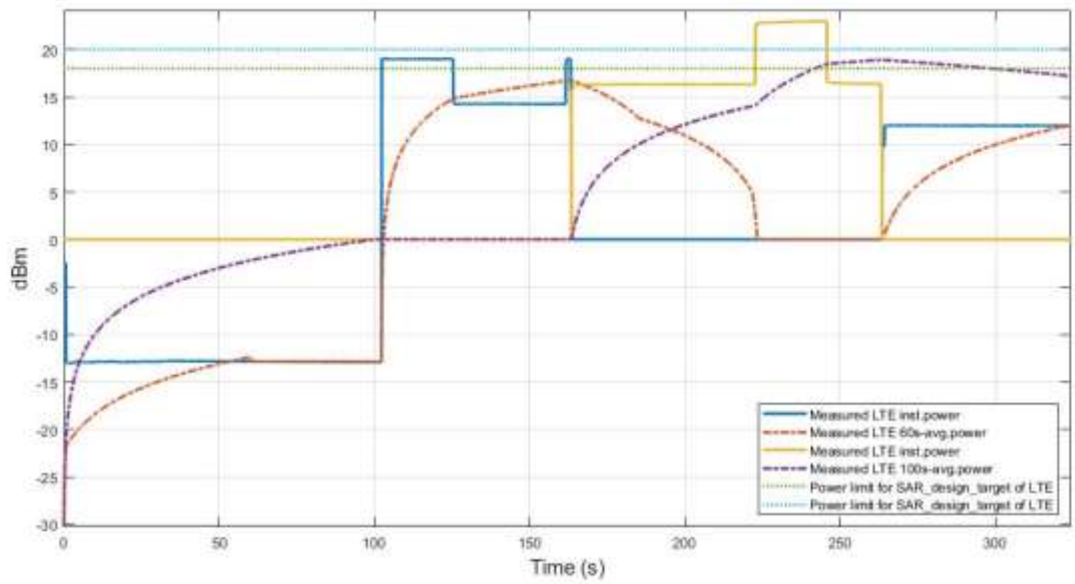

Figure 6.6-7 Conducted TxPower in SAR Window Change test TC08

Figure 6.6-7 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 66 and Band 48 for the duration of the test. Around time stamp of ~170s, a handover from Band 48 to Band 66 was executed, resulting in reduction of time-averaged power of Band 48 and simultaneous increase in time-averaged power of Band 66. Around time stamp of ~270s, handover back to Band 48 was executed, resulting in reduction of time-averaged power of Band 66 and increase of time-averaged power of Band 48. It can be seen that transition time of time-averaged values for Band 7 is longer than Band 48, which is the consequence of 100s timeaveraging for Band 66 versus shorter 60s averaging for Band 48. Figure 6.6-8 shows the time-averaged 1gSAR value for each of Band 7 and Band 48, 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.

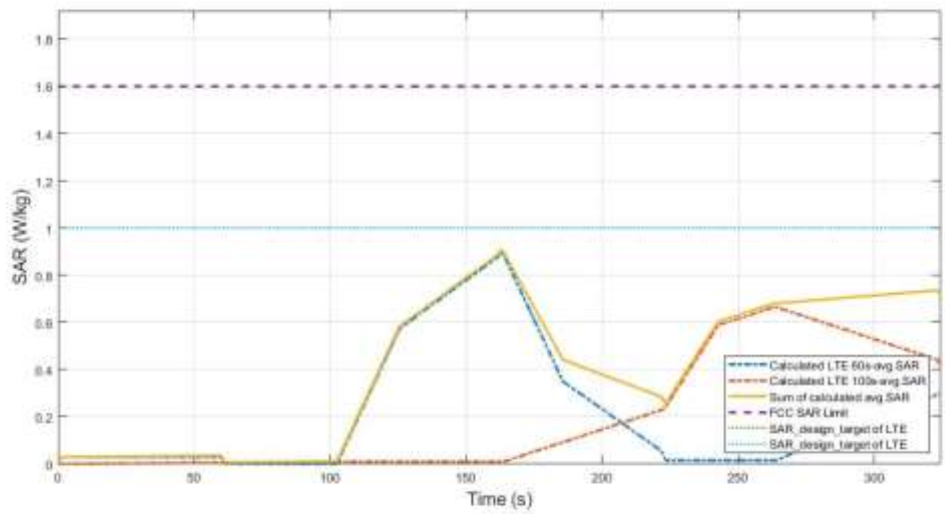

Figure 6.6-8 Total time-averaged SAR in TC08

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.795 W/kg
Device uncertainty	1 dB

6.7 Switch in SAR exposure test results

The test results in this section are obtained following the procedure in Section 3.3.5. The test cases correspond to TC#9 in Table 6.2.1.

TC09: NSA_FR1_Dominant_Power_Switching

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 110s. 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.

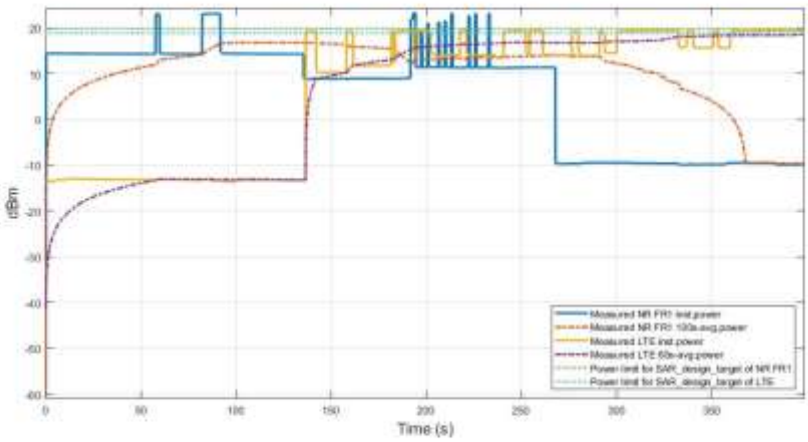

Figure 6.7-1 Time average SAR of LTE B48 and FR1 n66 in EN-DC case

Figure 6.7-1 shows the instantaneous and time-averaged Tx power for both LTE band B48 and NR FR1 band n66 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. Figure 6.7-2 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 1.2W/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.

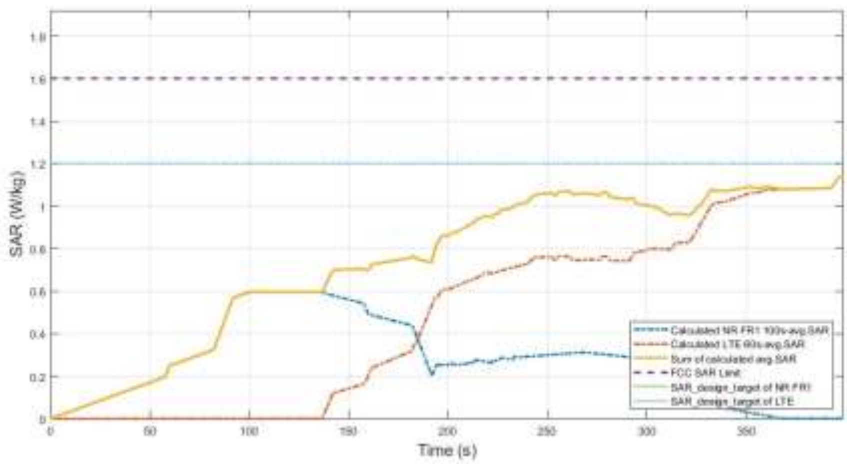

Figure 6.7-2 Total time-averaged SAR in TC09

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.14 W/kg
Device uncertainty	1 dB

6.8 Change in RSI value results

The test results in this section are obtained following the procedure in Section 3.3.4. The test cases correspond to TC#13 in Table 6.2.1.

