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

FCC ID	:	**A4RGZC4K**
Equipment	:	**Phone**
Model Name	:	**GZC4K, GQ57S**
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. 28, 2024 and testing was started from Apr. 15, 2024 and completed on Apr. 19, 2024. 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 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
FA3N2326-01B	01	Initial issue of report	Apr. 23, 2024

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 $LSAR$.

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

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 Plimit 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 3-6 GHz, however Samsung S.LSI TAS will use 60sec only for all bands regardless of frequency, because 60s averaging provides more conservative and strict SAR management, TAS feature met the regulatory conditions with 100s averaging will meet the same regulatory condition with more margin if 60s averaging is applied. Therefore 100s to 60s TAS validation is not required.

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.

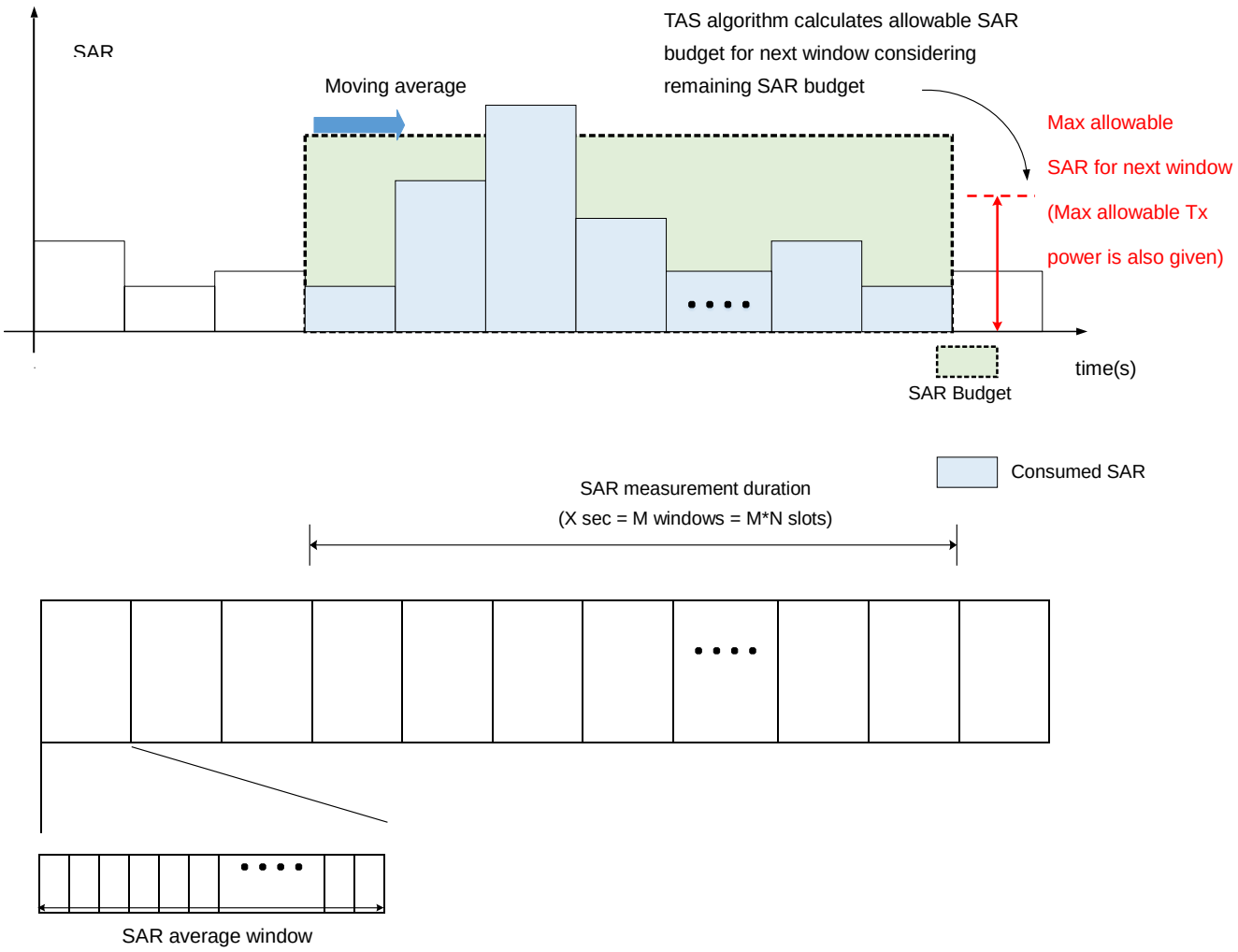
3.3.1 Time-varying Tx power transmission scenario

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 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



Average SAR value in a slot can be calculated from average Tx power in the slot
(Assume that SAR vs Tx power relation is obtained from real measurement)

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.

