FCC TAS validation – Part 2: Tests under dynamic transmit power scenarios

FCC ID	:	**A4RGC3VE**
Equipment	:	**Phone**
Model Name	:	**GC3VE**
Applicant	:	**Google LLC** **1600 Amphitheatre Parkway,** **Mountain View, California, 94043 USA**
Standard	:	**FCC 47 CFR Part 2 (2.1093)**

The product was received on Feb. 09, 2023 and testing was started from Jun. 15, 2023 and completed on Jun. 20, 2023. We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample provide by manufacturer and the test data has been evaluated in accordance with the test procedures given in 47 CFR Part 2.1093 and FCC KDB and has been pass the FCC requirement.

The test results in this report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory, the test report shall not be reproduced except in full.

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History of this test report

Report No.	Version	Description	Issued Date
FA2D0206-03C	01	Initial issue of report	Jun. 30, 2023
FA2D0206-03C	02	Update section 5.1	Jul. 18, 2023

1. Introduction

This purpose of this Part 2 report is to demonstrate that the DUT complies with FCC RF exposure compliance requirement under varying Tx power transmission scenarios, thus validating the Samsung S.LSI TAS algorithm feature for FCC equipment authorization of the handset.

The values of Plimit used in this report per scenario are determined in Part 0 report.

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 Part 0, the RF exposure is proportional to the Tx power for sub-6. Thus, we rely on conducted power measurements (sub-6) 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 over time , denoted as $TxPower(t)$, with time index t for each radio
2. Convert measured powers to RF exposure values using linear relationship shown below. In below expression, P$imit$,sub-6 would be the measured power at which FR1 technology meets measured SAR level of SAR_design_target as described in Part 0.

$$\text{SAR (t)} = \frac{\text{TxPower(t)}}{Plimit,sub-6} * SAR\_design\_target \qquad (2.1.1)$$

3. Compute the average RF exposure over the most recent measurement duration which are denoted as $TSAR$ for sub6 . These durations are as specified by FCC. This measurement duration interval is then given by [$t - TSAR$, t] for sub-6.

4. Divide the RF exposure by corresponding FCC limit and ensure the sum denoted as TER (total exposure ratio) is less than 1 for all. The following equation describes the calculation of TER and its target constraint. *LSAR* is the number of fixed, mobile or portable RF sources using SAR-based formula, the expressions below is general considering a number radios in general denoted by $LSAR$.

$$\sum_{lSAR=0}^{LSAR-1} \frac{SARavr, lSAR}{FCC\ SAR} \le 1 \qquad (2.1.2)$$

3. SAR Time Averaging Validation Test Procedures

In this section, we cover the test plan and test procedure for validating Samsung SLSI TAS feature 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 sub-6 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. 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 criteria for validating TAS

This section provides general guidance for selecting test cases in TAS feature 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 Part 0. 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 from Part 0 with different values of Plimit – select 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 among all bands in Part 0. 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 sub-6. The criteria for selecting test case to demonstrate compliance across time window change is to pick a technology/band corresponding to each time window from Part 0 such that Plimit is less than Pmax.

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.

3.3.1.1 Test procedure

1. Using the Pmax and Plimit obtained in Part 0/1, 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 result.

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

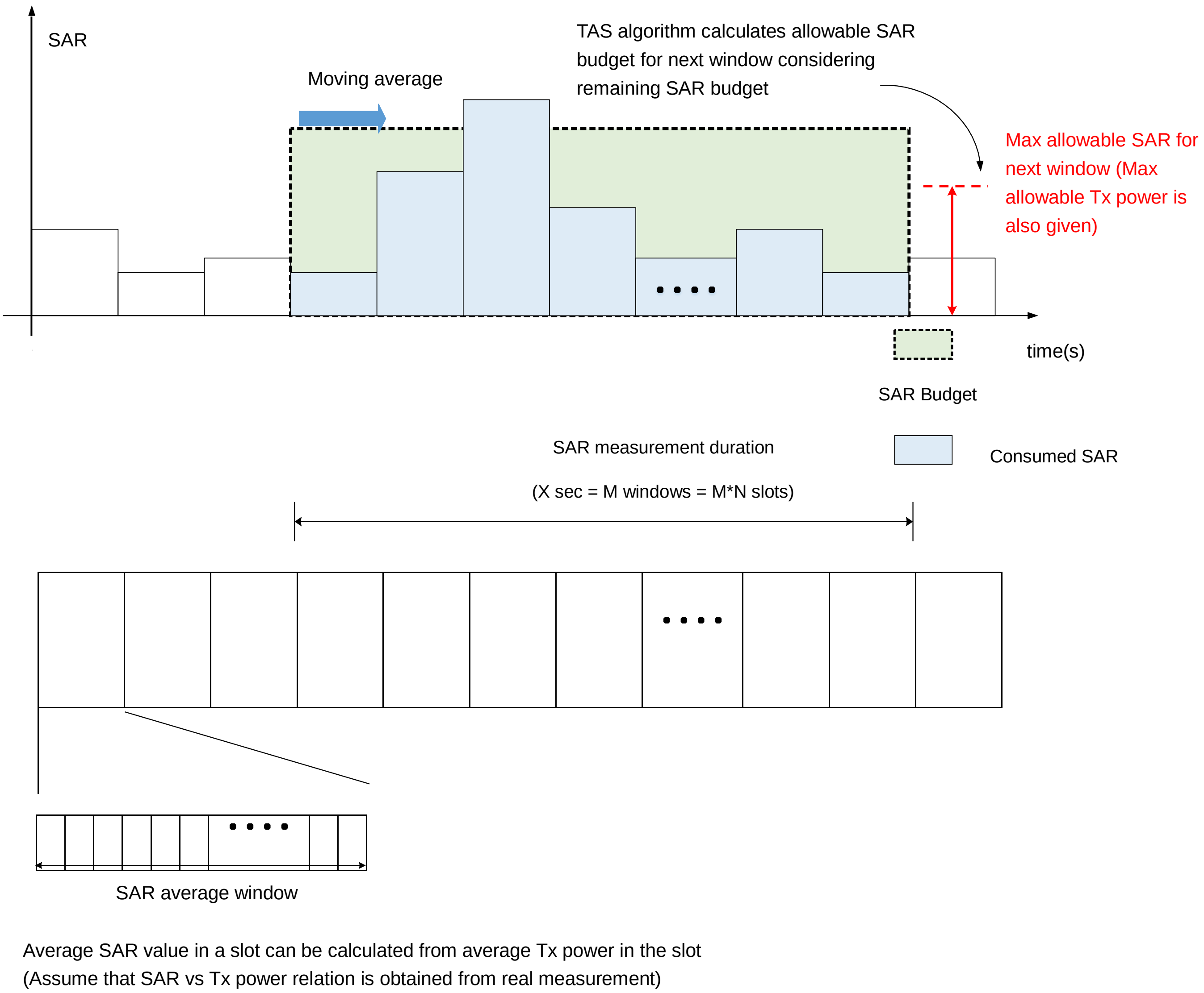

Figure 3.3-1 SAR measurement from Tx power using block-wise processing

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 Part 0/1

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.SLSI 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 a combined SAR exposure criterion as shown below.Test procedure

$$\text{SAR 1 (t)} = \frac{\text{TxPower(t)}}{Plimit{,}sub6} * SAR\_design\_target \qquad (3.3.1)$$

$$\text{SAR 2 (t)} = \frac{\text{TxPower(t)}}{Plimit{,}sub6} * SAR\_design\_target \qquad (3.3.2)$$

where $Plimit$,1, would correspond to measured power at which first technology/band meets measured SAR level of SAR_design_target1 as described in Part 0 wit time-averaging duration of T1,SAR . Similarly, the quantities $Plimit$,2, SAR_design_target2, T2,SAR are defined for the second technology/band. When first band is chosen below 3GHz, we would have T1, = 100s, and by choosing second ban to be above 3GHz we would use T2, = 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.

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 (e.g B2) 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 (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 60s
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 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 Eqn (3.3.1) and (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.

3.3.3.2 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 (B48) 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 (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 100s
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 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 Eqn (3.3.1) and (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.

4. Spatial TAS

In legacy TAS algorithm (V2.3), it was assumed that all antennas are correlated regardless of their direction of transmission in space. Thus, the main concept was to split the SAR/TER on the transmitting RATs even they are transmitting on different antennas. Such approach is considered as a worst case scenario in terms of transmitting power. Thus, to enhance the performance of the transmission power of RATs, we should consider the spatial properties of each antenna and the correlations between the antennas transmissions.

For example, consider a DUT with two antennas one at the top and one at the bottom and each are transmitting in two different direction with no common area affected by both. For such DUT architecture, if each antenna utilize the full SAR compliance while transmitting simultaneously, then the power transmission is still under compliance since no area is affected by both transmissions and thus no area will have SAR above SAR compliance.

For a DUT with N antennas, a spatial correlation matrix (R) can be constructed to map the correlation between each two antennas when they transmit simultaneously. Thus this correlation matrix is given as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ r_{21} & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N1} & r_{N2} & \cdots & r_{NN} \end{bmatrix}$$

And it has the following characteristics

a) r_{ij} is the correlation between antenna i and antenna j

b) The value of r_{ij} is either 0 or 1, where 1 means fully correlated and 0 means fully uncorrelated.

c) r_{ii} is the self-correlation of each antenna and it is always 1

For ENDC operation, the value of the correlation coefficients (r_{ij}) between the two transmitting antennas (*i,j*) will determine the splitting ratios between the two operating RATs as follow

a) If r_{ij} = 0 then each antenna will transmit with full SAR compliance

b) If r_{ij} = 1 then the full SAR compliance will be split among both antennas with ration a:*b*, where a + b =1

Since the R matrix entries depends on the antenna distribution of each DUT, then our spatial TAS algorithm is implemented to operate with any R matrix (antenna distribution agnostic).

The values of the R matrix entries should be determined by the OEM based on the DUT used. One way to determine the values of the R matrix entries is to use the SPLSR test mentioned in FCC KDB 447498 D01, section 4.3.2.

The SPLSR test is done between each pair of antennas as follow

i. Measure the SAR peak location for each antenna (x_i, y_i, z_i) and (x_j, y_j, z_j)

ii. Calculate $\Gamma_{\text{ij}} = \frac{(SAR_{1,max}+SAR_{j,max})^{1.5}}{D}$, where $SAR_{i,max} = SAR_{j,max} = SAR_{comp}$ and $D = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$

iii. Check if the value of $\Gamma_{ij} \leq 0.04$ for 1g and 0.1 for 10g then these two antennas are considered fully uncorrelated and we can set $r_{ij} = 0$. Otherwise, a Volumetric SAR evaluation can be done to check the non-correlation of both antennas and if not set $r_{ij} = 1$

iv. If volumetric SAR cannot meet FCC SAR compliance requirements, set $r_{ij} = 1$.

NOTE: The antennas corresponding to the selected RSIs or change in technology/band/window should be in the rij=1 (Same antenna group) if EUT is configured Spatial TAS algorithm.

5. Test Configurations

5.1 WWAN (sub-6) transmission

1. The Plimit values correspond to SAR_design_target.
2. GSM and WCDMA don't support time average feature of dynamic power varying, the power will be fixed at the static reduce power level at different exposure conditions for RF exposure compliance. For the GSM (TDD) Plimit power levels in the table correspond to the burst average power levels which don't account for TX duty cycle.
3. The device additionally support UL MIMO mode on n41/77/78
4. LTE and 5GNR TDD: Plimit power levels in the table correspond to the time-averaged power levels which accounts for TX duty cycle.
5. Maximum target power, Pmax, is configured in NV settings in EUT to limit maximum transmitting power. This power is converted into peak power in NV settings for TDD schemes

Table 5.1.1: P_{limit} for supported technologies and bands (P_{limit} corresponding to SAR design target)