TC13: SA_FR1_RF_SAR_Index_Change

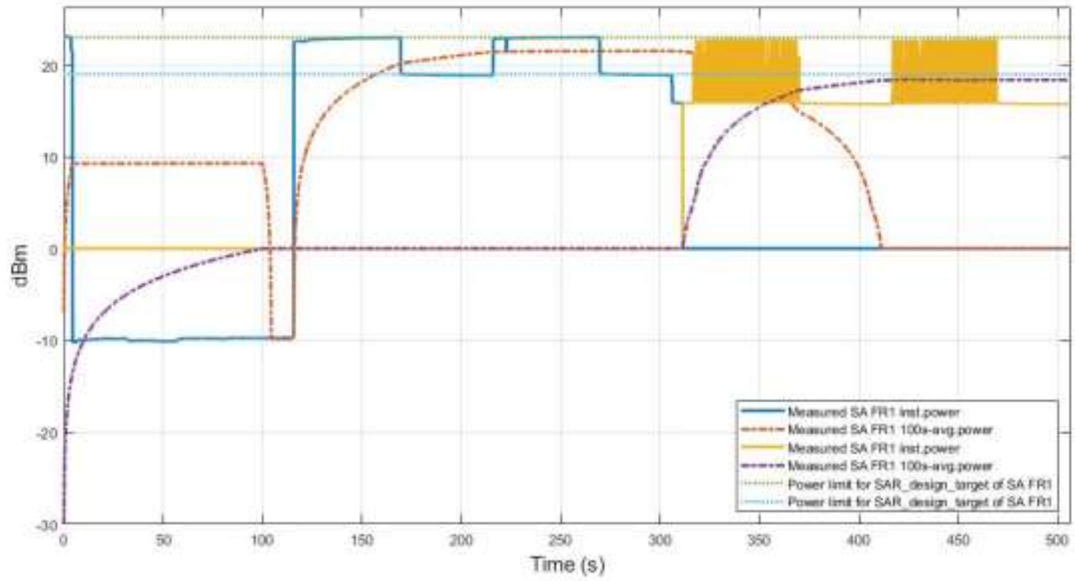

Figure 6.8-1 Conducted Tx power for SAR RSI change FR1 n66 in test TC13

Figure 6.8-1 shows the instantaneous and time-averaged conducted Tx power for both SA FR1 Band n66 for the duration of the test. Around time stamp of ~330s, the RSI value is changed from higher power RSI to lower power RSI, resulting
in reduction of target time-averaged power of SA FR1 Band n66. It can be seen that Plimit value of high RSI is lower than that of low RSI, so in high RSI region, more Tx power is limited compared to low RSI region. Figure 6.8-2 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.

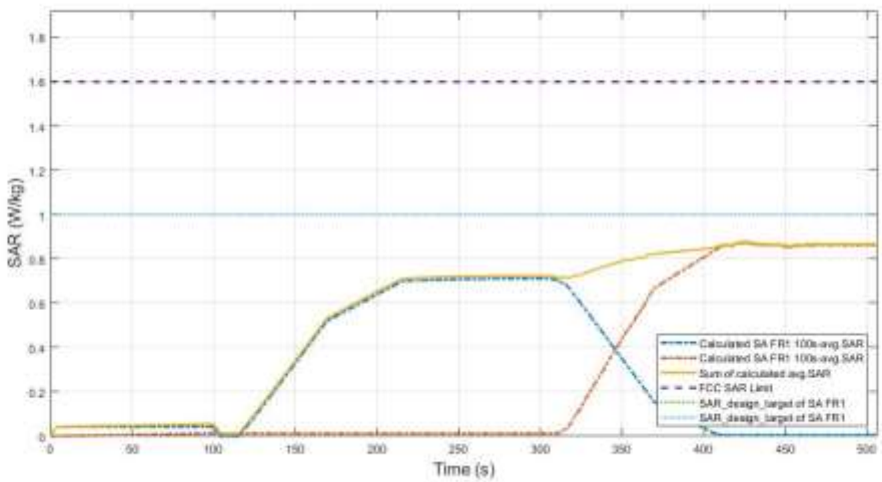

Figure 6.8-2 Total time-averaged SAR FR1 n66 in TC13

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.883 W/kg
Device uncertainty	1 dB

6.9 TAS to nonTAS H.O. test result

The test results in this section are obtained following the procedure in Section 3.3.3. The test cases correspond to TC#14 in Table 6.2.1.

TC14: LTE_to_WCDMA_H.O.

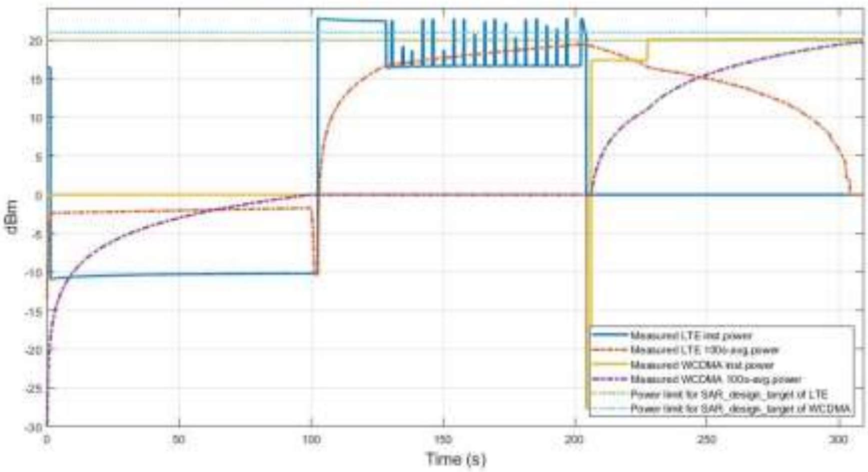

Figure 6.9-1 Conducted Tx power for SAR TAS to nonTAS H.O. in test TC14

Figure 6.9-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 7 and WCDMA Band 2 for the duration of the test. Around time stamp of ~220s, a handover from Band 7 to Band 2 was executed, resulting in reduction of time-averaged power of Band 7 and simultaneous increase in timeaveraged power of Band 2. Because WCDMA is nonTAS RAT, it always transmits maximum power. But when remaining SAR value is low after handover, nonTAS would limit the Tx power for a second to satisfy SAR Compliance. Figure 6.9-2 shows the time-averaged 1gSAR value for each of Band 2 and Band 7, 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.