Wireless technology/ band (No Accounting duty cycle)	Antenna	Duty cycle	Maximum Power Conditions Index 1 (P limit, Burst average power (dBm))	Head Standalone Index 2 (P limit, Burst average power (dBm))	Head Simultaneous Index 3 (P limit, Burst average power (dBm))	Hotspot Simultaneous Index 4 (P limit, Burst average power (dBm))	Body-worn Standalone Index 5 (P limit, Burst average power (dBm))	Body-worn Simultaneous Index 6 (P limit, Burst average power (dBm))	PMax Burst average power (dBm)
GSM850 GPRS 1TX	0	12.50%	32.5	34.8	34.1	33.9	35.1	34.4	32.5
GSM850 GPRS 2TX	0	25.00%	31.5	31.8	31.1	30.9	32.1	31.4	31.5
GSM850 GPRS 3TX	0	37.50%	30.5	30.0	29.3	29.1	30.3	29.6	30.5
GSM850 GPRS 4TX	0	50.00%	29.5	28.8	28.1	27.9	29.1	28.4	29.5
GSM850 EDGE 1TX	0	12.50%	27.0	34.8	34.1	33.9	35.1	34.4	27.0
GSM850 EDGE 2TX	0	25.00%	26.5	31.8	31.1	30.9	32.1	31.4	26.5
GSM850 EDGE 3TX	0	37.50%	26.5	30.0	29.3	29.1	30.3	29.6	26.5
GSM850 EDGE 4TX	0	50.00%	24.5	28.8	28.1	27.9	29.1	28.4	24.5
GSM850 GPRS 1TX	1	12.50%	32.1	30.2	29.5	33.9	34.6	33.9	32.1
GSM850 GPRS 2TX	1	25.00%	31.1	27.2	26.5	30.9	31.6	30.9	31.1
GSM850 GPRS 3TX	1	37.50%	30.1	25.4	24.7	29.1	29.8	29.1	30.1
GSM850 GPRS 4TX	1	50.00%	29.1	24.2	23.5	27.9	28.6	27.9	29.1
GSM850 EDGE 1TX	1	12.50%	26.6	30.2	29.5	33.9	34.6	33.9	26.6
GSM850 EDGE 2TX	1	25.00%	26.1	27.2	26.5	30.9	31.6	30.9	26.1
GSM850 EDGE 3TX	1	37.50%	26.1	25.4	24.7	29.1	29.8	29.1	26.1
GSM850 EDGE 4TX	1	50.00%	24.1	24.2	23.5	27.9	28.6	27.9	24.1
GSM1900 GPRS 1TX	0	12.50%	29.2	45.6	44.9	27.5	29.0	28.3	29.2
GSM1900 GPRS 2TX	0	25.00%	27.7	42.6	41.9	24.5	26.0	25.3	27.7
GSM1900 GPRS 3TX	0	37.50%	27.2	40.8	40.1	22.7	24.2	23.5	27.2
GSM1900 GPRS 4TX	0	50.00%	26.2	39.6	38.9	21.5	23.0	22.3	26.2
GSM1900 EDGE 1TX	0	12.50%	24.2	45.6	44.9	27.5	29.0	28.3	24.2
GSM1900 EDGE 2TX	0	25.00%	23.2	42.6	41.9	24.5	26.0	25.3	23.2
GSM1900 EDGE 3TX	0	37.50%	23.2	40.8	40.1	22.7	24.2	23.5	23.2
GSM1900 EDGE 4TX	0	50.00%	22.2	39.6	38.9	21.5	23.0	22.3	22.2
GSM1900 GPRS 1TX	2	12.50%	30.0	35.5	34.8	28.5	29.2	28.5	30.0
GSM1900 GPRS 2TX	2	25.00%	28.5	32.5	31.8	25.5	26.2	25.5	28.5
GSM1900 GPRS 3TX	2	37.50%	28.0	30.7	30.0	23.7	24.4	23.7	28.0
GSM1900 GPRS 4TX	2	50.00%	27.0	29.5	28.8	22.5	23.2	22.5	27.0
GSM1900 EDGE 1TX	2	12.50%	25.0	35.5	34.8	28.5	29.2	28.5	25.0
GSM1900 EDGE 2TX	2	25.00%	24.0	32.5	31.8	25.5	26.2	25.5	24.0
GSM1900 EDGE 3TX	2	37.50%	24.0	30.7	30.0	23.7	24.4	23.7	24.0
GSM1900 EDGE 4TX	2	50.00%	23.0	29.5	28.8	22.5	23.2	22.5	23.0
WCDMA B2	0	100.00%	23.8	35.2	34.5	17.3	19.4	18.7	23.8
WCDMA B2	2	100.00%	24.6	26.4	25.7	19.9	20.6	19.9	24.6
WCDMA B4	0	100.00%	23.8	34.5	33.8	17.6	18.3	17.6	23.8
WCDMA B4	2	100.00%	24.6	27.9	27.2	19.9	20.6	19.9	24.6
WCDMA B5	0	100.00%	24.7	29.4	28.7	25.0	25.7	25.0	24.7
WCDMA B5	1	100.00%	24.3	21.5	20.8	26.8	27.5	26.8	24.3

Table 5.1.2: P_{limit} for supported technologies and bands (P_{limit} corresponding to SAR design target)

Wireless technology/ band (Accounting duty cycle)	Antenna	Duty cycle	Maximum Power Conditions	Head		Hotspot	Body-worn		PMax Time average power (dBm)
				Standalone	Simultaneous	Simultaneous	Standalone	Simultaneous	
			Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	
			P limit						
			Time average power (dBm)						
LTE B2	1	100.00%	24.6	16.2	15.5	20.0	20.7	20.0	24.6
LTE B2	5	100.00%	23.8	18.2	17.5	20.3	21.0	20.3	23.8
LTE B7	0	100.00%	23.5	29.2	28.5	16.2	20.5	19.8	23.5
LTE B7	2	100.00%	24.5	25.9	25.2	20.6	21.3	20.6	24.5
LTE B12/17	0	100.00%	24.7	30.7	30.0	27.2	28.5	27.8	24.7
LTE B12/17	1	100.00%	24.3	22.0	21.3	27.8	28.5	27.8	24.3
LTE B13	0	100.00%	24.7	30.2	29.5	25.8	26.5	25.8	24.7
LTE B13	1	100.00%	24.3	23.0	22.3	28.5	29.2	28.5	24.3
LTE B14	0	100.00%	24.7	30.1	29.4	25.6	26.3	25.6	24.7
LTE B14	1	100.00%	24.3	22.1	21.4	28.3	29.0	28.3	24.3
LTE B25/2	0	100.00%	23.8	34.2	33.5	16.8	19.1	18.4	23.8
LTE B25/2	2	100.00%	24.6	25.7	25.0	20.2	20.9	20.2	24.6
LTE B26/5	0	100.00%	24.7	29.1	28.4	25.4	26.1	25.4	24.7
LTE B26/5	1	100.00%	24.3	20.7	20.0	26.9	27.6	26.9	24.3
LTE B30	0	100.00%	21.9	33.7	33.0	16.7	19.3	18.6	21.9
LTE B30	2	100.00%	22.2	26.8	26.1	20.0	20.7	20.0	22.2
LTE B41/38 PC3	0	63.30%	21.4	30.2	29.5	15.8	19.6	18.9	20.0
LTE B41/38 PC3	2	63.30%	22.4	26.3	25.6	20.3	21.0	20.3	21.0
LTE B41/38 PC2	0	43.30%	21.4	30.2	29.5	15.8	19.6	18.9	21.4
LTE B41/38 PC2	2	43.30%	22.4	26.3	25.6	20.3	21.0	20.3	22.4
LTE B48 PC3	6	63.30%	19.3	28.8	28.1	17.6	18.3	17.6	19.3
LTE B48 PC3	7	63.30%	21.7	24.5	23.8	20.7	21.4	20.7	21.7
LTE B66/4	0	100.00%	23.8	33.7	33.0	17.0	18.5	17.8	23.8
LTE B66/4	1	100.00%	24.6	17.2	16.5	21.2	21.9	21.2	24.6
LTE B66/4	2	100.00%	24.6	27.5	26.8	20.2	20.9	20.2	24.6
LTE B66/4	5	100.00%	23.8	19.1	18.4	21.0	21.7	21.0	23.8
LTE B71	0	100.00%	24.7	31.3	30.6	26.9	28.3	27.6	24.7
LTE B71	1	100.00%	24.3	22.7	22.0	28.0	28.7	28.0	24.3

Table 5.1.3: P_{limit} for supported technologies and bands (P_{limit} corresponding to SAR design target)

Wireless technology/ band (Accounting duty cycle)	Antenna	Duty cycle	Maximum Power Conditions	Head		Hotspot	Body-worn		PMax Time average power (dBm)
				Standalone	Simultaneous	Simultaneous	Standalone	Simultaneous	
			Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	
			P limit						
			Time average power (dBm)						
FR1 n2	1	100.00%	24.6	16.4	15.7	20.0	20.8	20.1	24.6
FR1 n2	5	100.00%	23.8	17.3	16.6	20.2	21.6	20.9	23.8
FR1 n5	0	100.00%	24.7	29.2	28.5	26.1	27.4	26.7	24.7
FR1 n5	1	100.00%	24.3	21.5	20.8	25.2	25.9	25.2	24.3
FR1 n7	0	100.00%	23.2	27.8	27.1	17.3	20.8	20.1	23.2
FR1 n7	2	100.00%	24.5	25.5	24.8	21.2	21.9	21.2	24.5
FR1 n12	0	100.00%	24.7	30.8	30.1	26.6	27.3	26.6	24.7
FR1 n12	1	100.00%	24.3	24.4	23.7	28.1	28.8	28.1	24.3
FR1 n25/2	0	100.00%	23.8	33.5	32.8	17.4	19.2	18.5	23.8
FR1 n25/2	2	100.00%	24.6	25.3	24.6	19.8	20.5	19.8	24.6
FR1 n30	0	100.00%	21.9	28.5	27.8	16.7	19.2	18.5	21.9
FR1 n30	2	100.00%	22.2	24.9	24.2	20.7	21.4	20.7	22.2
FR1 n38 PC3	0	100.00%	23.5	29.7	29.0	17.3	20.9	20.2	23.5
FR1 n38 PC3	1	100.00%	24.5	16.8	16.1	21.4	22.1	21.4	24.5
FR1 n38 PC3	2	100.00%	24.5	26.5	25.8	20.3	21.0	20.3	24.5
FR1 n38 PC3	5	100.00%	23.5	19.6	18.9	20.1	20.8	20.1	23.5
FR1 n41 PC3	0	100.00%	22.0	27.5	26.8	17.3	20.9	20.2	22.0
FR1 n41 PC3	1	100.00%	23.0	16.8	16.1	21.4	22.1	21.4	23.0
FR1 n41 PC3	2	100.00%	23.0	25.5	24.8	20.3	21.0	20.3	23.0
FR1 n41 PC3	5	100.00%	22.0	19.6	18.9	20.1	20.8	20.1	22.0
FR1 n41 PC2	0	50.00%	22.0	27.5	26.8	17.3	20.9	20.2	22.0
FR1 n41 PC2	1	50.00%	23.0	16.8	16.1	21.4	22.1	21.4	23.0
FR1 n41 PC2	2	50.00%	23.0	25.5	24.8	20.3	21.0	20.3	23.0
FR1 n41 PC2	5	50.00%	22.0	19.6	18.9	20.1	20.8	20.1	21.7
FR1 n66	0	100.00%	23.8	31.8	31.1	17.5	18.2	17.5	23.8
FR1 n66	1	100.00%	24.6	17.6	16.9	21.5	22.2	21.5	24.6
FR1 n66	2	100.00%	24.6	27.8	27.1	21.3	22.0	21.3	24.6
FR1 n66	5	100.00%	23.8	18.3	17.6	21.2	21.9	21.2	23.8
FR1 n71	0	100.00%	24.7	32.6	31.9	26.7	27.4	26.7	24.7
FR1 n71	1	100.00%	24.1	24.1	23.4	28.7	29.4	28.7	24.1
FR1 n77 PC3	1	100.00%	23.0	16.5	15.8	19.9	20.6	19.9	23.0
FR1 n77 PC3	5	100.00%	22.5	19.8	19.1	21.8	22.5	21.8	22.5
FR1 n77 PC3	6	100.00%	23.5	27.7	27.0	20.6	21.3	20.6	23.5
FR1 n77 PC3	7	100.00%	22.9	27.9	27.2	23.3	24.6	23.9	22.9
FR1 n77 PC2	1	50.00%	23.0	16.5	15.8	19.9	20.6	19.9	23.0
FR1 n77 PC2	5	50.00%	22.5	19.8	19.1	21.8	22.5	21.8	22.5
FR1 n77 PC2	6	50.00%	23.5	27.7	27.0	20.6	21.3	20.6	23.5
FR1 n77 PC2	7	50.00%	22.9	27.9	27.2	23.3	24.6	23.9	22.4
FR1 n78 PC3	1	100.00%	23.0	16.5	15.8	19.9	20.6	19.9	23.0
FR1 n78 PC3	5	100.00%	21.9	18.5	17.8	20.5	21.2	20.5	21.9
FR1 n78 PC3	6	100.00%	23.0	28.7	28.0	20.6	21.3	20.6	23.0
FR1 n78 PC3	7	100.00%	21.9	28.2	27.5	22.6	23.3	22.6	21.9
FR1 n78 PC2	6	50.00%	23.0	28.7	28.0	20.6	21.3	20.6	23.0
FR1 n78 PC2	7	50.00%	21.9	28.2	27.5	22.6	23.3	22.6	21.9

5.2 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 4.2.1.

Table 4.2.1 Sub-6GHz TAS validation test case list

No.	Test Scenario	Test case	Test configuration
1	Time-varying Tx power transmission	LTE_Time_Varying_Tx_Power_Case_1	LTE Band 48 pc3
2		LTE_Time_Varying_Tx_Power_Case_1	LTE Band 25/2
3		SA_FR1_Time_Varying_Tx_Power_Case_1	n41 pc3 (SA Mode)
4		SA_FR1_Time_Varying_Tx_Power_Case_1	n25 (SA Mode)
5	Time-varying Tx power transmission	LTE_Time_Varying_Tx_Power_Case_2	LTE Band 48 pc3
6		LTE_Time_Varying_Tx_Power_Case_2	LTE Band 25/2
7		SA_FR1_Time_Varying_Tx_Power_Case_2	n41 pc3 (SA Mode)
8		SA_FR1_Time_Varying_Tx_Power_Case_2	n25 (SA Mode)
9	Change operate states	SA_FR1_RF_SAR_Index_Change	FR1 n25 (SA Mode) Index 4 to Index 5
10	Wireless technology Handover TAS to non TAS	LTE_to_WCDMA_H.O.	LTE Band 48 pc3 to WCDMA B2
11	Antenna switch/ Time Window change case 1 60s-100s-60s	LTE_Averaging_Time_Window_Change 1	LTE Band 25/2 to LTE Band 48 pc3
12	Antenna switch/ Time Window change case 2 100s-60s-100s	LTE_Averaging_Time_Window_Change 2	LTE Band 48 pc3 to LTE B25/2
13	Drop call	Call_Disconnect_Reestablishment	LTE Band 25/2
14	SAR exposure switch	NSA_FR1_Dominant_Power_Switching	LTE Band 48 pc3 to FR1 n25(NSA Mode)
15	Re-selection in call	NR_TO_LTE_IRAT_HO	FR1 n25 (SA Mode) to LTE Band 48 pc3

Remark: UL MIMO antenna operating on different antenna groups, therefore TAS validation is not required.