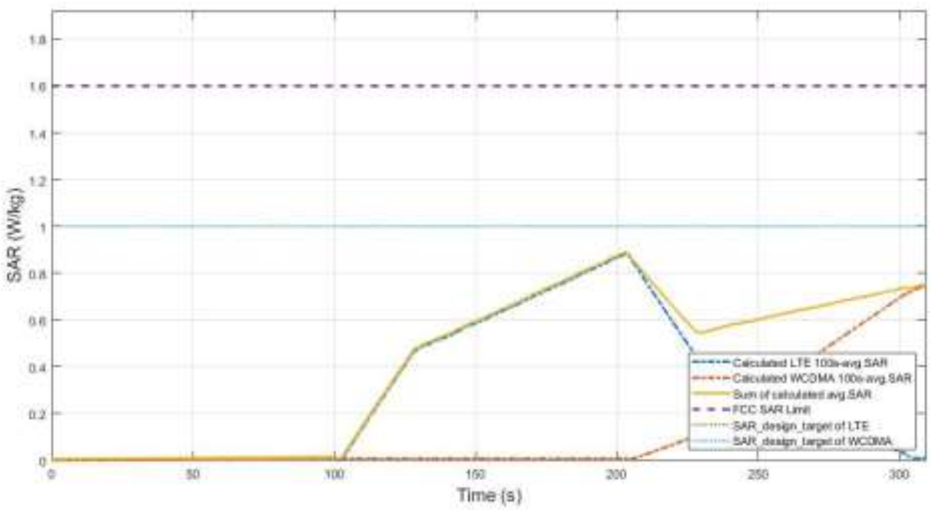

Figure 6.9-2 Total time-averaged SAR in TC14

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.892 W/kg
Device uncertainty	1 dB

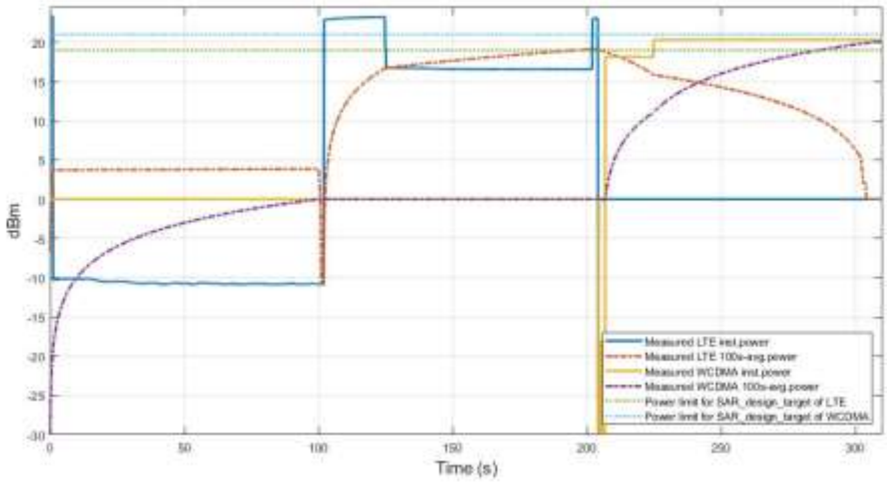

Figure 6.9-3 Conducted Tx power for SAR TAS to non TAS H.O. in test TC14

Figure 6.9-3 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 66 and WCDMA Band 2 for the duration of the test. Around time stamp of ~220s, a handover from Band 66 to Band 2 was executed, resulting in reduction of time-averaged power of Band 66 and simultaneous increase in time averaged
power of Band 2. Because WCDMA is nonTAS RAT, it always transmits maximum power. But when remaining SAR value is low after handover, nonTAS would limit the Tx power for a second to satisfy SAR Compliance. Figure 6.9-4 shows the time-averaged 1gSAR value for each of Band 2 and Band 66, 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.

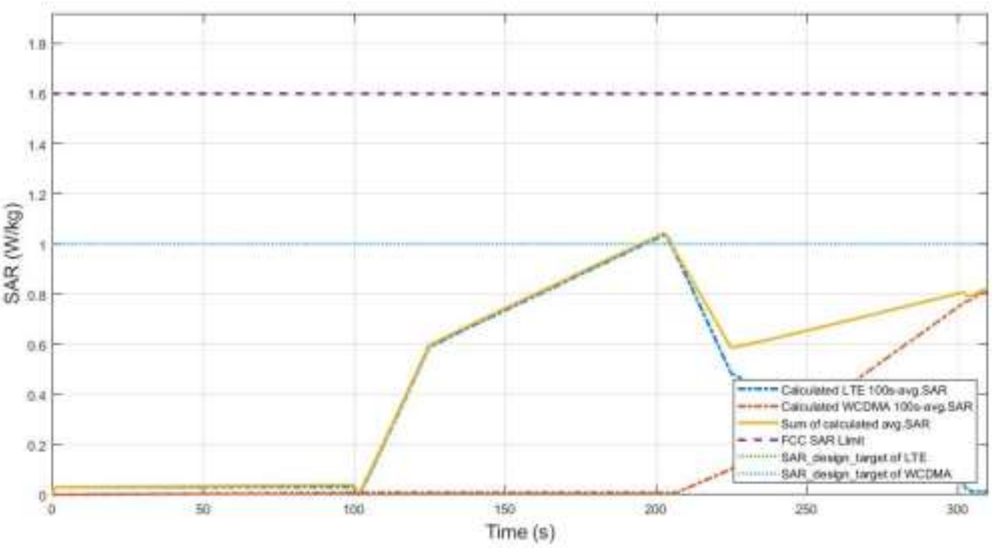

Figure 6.9-4 Total time-averaged SAR in TC14

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	1.043 W/kg
Device uncertainty	1 dB

7.FR2 Radiated Power Test Results for TAS validation

7.1 Measurement setup

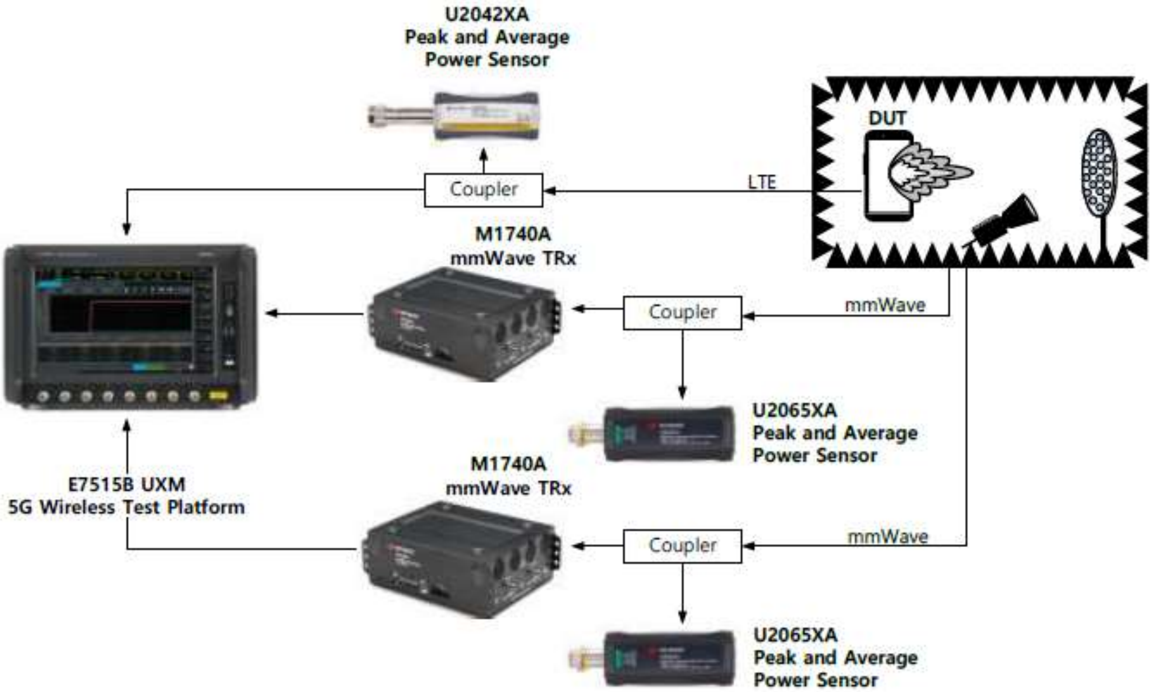

Figure 7.1-1 Test set-up for mmWave

In mmWave technology, we are not able to measure conducted power at antenna, so only radiated power in the form of EIRP (equivalent isotropically radiated power) will be measured in an anechoic chamber. The test setup is illustrated in Figure 7.1-1. For NSA (non-standalone) operation, legacy LTE technology will also be active and this connection can be done via a connected port of the DUT. A power sensor can be coupled to the LTE transmission. There is a concept of two orthogonal polarization measurements (horizontal and vertical) in mmWave, and so two additional power sensors are needed to measure both. There are remote radio-heads required to performance up/down-conversion of the mmWave signal from/to the call box. The Keysight UXM call box is capable of establishing both LTE and FR2 connections. The coupled power sensors in mmWave uplink will be logged along with the LTE power simultaneously for post-processing on the PC. The LTE power is then mapped to SAR, while the mmWave power readings will be mapped to PD using the characterization data. The direction of DUT is set to see the worst case corresponding to module and beam showing the highest PD in characterization as described in Section 4.3. By validation in this conservative worst PD case, all other cases can be regarded as to be validated as well.

In summary, PD test has to be executed as following procedure (more detailed procedure in Section 4.3).

1. Measure conduction sub 6GHz Tx power corresponds to SAR regulation and measure Tx EIRP corresponds to PD regulation. For mmWave, E-field PD measurement TE is used instead of EIRP measurements.
2. Set sub 6GHz and mmWave 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 and EIRP value using mmWave power meter.
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.

7.2 Time-varying Tx power measurement results

The results in this section were obtained following the procedure in Section 4.3.1 and corresponds to the test case TC10 in Table 5.2.1.

7.2.1 TC10: mmWave_Max_Tx_Power

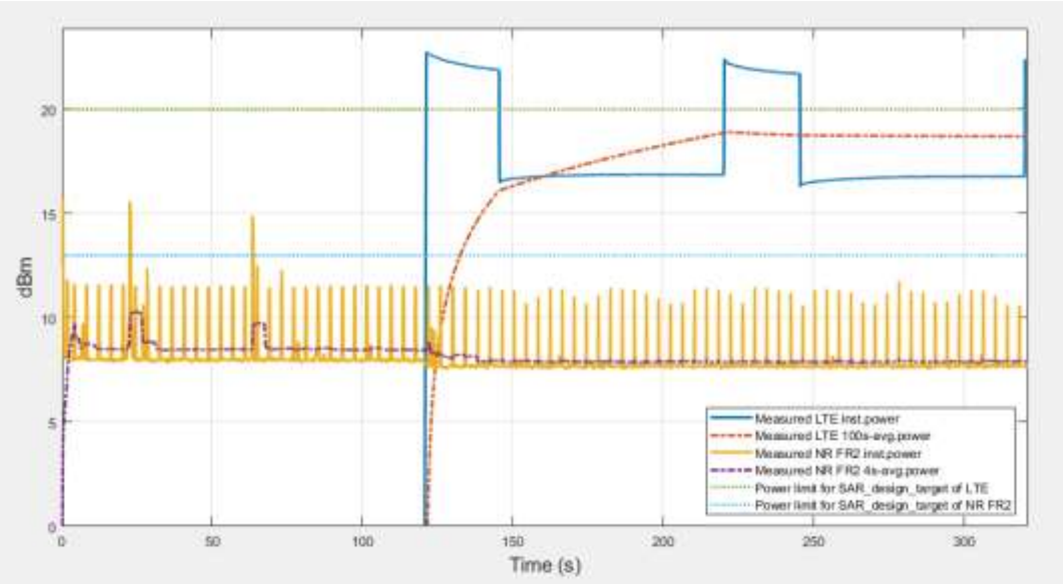

Figure 7.2-1 Conducted power of LTE B66 and radiated EIRP of FR2 n260 in EN-DC max power case TC10 mmWave Max Tx power

Figure 7.2-1 shows the instantaneous and time-averaged conducted power for LTE and radiated power for NR FR2. In this test, we assumed that Plimit value for LTE is 19dBm when SAR_design target is 1.0W/Kg, and the Plimit value of FR2 is 10.7dBm when PD_design_target is 4.42W/m2. When LTE is operated, FR2 power would be decreased to maintain TER value. After the average power of LTE is saturated as target power, the average power of FR2 is not decreased any more. As a result, although LTE is turned on, the TER value doesn't increase or decrease. Figure 7.2-2 shows the computed normalized and time-averaged SAR and PD values for LTE and NR FR2, respectively, as well as their sum which is the TER value. We can see that the TER is always under the FCC compliance limit of 1, thus validating the TAS feature in this test case.