Correlation matrix for Spatial TAS implementation for WWWAN antenna pairs

Antenna Group	AG0	AG1	AG2
	Ant 0, Ant 6	Ant 1, Ant 5	Ant 2, Ant 7

6. Conducted Power Test Results for Sub-6 TAS validation

6.1 Measurement set-up

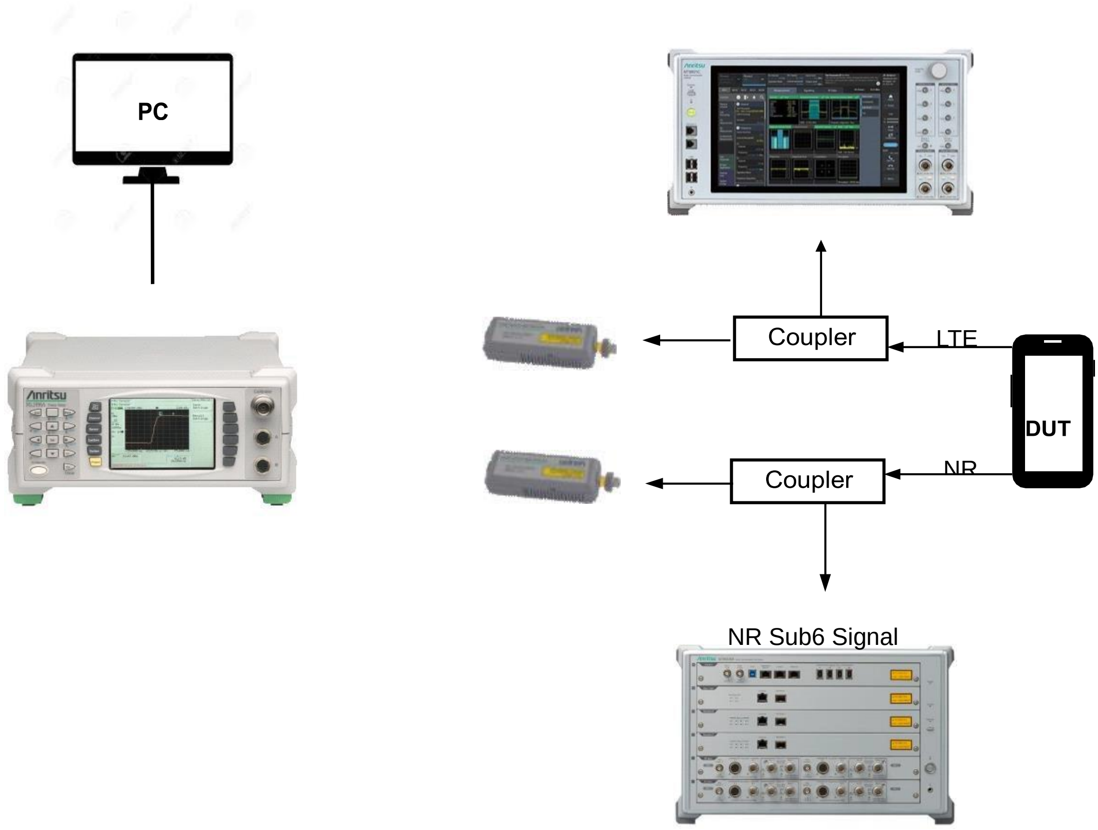

Figure 5.1-1 Test set-up for legacy and sub 6GHz

The test setup for TAS validation with sub-6GHz RATs only is shown in Figure 5.1-1.

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. Execute time-varying test scenarios. And record sub 6GHz power using sub 6GHz power meter equipment.
3. The time interval between subsequent conducted power measurements is 0.1s (typically much less than 1 second)
4. Plot the recorded results over measurement time. And evaluate the results for validation.
5. The required Power level is burst average power level controlled by call box, the power varying measurement correspond to time-average power levels after accounting for duty cycle in the case TDD modulation schemes (e.g. LTE, 5G FR1 TDD bands).

7. Test results:

7.1 Information

The following section contains the test results for the test cases in the Table 4.2.1

7.2 Measured Plimit and Pmax

The measured $Plimit$ for all the selected radio configurations are listed in following table. $Pmax$ 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.

Table6.2.1 Measured $Plimit$ and $Pmax$ of selected radio configurations

item	Test Scenario	Antenna	Power Index	Test band	Mode	BW/RB/offset	Pmax Setting (dBm)	measured Pmax (dBm)	Plimit Setting (dBm)	Measured Plimit (dBm)	Total Uncertainty (dB)
1	Time varying Tx power case 1	TX1_Ant 7	4	LTE B48 pc3	QPSK	20M/1/0	21.7	21.58	20.7	20.41	1
2		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	23.8	23.61	16.8	17.47	1.4
3		TX1_Ant 0	5	n41 pc3 (SA Mode)	QPSK	100M/1/1	22	22.04	20.9	20.43	1.5
4		TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	23.8	23.34	17.4	17.47	1.4
5	Time varying Tx power case 2	TX1_Ant 7	4	LTE B48 pc3	QPSK	20M/1/0	21.7	21.58	20.7	20.41	1
6		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	23.8	23.61	16.8	17.47	1.4
7		TX1_Ant 0	5	n41 pc3 (SA Mode)	QPSK	100M/1/1	22	22.04	20.9	20.43	1.5
8		TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	23.8	23.34	17.4	17.47	1.4
9	Change in operating state	TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	23.8	23.34	17.4	17.47	1.4
		TX1_Ant 0	5	n25 (SA Mode)	QPSK	40M/1/1	23.8	23.34	19.2	19.48	1.4
10	LTE_to_WCDMA_H.O.	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	19.4	19.61	17.6	17.52	1.1
		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	-	23.8	23.88	17.3	17.61	1.4
11	LTE_Averaging_Time_Window_Change 1	TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	23.8	23.61	16.8	17.47	1.4
		TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	19.4	19.61	17.6	17.52	1.1
12	LTE_Averaging_Time_Window_Change 2	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	19.4	19.61	17.6	17.52	1.1
		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	23.8	23.61	16.8	17.47	1.4
13	Call_Disconnect_Reestablishment	TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	23.8	23.61	16.8	17.47	1.4
14	NSA_FR1_Dominant_Power_Switching	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	19.4	19.61	17.6	17.52	1.1
		TX1_Ant 0	4	n25 (NSA Mode)	QPSK	40M/1/1	23.8	23.34	17.4	17.47	1.4
15	NR_TO_LTE_IRAT_HO	TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	23.8	23.34	17.4	17.47	1.4
		TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	19.4	19.61	17.6	17.52	1.1

1. Note that the EUT has multiple power indexes to manage the output power for different conditions corresponding to RF exposure conditions in above table, detailed power index trigger conditions are illustrated in the operational description, and 1g and 10g SAR design target are shown in the part 0 report.

Table6.2.2 Sub-6 summary test results

item	FCC	Antenna	Power Index	Test band	Mode	BW/RB/offset	1g SAR design target (W/kg)	1g Time average SAR (W/kg)	deviation (dB)	Total Uncertainty (dB)
1	Time varying Tx power case 1	TX1_Ant 7	4	LTE B48 pc3	QPSK	20M/1/0	0.676	0.612	-0.43	1
2		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	0.617	0.686	0.46	1.4
3		TX1_Ant 0	5	n41 pc3 (SA Mode)	QPSK	100M/1/1	0.708	0.546	-1.13	1.5
4		TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	0.617	0.601	-0.11	1.4
5	Time varying Tx power case 2	TX1_Ant 7	4	LTE B48 pc3	QPSK	20M/1/0	0.676	0.584	-0.64	1
6		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	0.617	0.645	0.19	1.4
7		TX1_Ant 0	5	n41 pc3 (SA Mode)	QPSK	100M/1/1	0.708	0.541	-1.17	1.5
8		TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	0.617	0.562	-0.41	1.4
9	Change in operating state	TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	0.617	0.727	0.71	1.4
		TX1_Ant 0	5	n25 (SA Mode)	QPSK	40M/1/1	0.724	0.727	0.02	1.4
10	LTE_to_WCDMA_H.O.	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	0.661	0.701	0.26	1.1
		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	-	0.617	0.701	0.55	1.4
11	LTE_Averaging_Time_Window_Change 1	TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	0.617	0.814	1.20	1.4
		TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	0.661	0.814	0.90	1.1
12	LTE_Averaging_Time_Window_Change 2	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	0.661	0.79	0.77	1.1
		TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	0.617	0.79	1.07	1.4
13	Call_Disconnect_Reestablishment	TX1_Ant 0	4	LTE B25/2	QPSK	20M/1/0	0.617	0.683	0.44	1.4
14	NSA_FR1_Dominant_Power_Switching	TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	0.661	0.573	-0.62	1.1
		TX1_Ant 0	4	n25 (NSA Mode)	QPSK	40M/1/1	0.617	0.573	-0.32	1.4
15	NR_TO_LTE_IRAT_HO	TX1_Ant 0	4	n25 (SA Mode)	QPSK	40M/1/1	0.617	0.774	0.98	1.4
		TX0_Ant 6	4	LTE B48 pc3	QPSK	20M/1/0	0.661	0.774	0.69	1.1

7.3 Time-varying Tx power measurement results

Following the test procedure in Section 3.3, 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 for TC #1-4 inTable 6.2.1. by generating the test sequence A or B given in Appendix.

6.3.1 TC01: LTE Band 48_Time_Varying_Tx_Power_Case_1

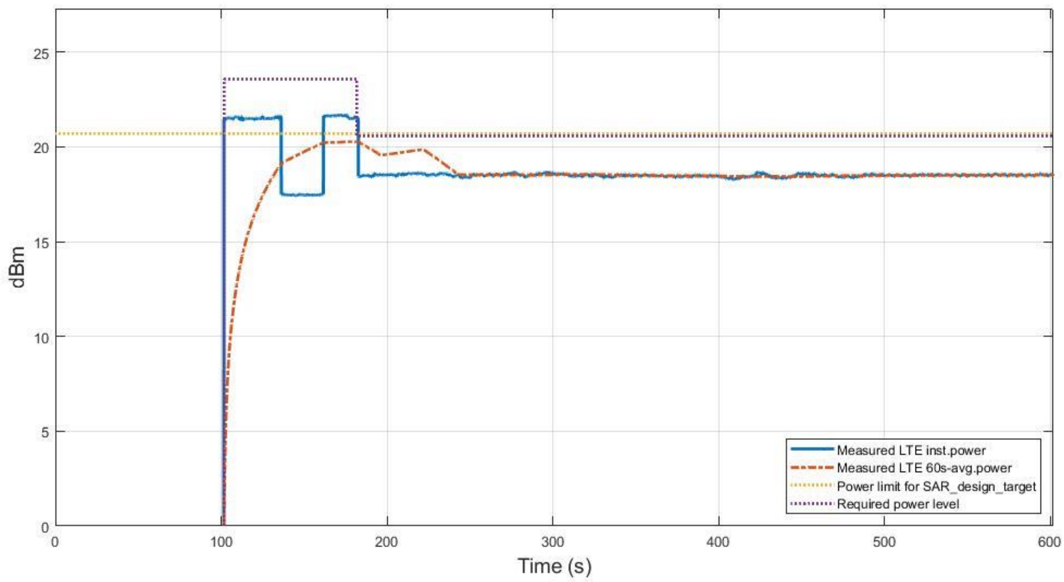

Figure 6.3-1 Time average conducted power

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.

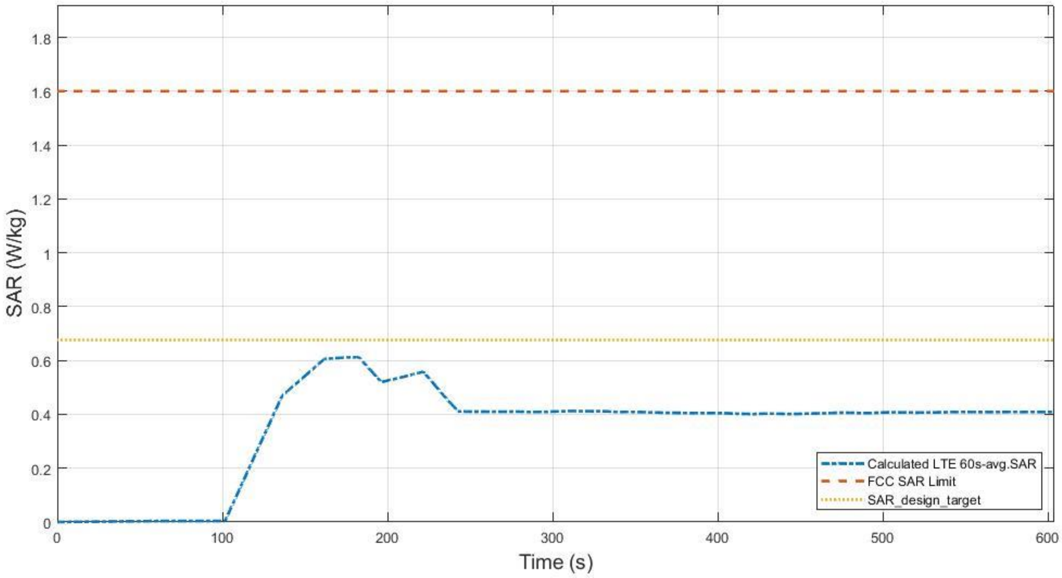

Figure 6.3-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.612 W/kg
Device uncertainty	1 dB

6.3.2 TC02: LTE Band 25/2_Time_Varying_Tx_Power_Case_1

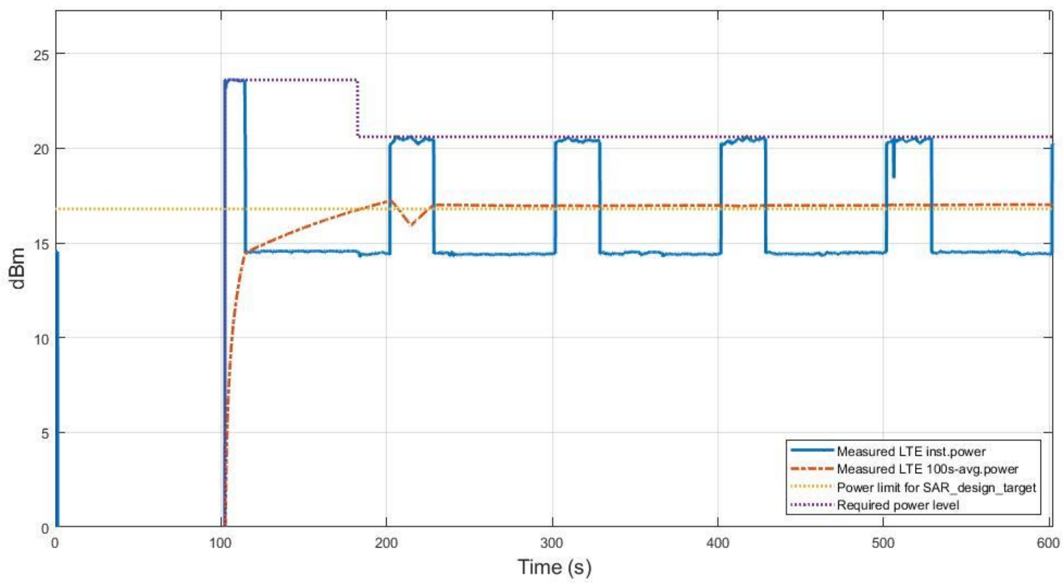

Figure 6.3-3 Time-average conducted power

Figure 6.3-3 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 6.3-3, 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 6.3-4 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

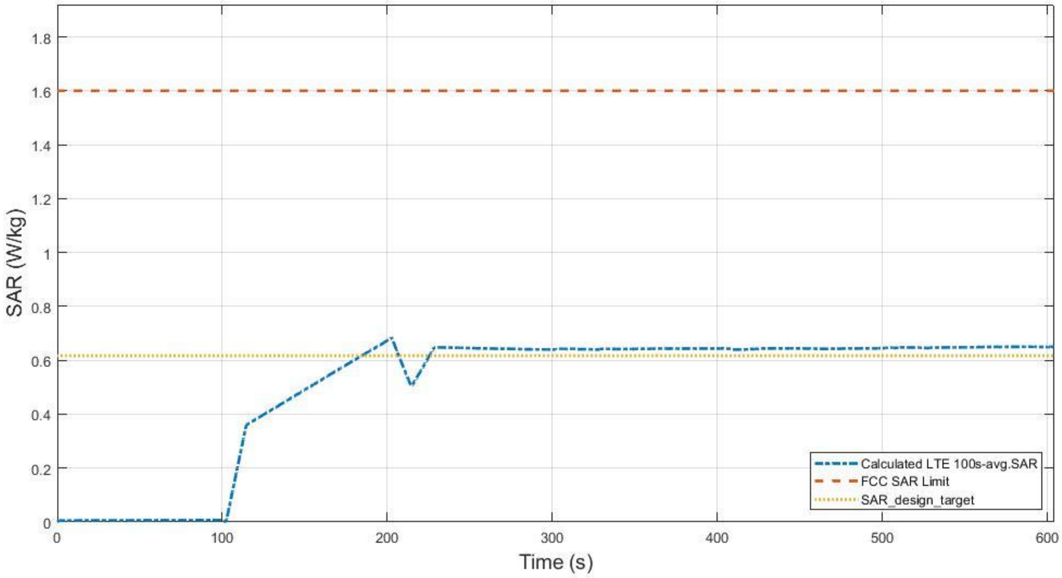

Figure 6.3-4 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.686 W/kg
Device uncertainty	1.4 dB

6.3.3 TC03: FR1 n41 SA mode_Time_Varying_Tx_Power_Case_1

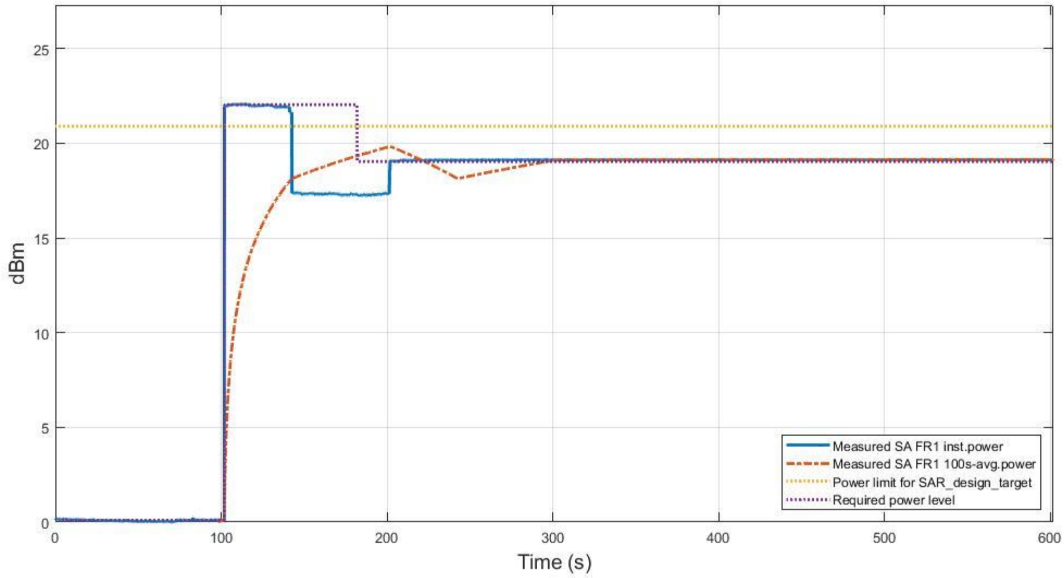

Figure 6.3-5 Time-average conducted power

Figure 6.3-5 shows the instantaneous and time-averaged Tx power with test sequence B. 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.

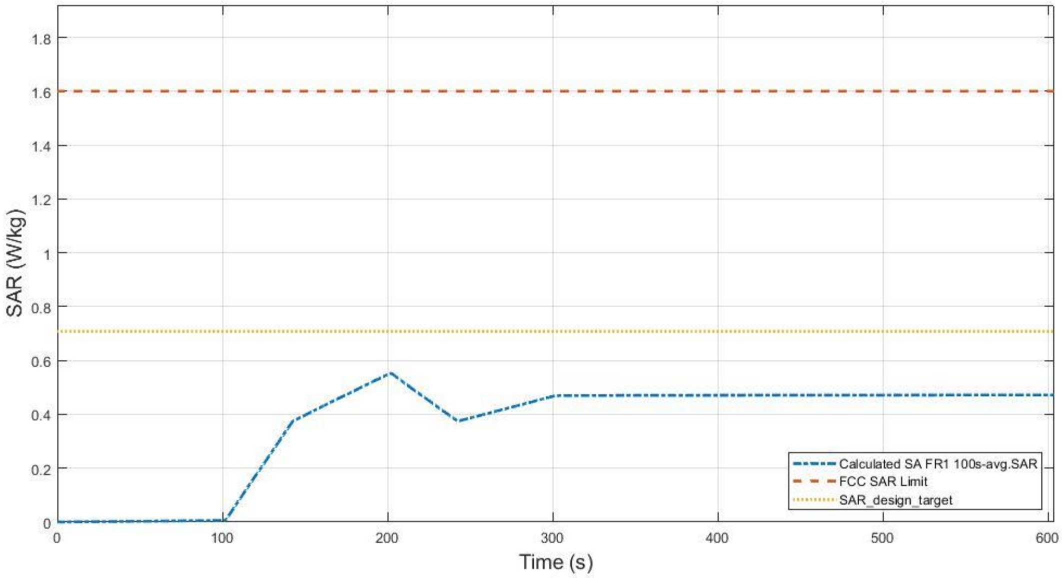

Figure 6.3-4 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s-time average 1gSAR (blue curve)	0.546 W/kg
Device uncertainty	1.5 dB

6.3.4 TC04: FR1 n25 SA mode_Time_Varying_Tx_Power_Case_1

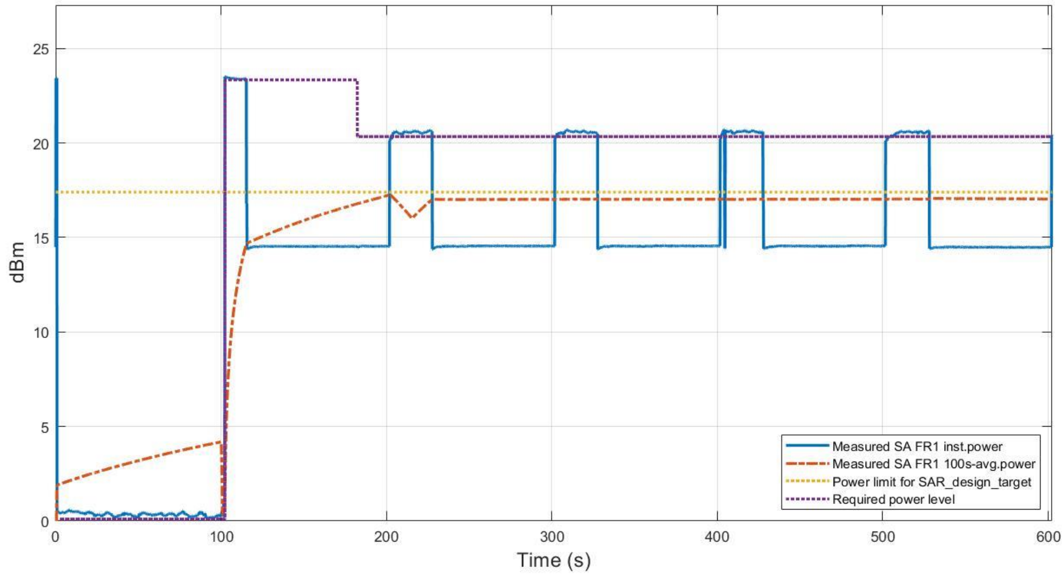

Figure 6.3-7 Conducted Tx power

Figure 6.3-7 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 6.3-8 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

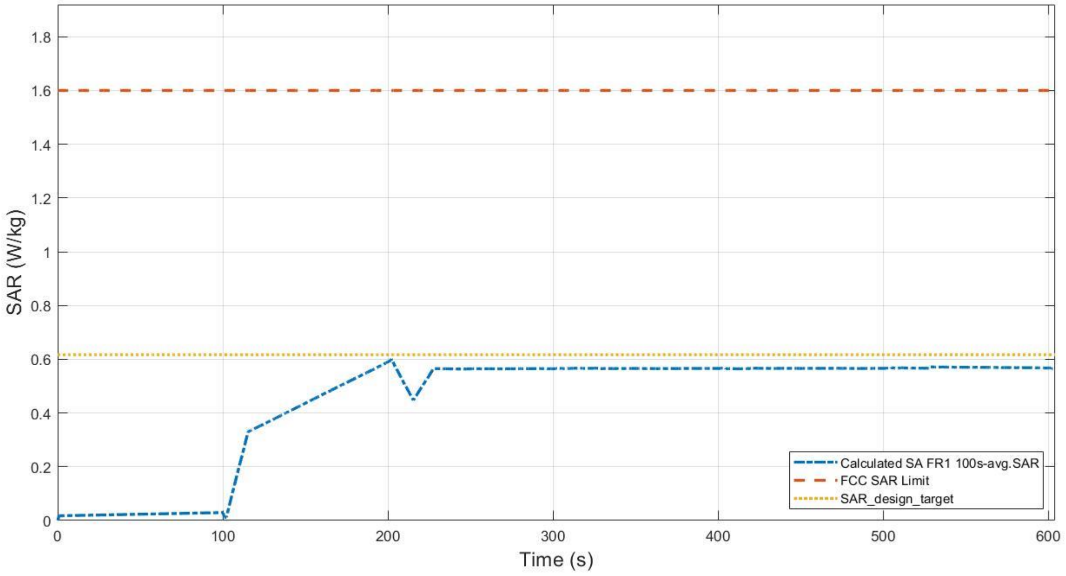

Figure 6.3-8 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s time average 1gSAR (blue curve)	0.601 W/kg
Device uncertainty	1.4 dB