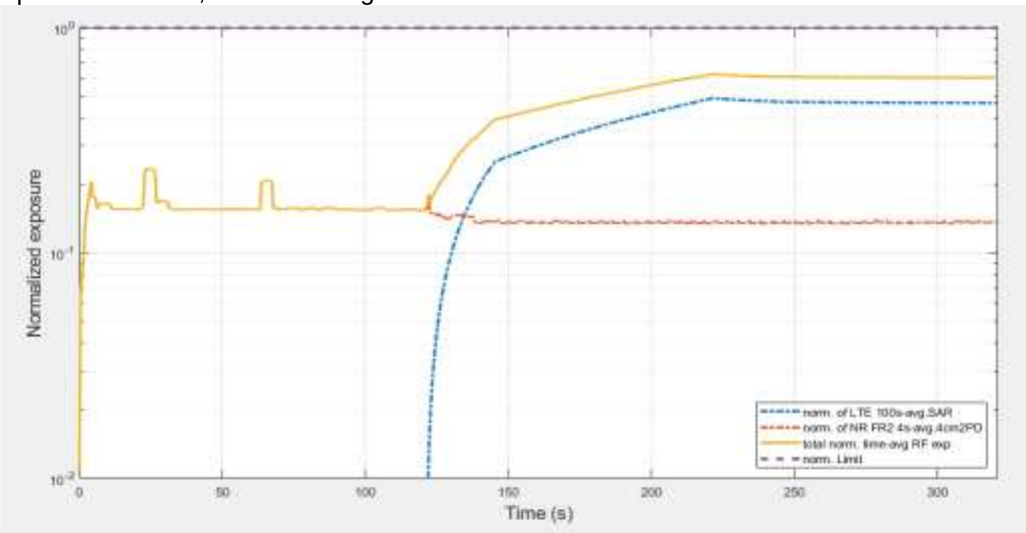

Figure 7.2-2 Total normalized time-average RF exposure in TC10

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.626
Validated	

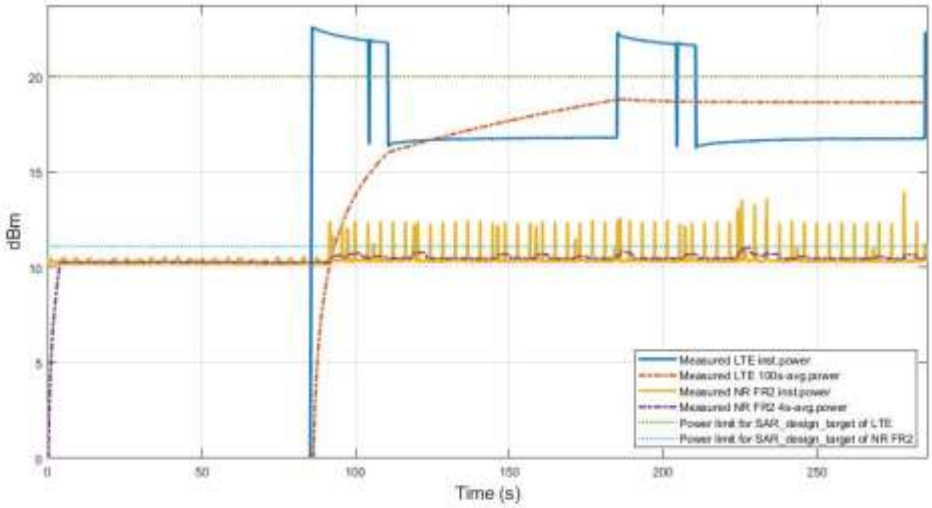

Figure 7.2-3 Conducted power of LTE B66 and radiated EIRP of FR2 n261 in EN-DC max power caseTC10

Figure 7.2-3 shows the instantaneous and time-averaged conducted power for LTE and radiated power for NR FR2. In this test, we assumed that Plimit value for LTE is 19dBm when SAR_design target is 1.0W/Kg, and the Plimit value of FR2 is 8.8dBm when PD_design_target is 4.42W/m2. When LTE is operated, FR2 power would be decreased to maintain TER value. After the average power of LTE is saturated as target power, the average power of FR2 is not decreased any more. As a result, although LTE is turned on, the TER value doesn't increase or decrease. Figure 7.2-4 shows the computed normalized and time-averaged SAR and PD values for LTE and NR FR2, respectively, as well as their sum which is the TER value. We can see that the TER is always under the FCC compliance limit of 1, thus validating the TAS feature in this test case.

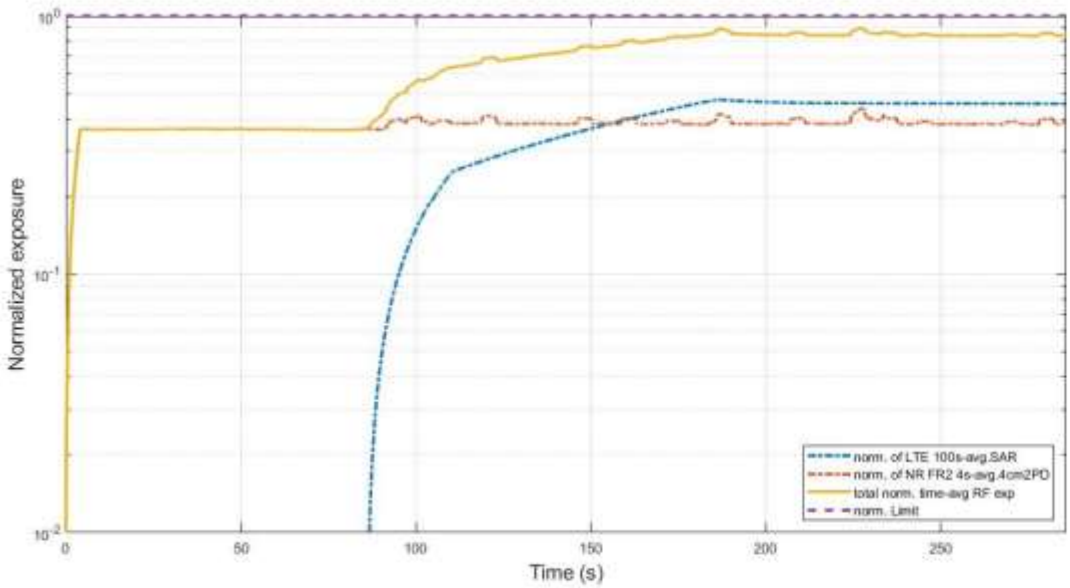

Figure 7.2-4 Total normalized time-average RF exposure in TC10

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.897
Validated	

7.3 SAR vs. PD exposure switch

The results in this section were obtained following the procedure in Section 4.3.2 and corresponds to the test case TC11 in Table 5.2.1.

7.3.1 TC11: mmWave_Dominant_Power_Switching

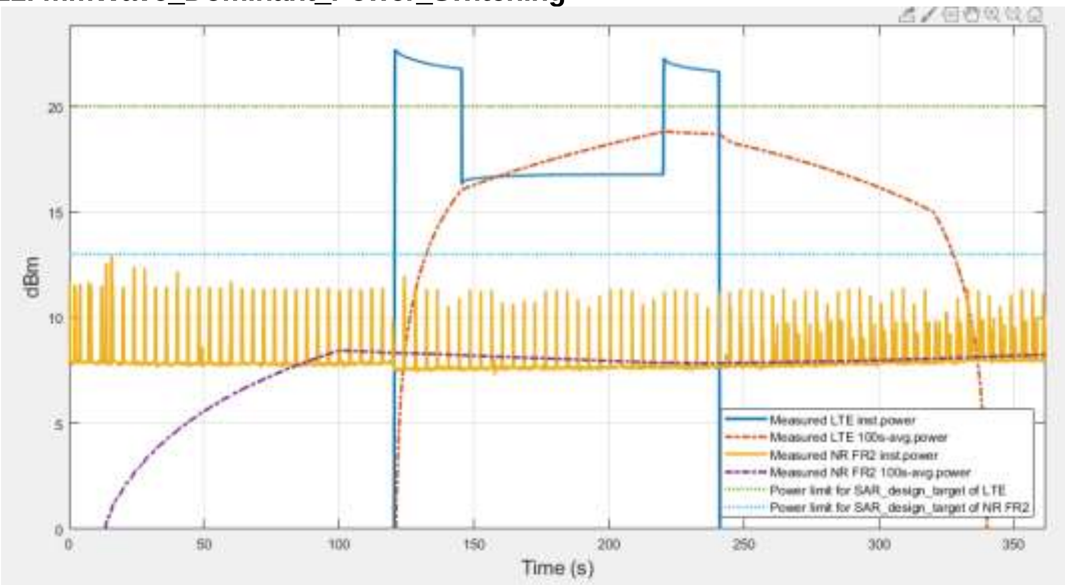

Figure 7.3-1 Conducted power of LTE B66 and radiated EIRP of FR2 n260 in EN-DC max power case TC11

Figure 7.3-1 shows the instantaneous and time-averaged conducted power for LTE and radiated power for NR FR2. In this test, we assumed that Plimit value for LTE is 19dBm when SAR_design_target is 1.0W/Kg, and the Plimit value of FR2 is 10.7dBm when PD_design_target is 4.42W/m2. When LTE is operated, FR2 power would be decreased to maintain TER value. After the average power of LTE is saturated as target power, the average power of FR2 is not decreased any more. After LTE is turned off, the average power of FR2 is increased to restore the original target power. As a result, whether LTE is turned on or not, the TER value dramatically doesn't increase or decrease.