6.3.5 TC05: LTE band 48_Time_Varying_Tx_Power_Case_2

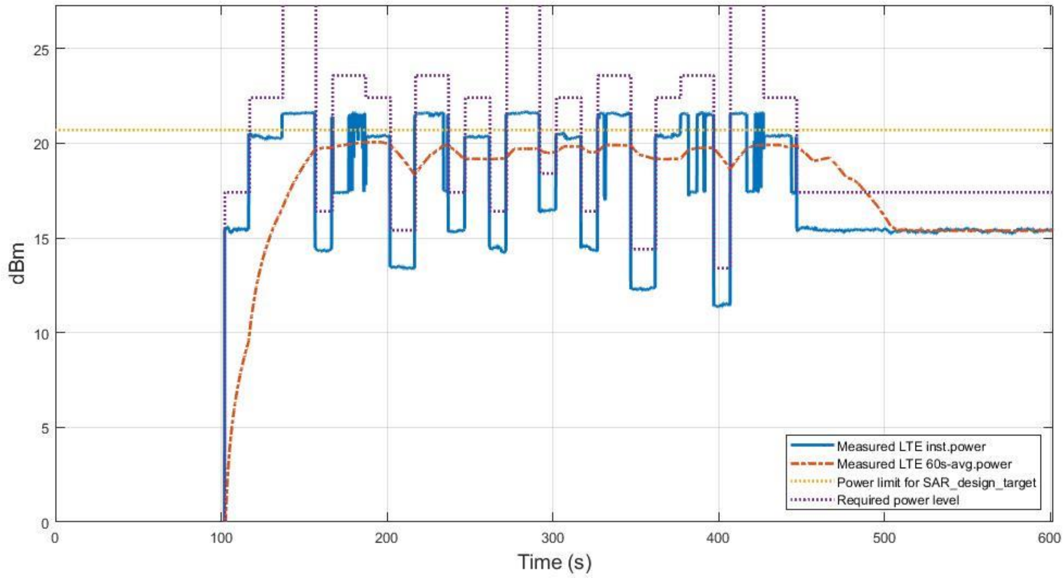

Figure 6.3-9 Conducted Tx power

Figure 6.3-9 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 6.3-10 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

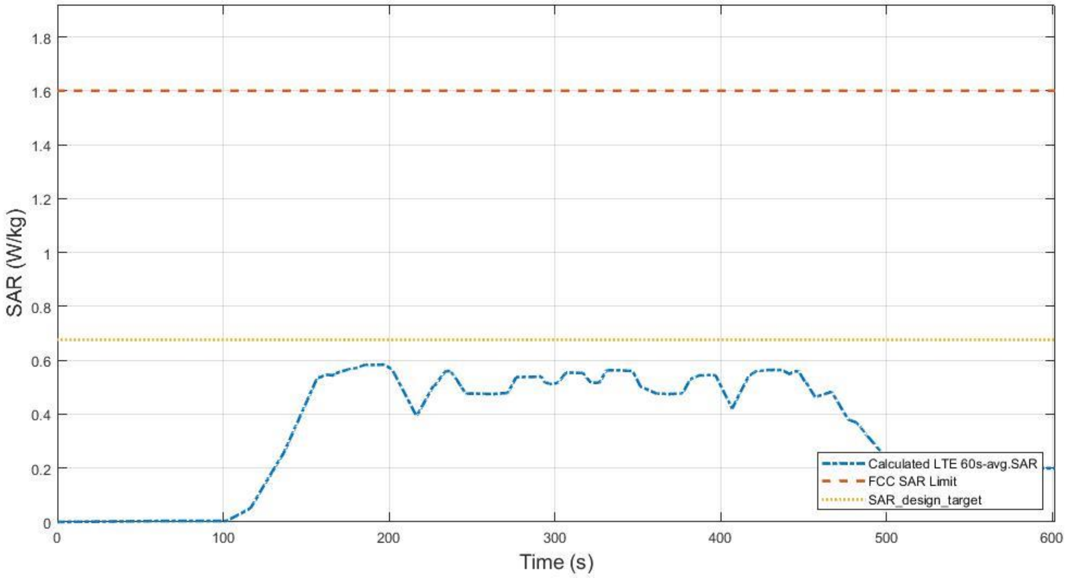

Figure 6.3-10 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s time average 1gSAR (blue curve)	0.584 W/kg
Device uncertainty	1 dB

6.3.6 TC06: LTE Band 25/2_Time_Varying_Tx_Power_Case_2

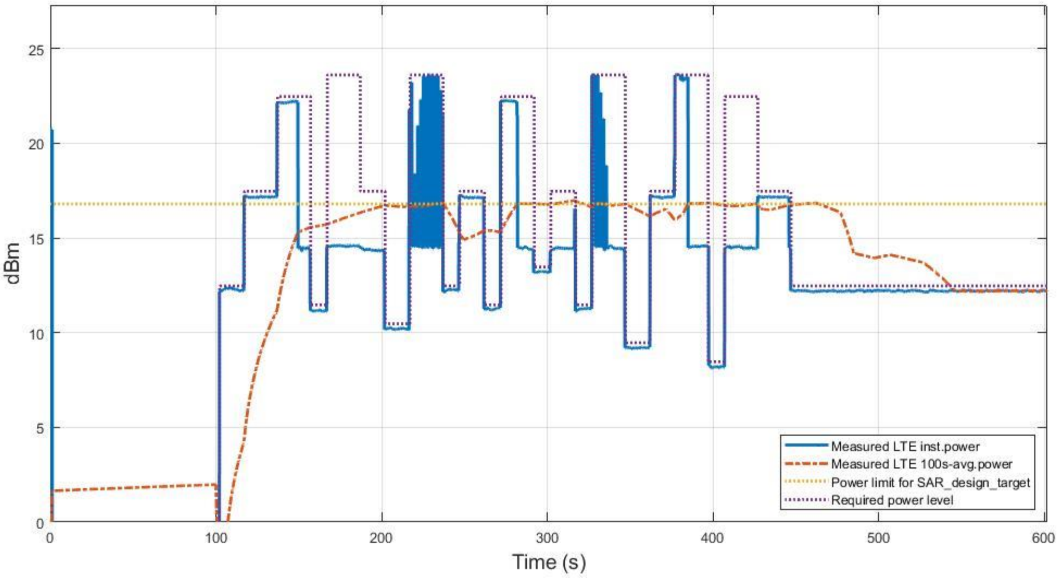

Figure 6.3-11 Conducted Tx power

Figure 6.3-11 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 6.3-12 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

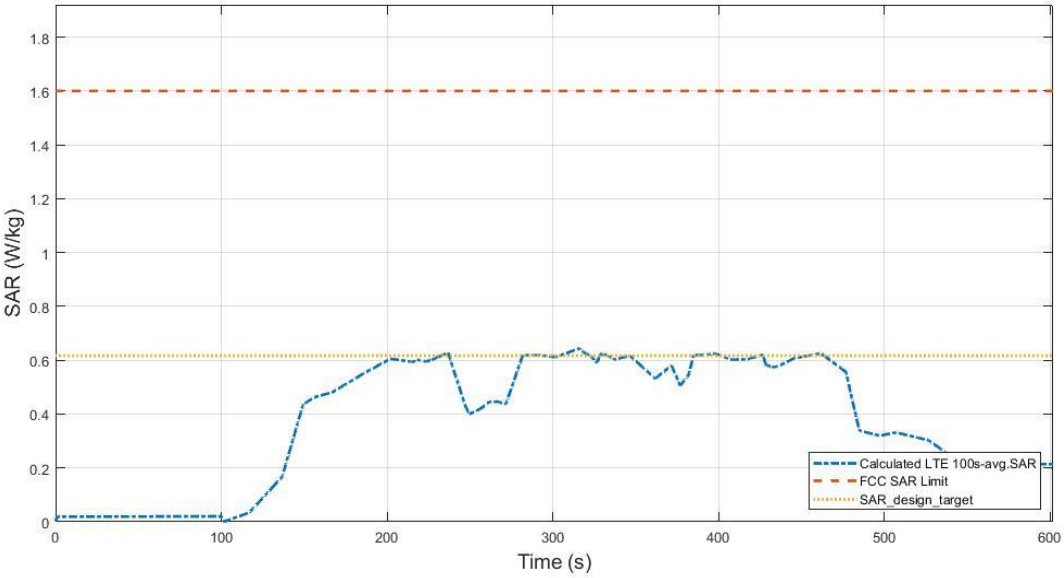

Figure 6.3-12 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s time average 1gSAR (blue curve)	0.645 W/kg
Device uncertainty	1.4 dB

6.3.7 TC07: FR1 n41 SA mode _Time_Varying_Tx_Power_Case_2

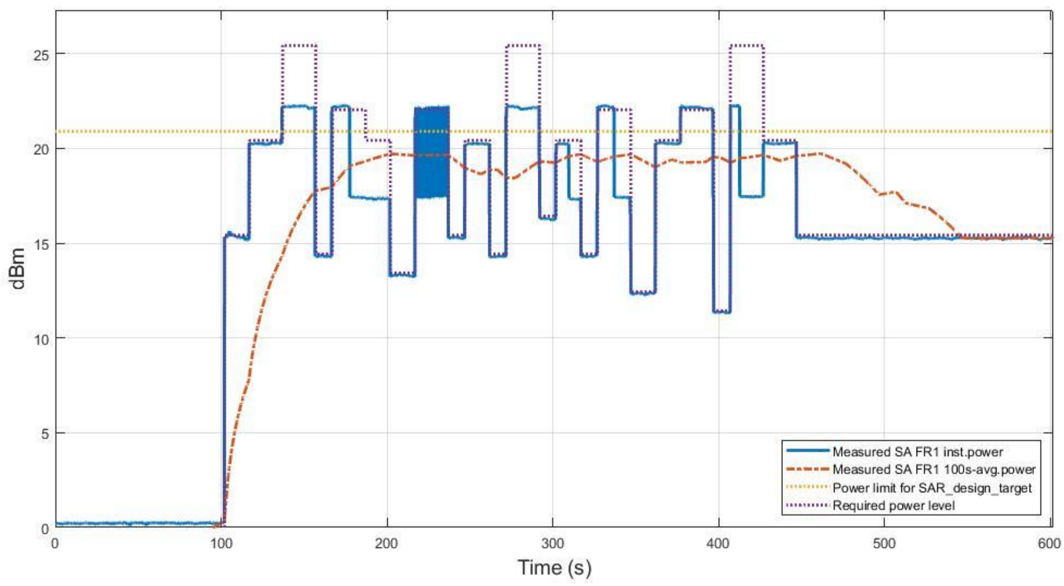

Figure 6.3-13 Conducted Tx power

Figure 6.3-13 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 6.3-14 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

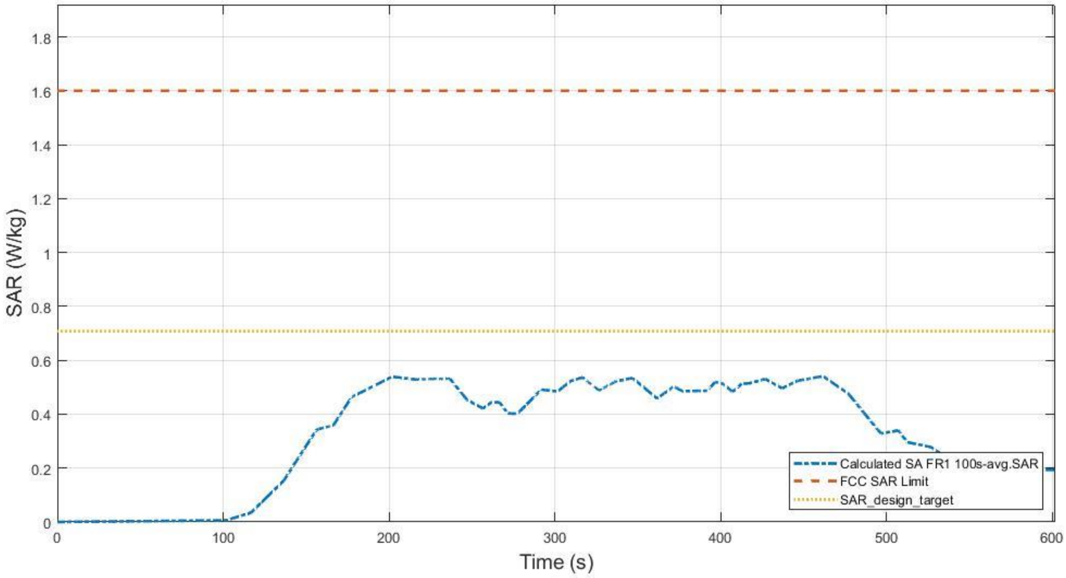

Figure 6.3-14 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s time average 1gSAR (blue curve)	0.541 W/kg
Device uncertainty	1.5 dB

6.3.8 TC08: FR1 n25 SA mode_Time_Varying_Tx_Power_Case_2

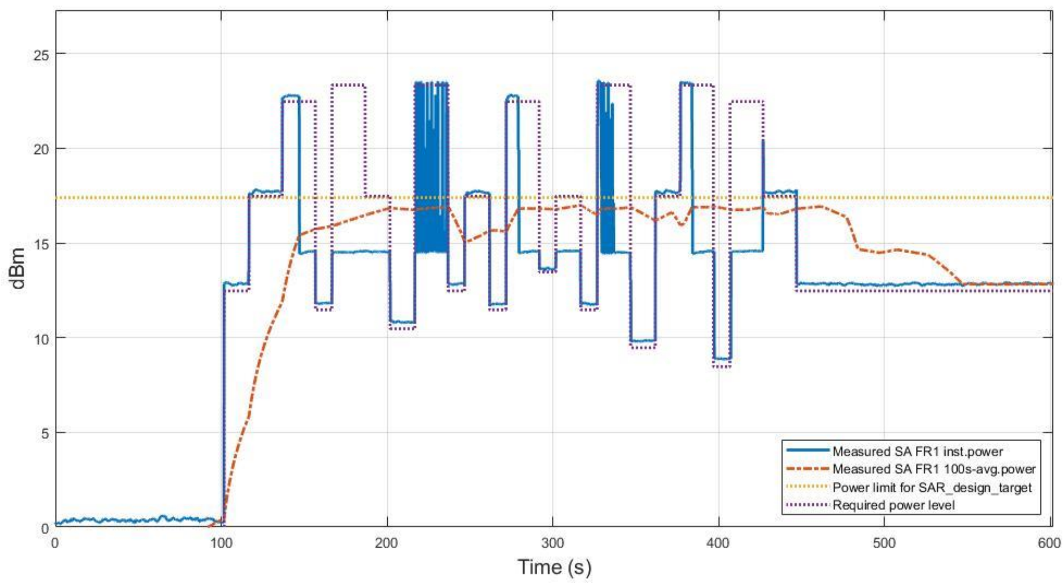

Figure 6.3-15 Conducted Tx power

Figure 6.3-15 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 6.3-16 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

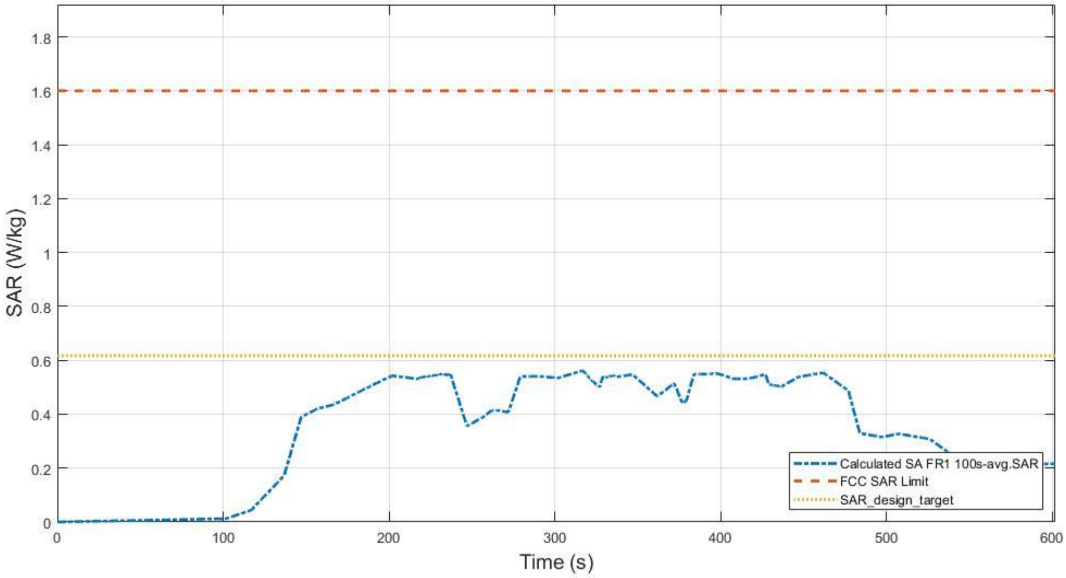

Figure 6.3-16 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 100s time average 1gSAR (blue curve)	0.562 W/kg
Device uncertainty	1.4 dB

7.4 Change operate states

The test results in this section are obtained following the procedure in Section 3.3.2. The test cases correspond to TC#9 in Table 6.2.1.

6.4.1 TC9: SA_FR1 n25_RF_SAR_Index_Change

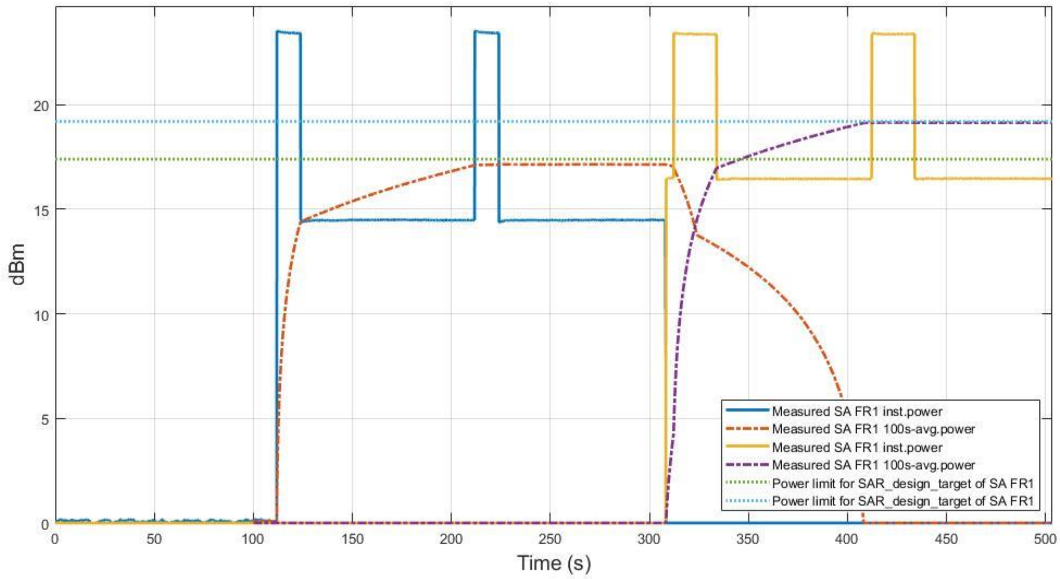

Figure 6.4-1 Conducted Tx power for SAR states change

Figure 6.4-1 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 ~330s, the RFI value is changed from power index 4 to power index 5, resulting in reduction of target time-averaged power of SA FR1 Band n25. It can be seen that Plimit value of power index 5 is lower than that of power index 4, so in power index 5 region, more Tx power is limited compared to power index 4 region. Figure 6.4-2 shows the time-averaged 1gSAR value for each of power index 5 and power index 4 value, as well as the total SAR value.

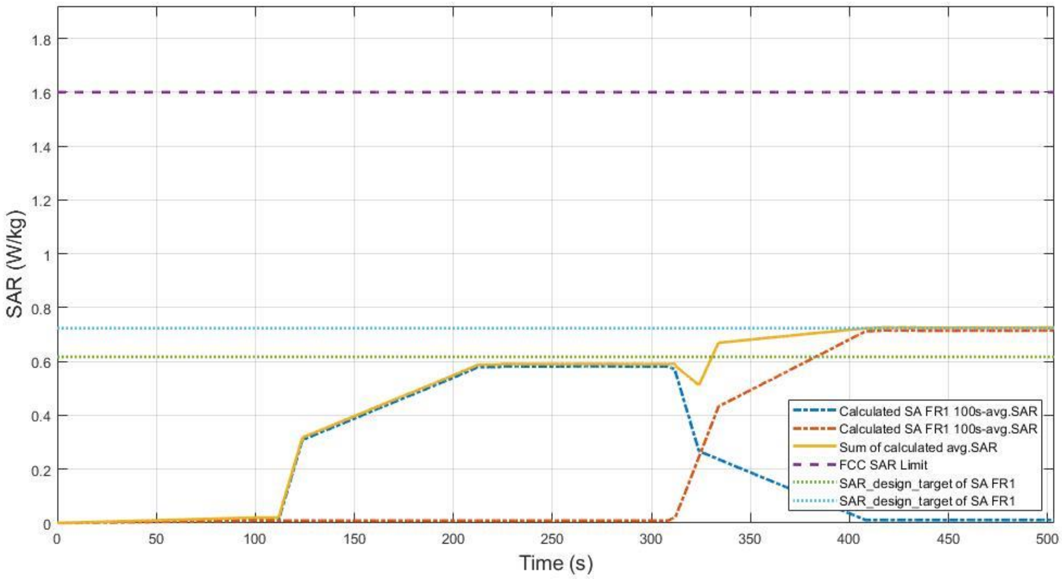

Figure 6.4-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.727 W/kg
Device uncertainty	1.4 dB

7.5 LTE Handover WCDMA results

The test results in this section are obtained following the procedure in Section 3.3.2. The test cases correspond to TC#10 in Table 6.2.1.

6.5.1 TC10: LTE Band 48 TAS to WCDMA Band 2 nonTAS H.O.

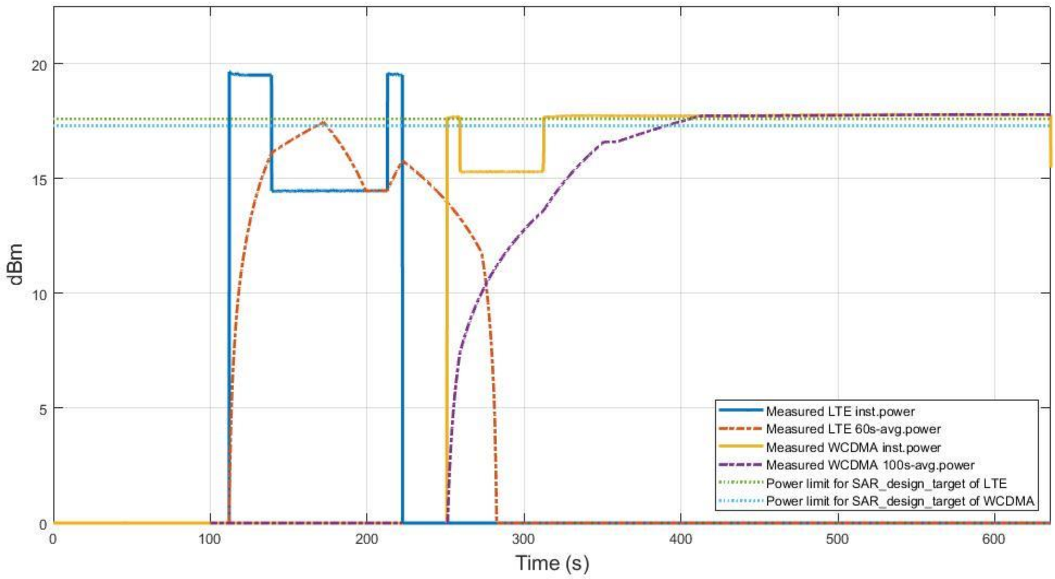

Figure 6.5-1 Conducted Tx power for SAR TAS to nonTAS H.O

Figure 6.5-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 48 and WCDMA Band 2 for the duration of the test. Around time stamp of ~220s, a handover from LTE Band 48 to WCDMA Band 2 was executed, resulting in reduction of time-averaged power of LTE Band 48 and simultaneous increase in time- averaged power of WCDMA 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 6.5-2 shows the time-averaged 1gSAR value for each of LTE Band 48 and WCDMA Band 2 as well as the total SAR value.

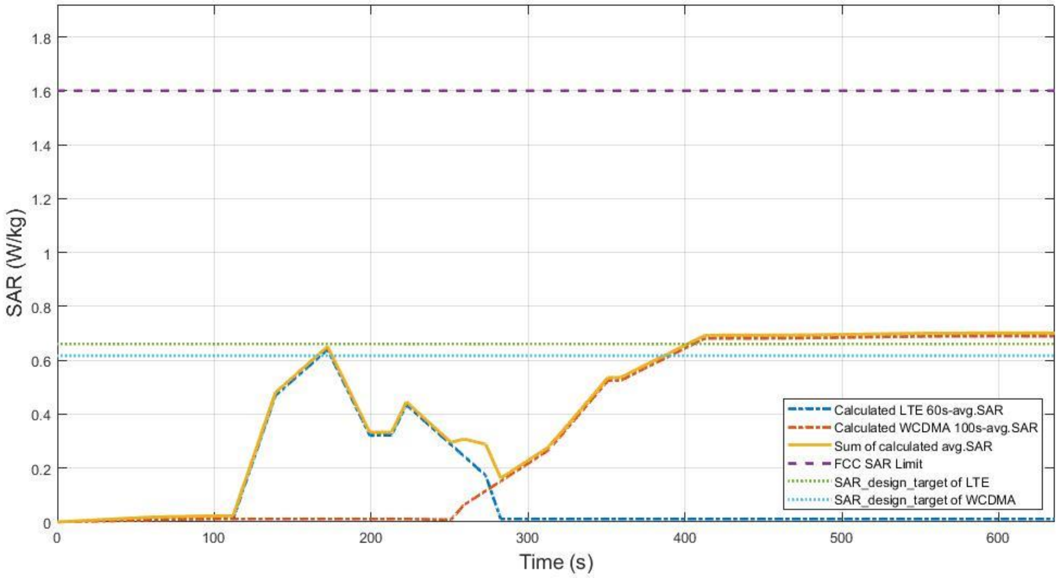

Figure 6.5-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.701 W/kg
Device uncertainty	1.4 dB

7.6 Change in band/time-window test results

The test results in this section are obtained following the procedure in Section 3.3.2. The test cases correspond to TC#11-12 in Table 6.2.1.