Figure 7.3-2 shows the computed normalized and time-averaged SAR and PD values for LTE and NR FR2, respectively, as well as their sum which is the TER value. We can see that the TER is always under the FCC compliance limit of 1, thus validating the TAS feature in this test case.

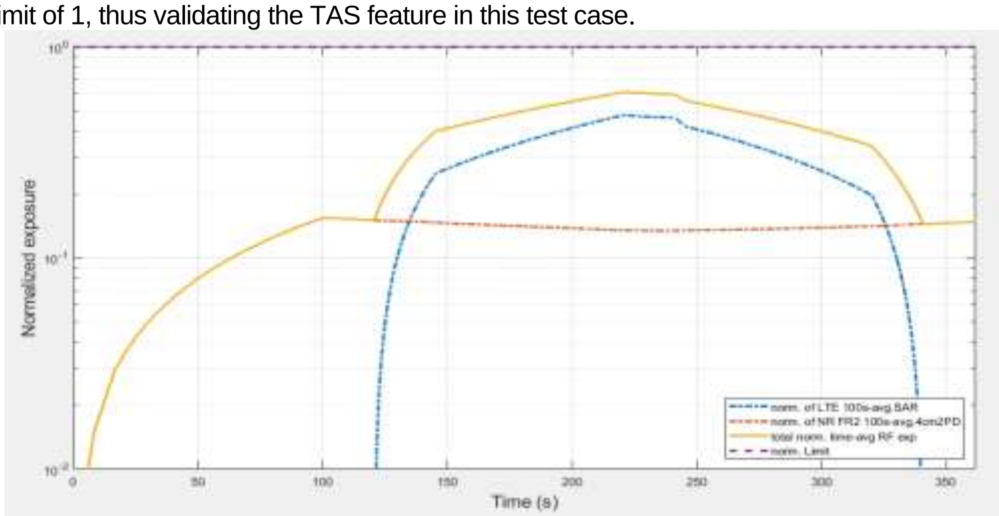

Figure 7.3-2 Total normalized time-average RF exposure in TC11

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.611
Validated	

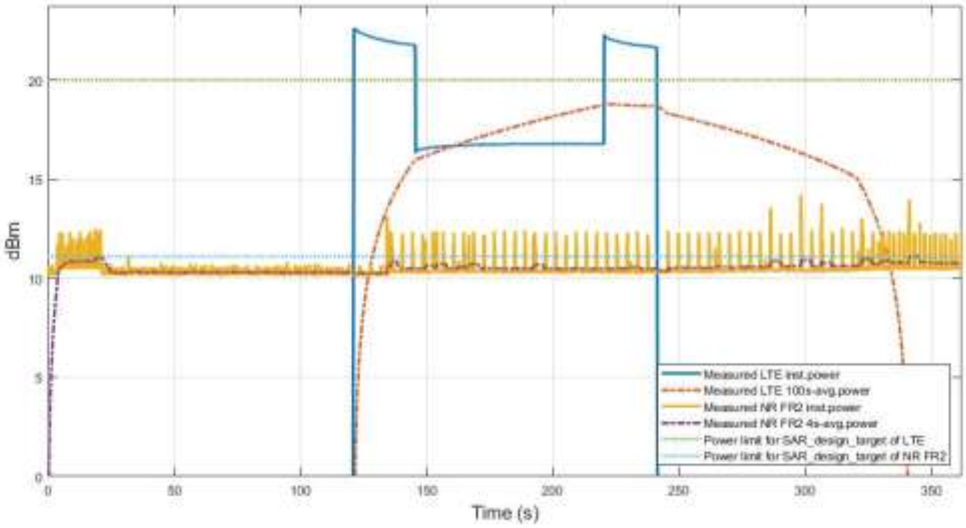

Figure 7.3-3 Conducted power of LTE B66 and radiated EIRP of FR2 n261 in EN-DC max power case TC11

Figure 7.3-3 shows the instantaneous and time-averaged conducted power for LTE and radiated power for NR FR2. In this test, we assumed that Plimit value for LTE is 19dBm when SAR_design_target is 1.0W/Kg, and the Plimit value of FR2 is 8.8dBm when PD_design_target is 4.42W/m2. When LTE is operated, FR2 power would be decreased to maintain TER value. After the average power of LTE is saturated as target power, the average power of FR2 is not decreased any more. After LTE is turned off, the average power of FR2 is increased to restore the original target power. As a result, whether LTE is turned on or not, the TER value dramatically doesn’t increase or decrease.

Figure 7.3-4 shows the computed normalized and time-averaged SAR and PD values for LTE and NR FR2, respectively, as well as their sum which is the TER value. We can see that the TER is always under the FCC compliance limit of 1, thus validating the TAS feature in this test case.

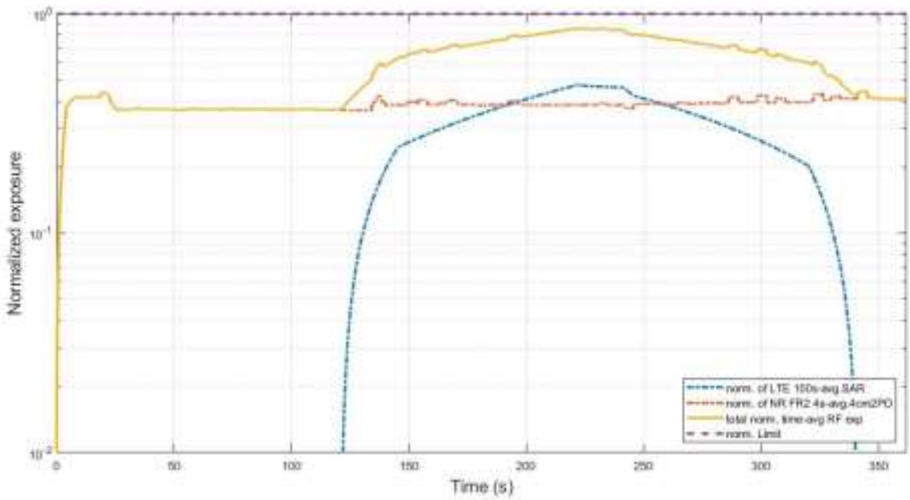

Figure 7.3-4 Total normalized time-average RF exposure in TC11

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.858
Validated	

7.4 FR2 Beam change

The results in this section were obtained following the procedure in Section 4.3.2 and corresponds to the test case TC12 in Table 5.2.1.