6.6.1 TC11: LTE_Averaging_Time_Window_Change_1 (LTE Band 25/2 ant 0 to LTE Band 48 ant 6)

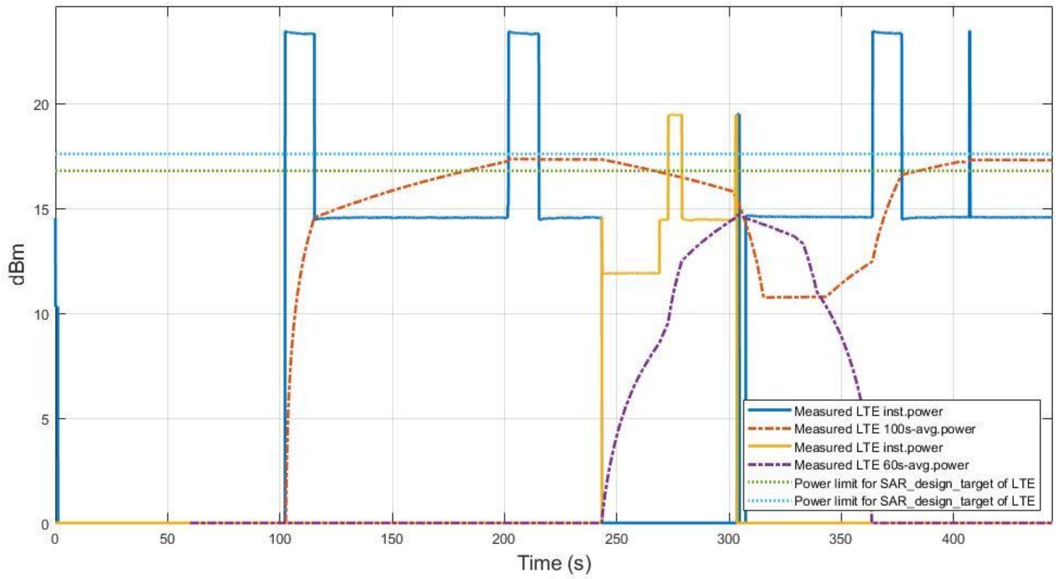

Figure 6.6-1 Conducted Tx power for SAR window change

Figure 7.6-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 25/2 and Band 48 for the duration of the test. Around time stamp of ~240s, a handover from Band 25/2 to Band 48 was executed, resulting in reduction of time-averaged power of Band 25/2 and simultaneous increase in time-averaged power of Band 48. Around time stamp of ~300s, handover back to Band 25/2 was executed, resulting in reduction of time-averaged power of Band 48 and increase of time-averaged power of Band 25/2. It can be seen that transition time of time-averaged values for Band 25/2 is longer than Band 48, which is the consequence of 100s time- averaging for Band 25/2 versus shorter 60s averaging for Band 48. Figure 7.6-2 shows the time-averaged 1gSAR value for each of Band 25/2 and Band 48, as well as the total SAR value.

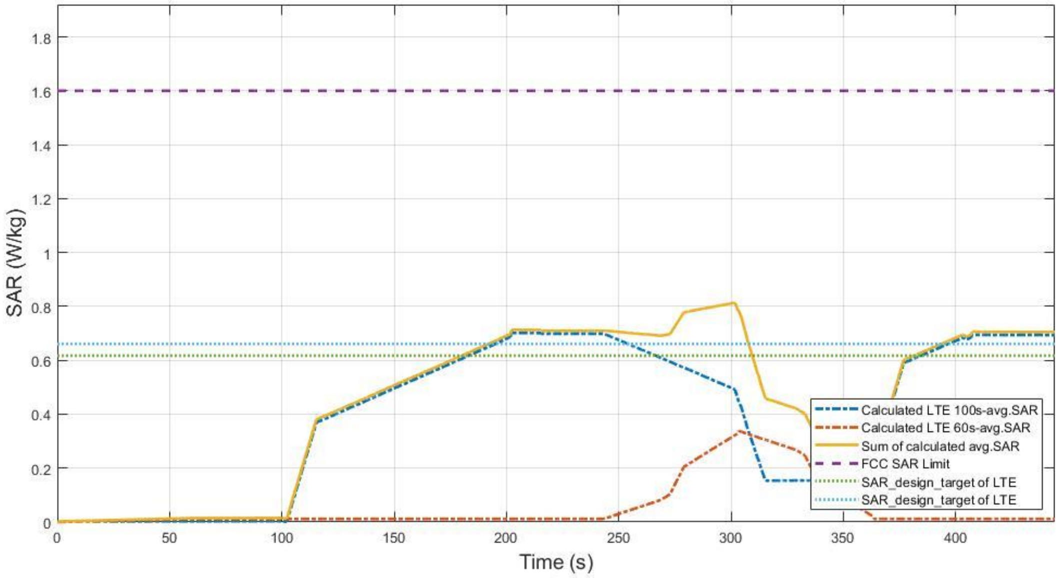

Figure 6.6-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.814 W/kg
Device uncertainty	1.4 dB

6.6.2 TC12: LTE_Averaging_Time_Window_Change_2 (LTE Band 48 ant 6 to LTE Band 25/2 ant 0)

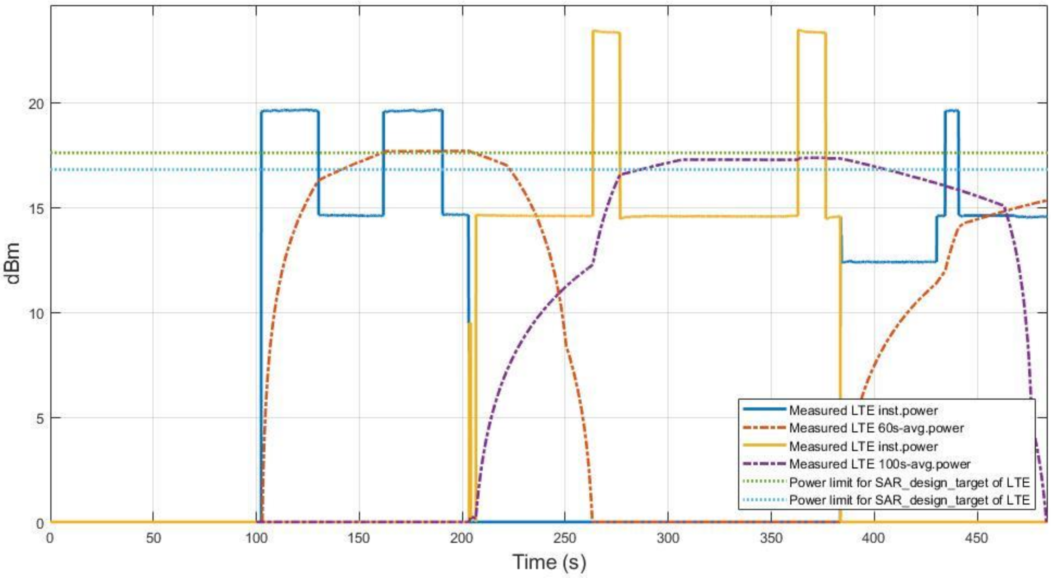

Figure 6.6-3 Conducted TxPower in SAR Window Change test

Figure 7.6-3 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 25/2 and Band 48 for the duration of the test. Around time stamp of ~200s, a handover from Band 48 to Band 25/2 was executed, resulting in reduction of time-averaged power of Band 48 and simultaneous increase in time-averaged power of Band 25/2. Around time stamp of ~380s, handover back to Band 48 was executed, resulting in reduction of time-averaged power of Band 25/2 and increase of time-averaged power of Band 48. It can be seen that transition time of time-averaged values for Band 25/2 is longer than Band 48, which is the consequence of 100s time- averaging for Band 25/2 versus shorter 60s averaging for Band 48. Figure 7.6-4 shows the time-averaged 1gSAR value for each of Band 25/2 and Band 48, as well as the total SAR value.

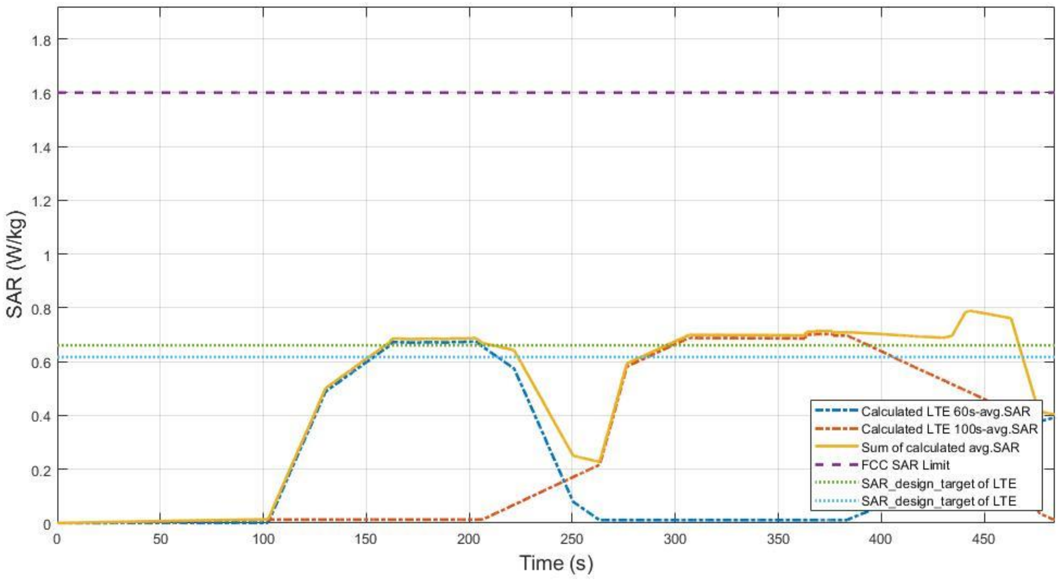

Figure 6.6-4 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.790 W/kg
Device uncertainty	1.4 dB

7.7 Change in call test results

The test results in this section are obtained following the procedure in Section 3.3.1. The test case corresponds to TC#13 in Table 6.2.1.

6.7.1 TC13: LTE Band 25/2_Call_Disconnect_Reestablishment

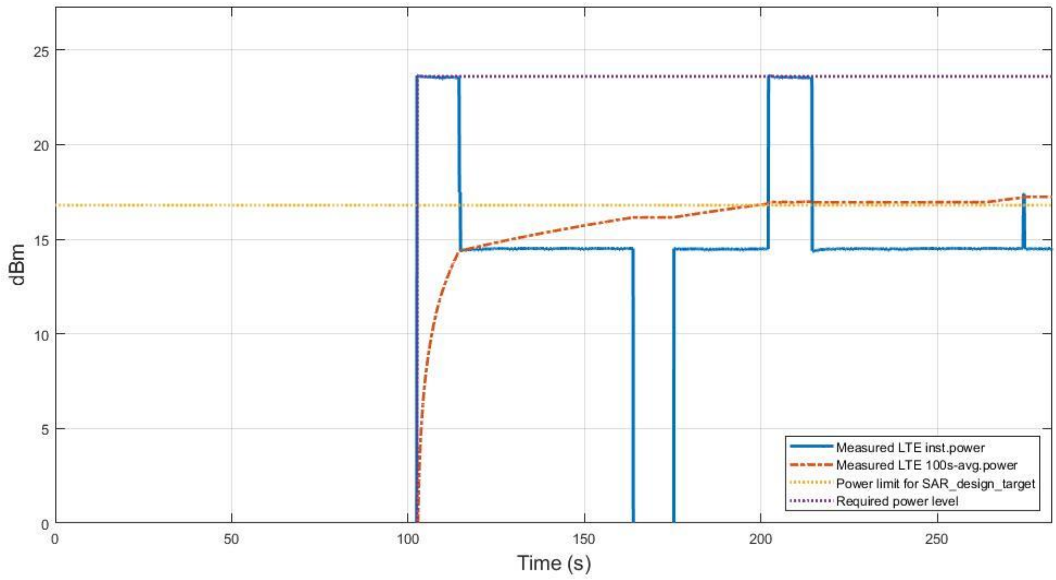

Figure 6.7-1 Conducted Tx power in Call_Disconnect_Reestablishment

Figure 6.7-1 shows the instantaneous and time-averaged Tx power for this test. The call disconnected around 170s 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 6.7-2 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.