7.4.1 TC12: mmWave_Module_Beam_Change

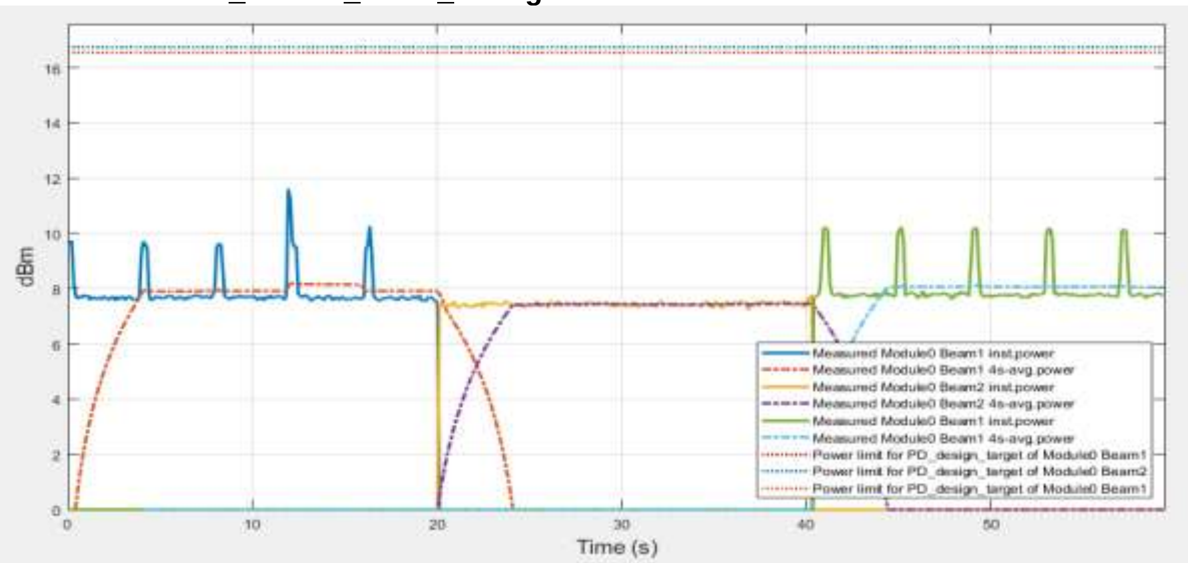

Figure 7.4-1 Measured radiated EIRP of FR2 n260 in mmWave Module beam change case TC12

Figure 7.4-1 shows the instantaneous and time-averaged radiated power for NR FR2. We don't show the LTE transmit power, since it would be at the lowest level and doesn't meaningfully contribute to the TER. In this test, we assumed that the Plimit value of FR2 is 10.7dBm when PD_design_target is 4.42W/m2. Figure 7.4-2 shows

the computed time-averaged PD for each selected module/beam setting as well as the total sum. When beam or module of FR2 would be changed, the sum of each beam/module is not higher than the target power limit. As a result, whether beam/module is changed or not, the TER value dramatically doesn't increase.

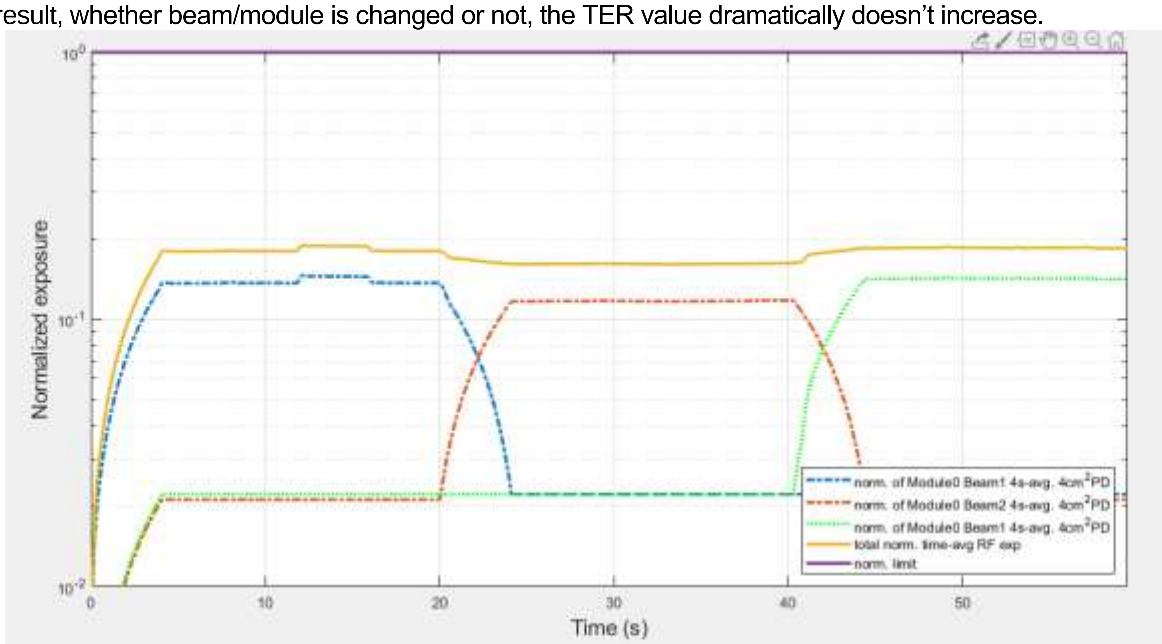

Figure 7.4-2 Total normalized time-average RF exposure in TC12

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.189
Validated	

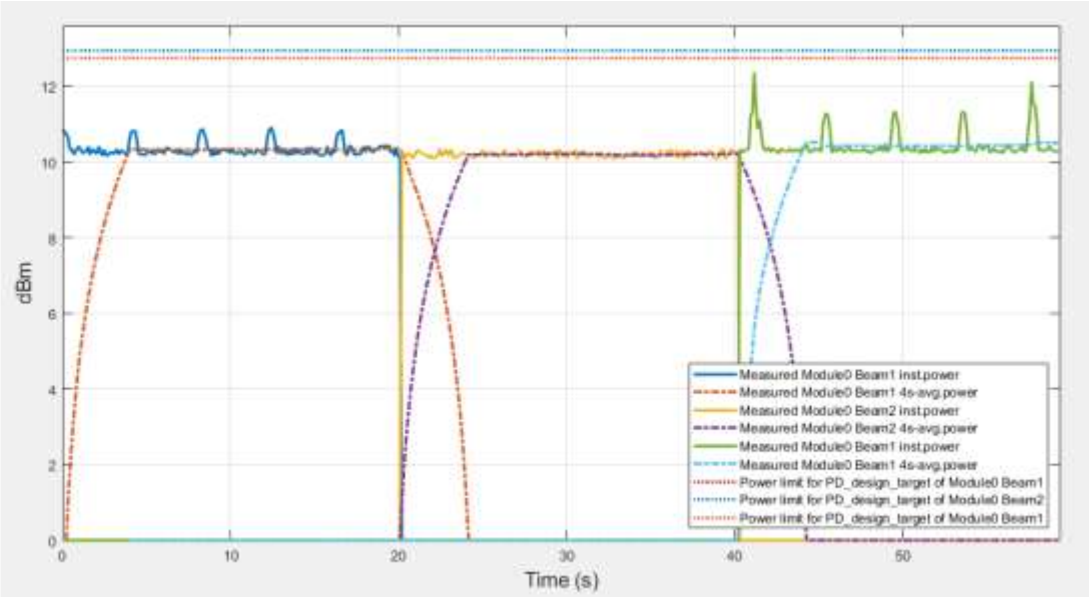

Figure 7.4-3 Measured radiated EIRP of FR2 n261 in mmWave Module beam change case TC12

Figure 7.4-3 shows the instantaneous and time-averaged radiated power for NR FR2. We don't show the LTE transmit power, since it would be at the lowest level and doesn't meaningfully contribute to the TER. In this test, we assumed that the Plimit value of FR2 is 9.2dBm when PD_design_target is 4.42W/m2. Figure 7.4-4 shows the computed time-averaged PD for each selected module/beam setting as well as the total sum. When beam or module of FR2 would be changed, the sum of each beam/module is not higher than the target power limit. As a result, whether beam/module is changed or not, the TER value dramatically doesn't increase.