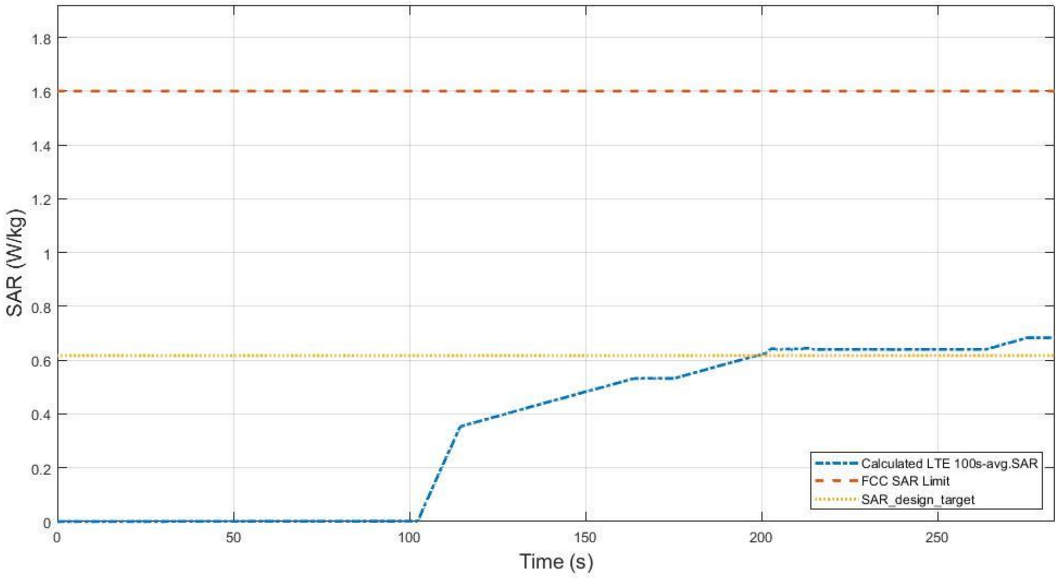

Figure 6.7-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max 60s time average 1gSAR (blue curve)	0.683 W/kg
Device uncertainty	1.4 dB

7.8 Switch in SAR exposure test results

The test results in this section are obtained following the procedure in Section 3.3.2. The test cases correspond to TC#14 in Table 6.2.1.

6.8.1 TC14: NSA_FR1_Dominant_Power_Switching (ENDC LTE Band 48_FR1 n25)

In this LTE Band 48+FR1 n25 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.

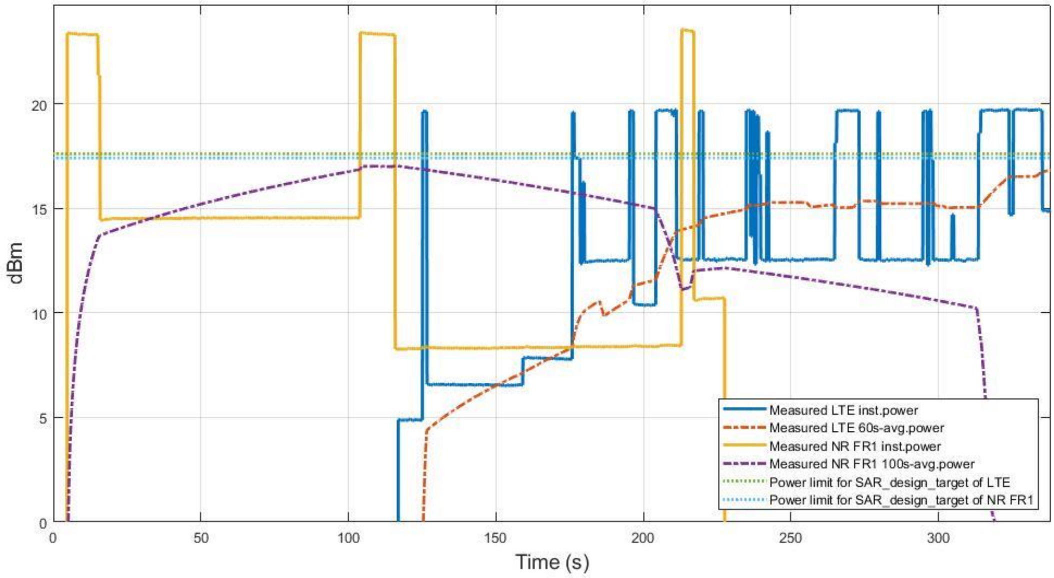

Figure 6.8-1 Time average SAR of LTE B48 and FR1 n25 in EN-DC case

Figure 6.8-1 shows the instantaneous and time-averaged Tx power for both LTE band B48 and NR FR1 band n25 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 6.8-2 shows the computed time-averaged SAR value for LTE and FR1 as well as the sum. It was confirmed that algorithm operated under the SAR design target + total uncertainty, 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.

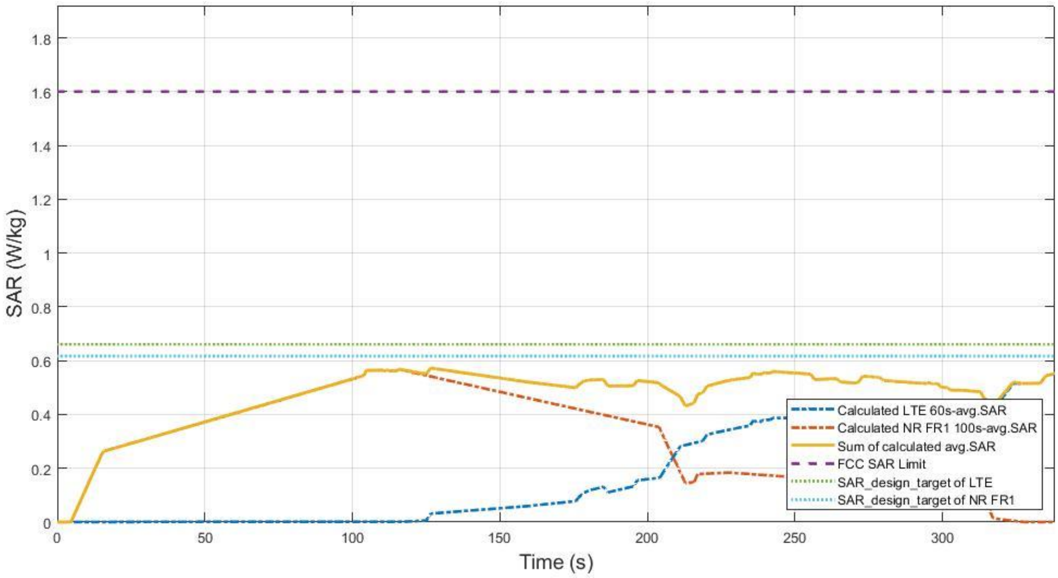

Figure 6.8-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.573 W/kg
Device uncertainty	1.4 dB

7.9 Re-selection in call test results

The test results in this section are obtained following the procedure in Section 3.3.2. The test cases correspond to TC#15 in Table 6.2.1.

6.9.1 TC15: FR1 n25 to LTE Band 48 IRAT Re-selection

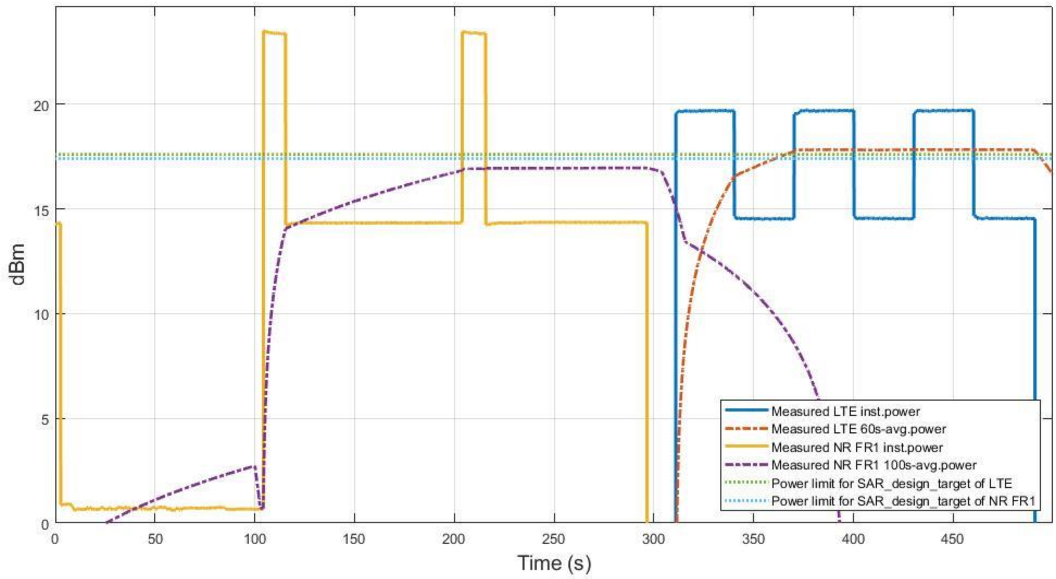

Figure 6.9-1 Conducted Tx power for SAR IRAT re-selection

Figure 6.9-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 48 and NR FR1 Band n25 for the duration of the test. Around time stamp of ~310s, a RAT re-selection from LTE Band 48 to NR FR1 Band n25 was executed, resulting in reduction of time-averaged power of Band 48 and simultaneous increase in time-averaged power of Band n25. Figure 6.9-2 shows the time-averaged 1gSAR value for each of LTE Band 48 and NR FR1 Band n25, as well as the total SAR value.

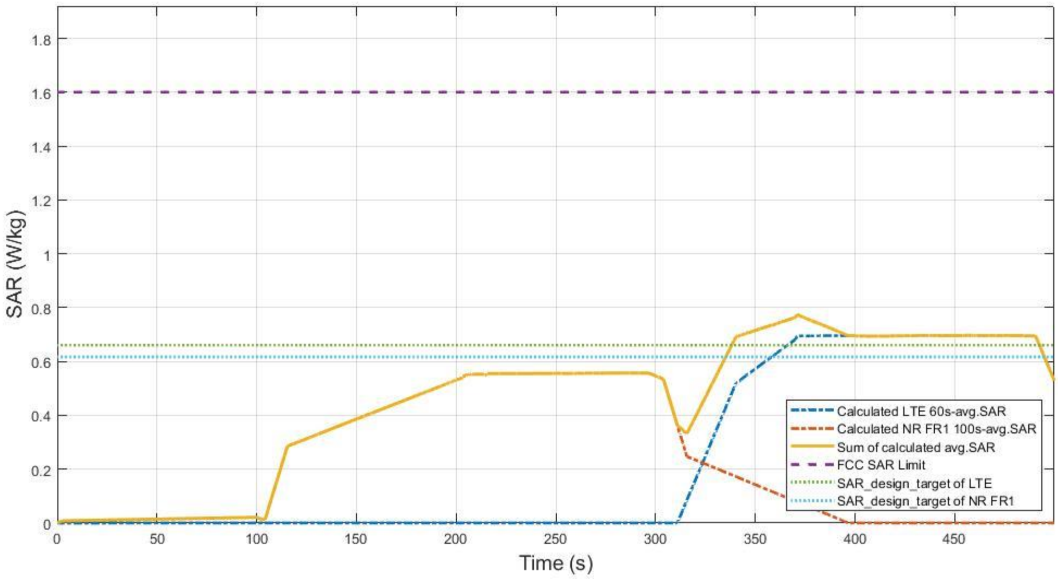

Figure 6.9-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.774 W/kg
Device uncertainty	1.4 dB

8. Conclusions

Samsung S.LSI TAS feature employed in this product has been validated through the conducted power measurement as demonstrated in this report, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0 for all the transmission scenarios. Therefore, the EUT complies with FCC RF exposure requirement.

9. Annex

9.1 Test sequence is generated based on below parameters of the DUT:

1. Measured maximum power (Pmax)
2. Measured Tx power (Plimit) to satisfy SARCompliance
3. Setup time to make SARRemaining be full
4. Do test according to test sequence

9.2 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.

9.3 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 8.3.1.

Table 8.3.1 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
10	Plimit – 9
20	Plimit + 5
20	Plimit
15	Plimit – 5

10. Test Equipment List

Manufacturer	Name of Equipment	Type/Model	Serial Number	Calibration	
				Last Cal.	Due Date
Anritsu	Radio Communication Analyzer	MT8821C	6201381768	Mar. 07, 2023	Mar. 06, 2024
Anritsu	5G Wireless Test Platform	MT8000A	6262208374	May. 08, 2023	May. 07, 2024
Testo	Hygro meter	608-H1	45196600	Nov. 02, 2022	Nov. 01, 2023
Anritsu	Signal Generator	MG3710A	6201502524	Oct. 12, 2022	Oct. 11, 2023
Anritsu	Power Meter	ML2496A	2119003	Jun. 22, 2022	Jun. 21, 2023
Anritsu	Power Sensor	MA2411B	1911333	Jun. 22, 2022	Jun. 21, 2023
Anritsu	Power Sensor	MA2411B	1911334	Jun. 22, 2022	Jun. 21, 2023
Warison	Directional Coupler	WCOU-10-50S-10	WR889BMC4B1	Note 1	
ATM	500M-18GHz Dual Directional Coupler	C122H-10	P610410z-02	Note 1	
Woken	Attenuator 1	WK0602-XX	N/A	Note 1	
Woken	Attenuator 2	PE7005-10	N/A	Note 1	
Woken	Attenuator 3	PE7005- 3	N/A	Note 1	

Note (1): Prior to conducted power measurement, the path loss from the EUT to the power meter, which includes the RF cable, attenuator and directional coupler, was measured and determined.