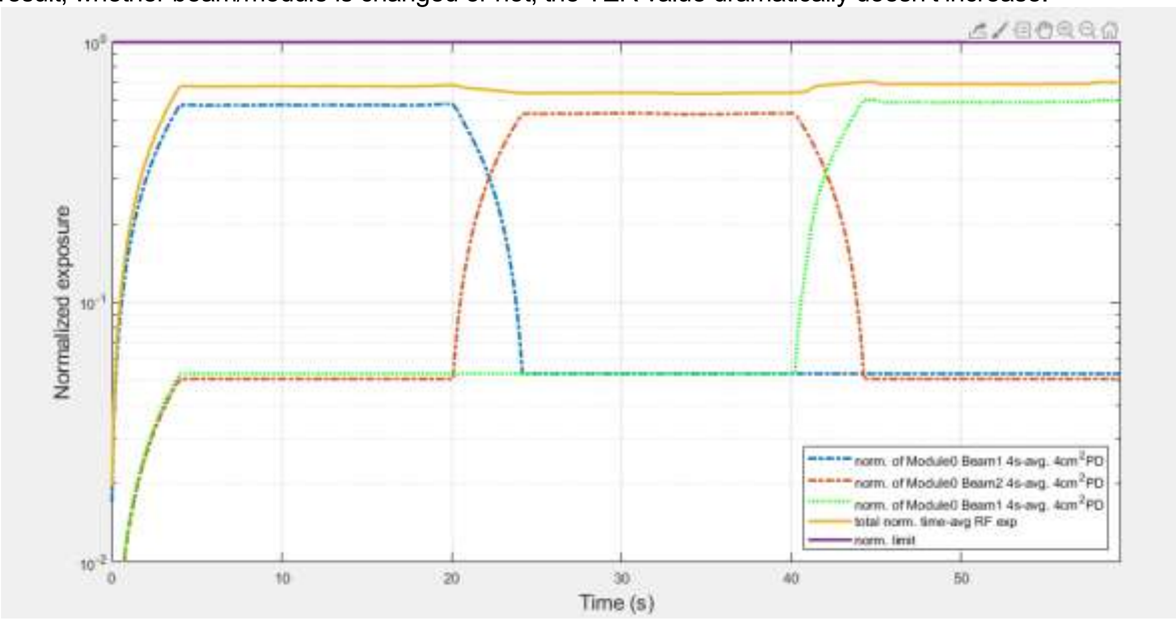

Figure 7.4-4 Total normalized time-average RF exposure in TC12

FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (yellow curve)	0.703
Validated	

8. Conclusions

Samsung Time-Averaging SAR (TAS) feature employed in A has been validated through conducted power measurement as well as SAR measurement.
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 1.

9. Equipment List

Manufacturer	Type / Model	S/N	Calib. Date	Calib.Interval	Calib.Due
-	CATR System Control PC	-	N/A	N/A	N/A
Keysight	5G Compact Antenna Test Range Chamber	230 #27	N/A	N/A	N/A
Keysight	Power Sensor / U2065XA	MY60000018	02/09/2021	Annual	02/09/2022
Keysight	Power Sensor / U2065XA	MY60000014	02/09/2021	Annual	02/09/2022
Keysight	Power Sensor / U2042XA	MY60050004	02/09/2021	Annual	02/09/2022
Keysight	UXM 5G Wireless Test Platform / E7515B	MY60102101	05/17/2021	Annual	05/17/2022
Keysight	mmWave Transceiver / M1740A	MY59292349	10/07/2021	Annual	10/07/2022
Keysight	mmWave Transceiver / M1740A	MY59292403	10/07/2021	Annual	10/07/2022
Keysight	5G Common Interface Unit / E7770A	MY58290875	N/A	N/A	N/A
Testo	608-H1/Thermometer	2183499992	12/09/2021	Annual	12/09/2022
Mini Circuits	Directional Coupler / ZCDC10-V245+	913911	12/14/2021	Annual	12/14/2022
Mini Circuits	Directional Coupler / ZCDC10-V245+	913901	12/14/2021	Annual	12/14/2022
Mini Circuits	2 Way DC Pass Power Splitter / ZN2PD-63-S+	UU95102009	04/13/2021	Annual	04/13/2022
Narda	Directional Coupler / 4216-10	01490	12/14/2021	Annual	12/14/2022
Narda	Directional Coupler / 4216-10	01489	12/14/2021	Annual	12/14/2022
Narda	Directional Coupler / 4226-10	03089	04/05/2021	Annual	04/05/2022
Anritsu	Radio Communication Analyzer / MT8821C	6261760829	12/03/2021	Annual	12/03/2022
Anritsu	Radio Communication Test Station / MT8000A	6262036812	12/20/2021	Annual	12/20/2022
Anritsu	Power Meter / ML2496A	2041001	12/16/2021	Annual	12/16/2022
Anritsu	Power Sensor / MA2475D	1911225	12/16/2021	Annual	12/16/2022
Anritsu	Power Sensor / MA2475D	1911226	12/16/2021	Annual	12/16/2022
UIY	Highpass Filter / UIYHPF7043A1t4SF	JH00026301	09/06/2021	Annual	09/06/2022
Micro Lab	Lowpass Filter / LA-15N	-	10/06/2021	Annual	10/06/2022

10. 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)

Appendix A.

1.1 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

1.2 Test Sequence A waveform:

Based on the parameters above, the Test Sequence A is generated with two power levels. One is maximum power level and the other is lower power level. The lower power level is defined as 3dB lower value than maximum power level. At first, maximum power level is applied for 120 seconds (SAR_time_window x 1.2). After then, lower power level is used until this test is finished.

1.3 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 1.3.1

Table 1.3.1 Table of test sequence B

Time duration (second)	Power level (dB)
15	Plimit - 5
20	Plimit
20	Plimit + 5
10	Plimit – 6
20	Pmax
15	Plimit
15	Plimit -7
20	Pmax
10	Plimit-5
15	Plimit
10	Plimit-6
20	Plimit + 5
10	Plimit – 4
15	Plimit
10	Plimit – 6
20	Pmax
15	Plimit-8
15	Plimit
20	Pmax
1	Plimit – 9
20	Plimit + 5
20	Plimit
15	Plimit – 5