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

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

where $Plimit$,1,FR1 would correspond to measured power at which first technology/band meets measured SAR level of SAR_design_target1 as described in Part 0 and Part 1 wit time-averaging duration of T1,SAR .Similarly, $Plimit$,FR2 would be the measured EIRP at which FR2 technology meets measured PD level of PD $\_design\_target$ as described in Part 0. Similarly, the quantities $Plimit$,2,FR1, SAR_design_target2, T2,SAR are defined for the second technology/band.

3.3.4 Change in Power Index

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of RSI resulting from different SAR index state detected by host platform software. It involves changing the Plimit value during the test for the same technology to emulate power Index change.

3.3.5 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.

3.3.6 Test procedure for handover between two TAS RATs

1. Establish radio connection of DUT with call box e.g. using LTE in Band B2
2. Configure call box to set DUT Tx power to a low value of 0dBm for 110s.
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 120s.
4. Change RAT from LTE to WCDMA in Band B2 while disabling TAS and configure call box to send “ALL UP” power control commands in WCDMA
5. Continue call in WCDMA at maximum power for 400s

3.3.7 Test configuration for Uplink CA

The criteria for selecting this test case is to demonstrate the compliance of the TAS algorithm when an LTE or FR1 transmission is done over multiple CC. This test shows that the TAS algorithm compliance is independent on the Transmission scenarios (single CC or CA), select any one technology that the EUT supports to demonstrate compliance.

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. The TAS algorithm from the latest Samsung submission document revision v2.7 is implemented.

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 $\Gamma_{ij} = \frac{(SAR_{1,max}+SAR_{j,max})^{1.5}}{D}$, 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 NTN 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/NTN Plimit power levels in the table correspond to the burst average power levels which don't account for TX duty cycle.
3. UMTS, LTE and 5GNR TDD: Plimit power levels in the table correspond to the time-averaged power levels which accounts for TX duty cycle.
4. 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)

Plimit (dBm)														
Technology	Mode	Antenna	Index 1	Index 2	Index 3	Index 2 Head SAR Design_Target (W/kg)	Index 3 Head SAR Design_Target (W/kg)	Index 5	Index 6	Index 5 Body SAR Design_Target (W/kg)	Index 6 Body SAR Design_Target (W/kg)	Index 4	Index 4 Hotspot SAR Design_Target (W/kg)	Uncertainty (dB)
GSM850	GSM 1TX	ANT1	32.3	26.5	25.8	0.76	0.64	34.2	33.5	0.76	0.64	33.5	0.64	1.2
	GPRS 1TX		32.3	26.5	25.8	0.76	0.64	34.2	33.5	0.76	0.64	33.5	0.64	1.2
	GPRS 2TX		31.3	23.7	23.0	0.79	0.67	31.2	30.5	0.79	0.67	30.5	0.68	1.0
	GPRS 3TX		30.3	21.9	21.2	0.79	0.67	29.4	28.7	0.79	0.67	28.7	0.68	1.0
	GPRS 4TX		29.3	20.7	20.0	0.79	0.67	28.2	27.5	0.79	0.67	27.5	0.68	1.0
	EGPRS 1TX		26.3	26.7	26.0	0.79	0.67	34.2	33.5	0.79	0.67	33.5	0.68	1.0
	EGPRS 2TX		25.3	23.7	23.0	0.79	0.67	31.2	30.5	0.79	0.67	30.5	0.68	1.0
	EGPRS 3TX		24.3	21.9	21.2	0.79	0.67	29.4	28.7	0.79	0.67	28.7	0.68	1.0
	EGPRS 4TX		23.3	20.7	20.0	0.79	0.67	28.2	27.5	0.79	0.67	27.5	0.68	1.0
	GSM 1TX	ANT0	32.5	38.5	37.8	0.79	0.67	34.1	33.4	0.79	0.67	33.4	0.68	1.0
	GPRS 1TX		32.5	38.5	37.8	0.79	0.67	34.1	33.4	0.79	0.67	33.4	0.68	1.0
	GPRS 2TX		31.5	35.5	34.8	0.83	0.7	30.5	29.8	0.83	0.7	28.8	0.71	0.8
	GPRS 3TX		30.5	33.7	33.0	0.83	0.7	29.2	28.5	0.83	0.7	28.5	0.71	0.8
	GPRS 4TX		29.5	32.5	31.8	0.83	0.7	27.9	27.2	0.83	0.7	27.2	0.71	0.8
	EGPRS 1TX		26.5	38.5	37.8	0.83	0.7	34.1	33.4	0.83	0.7	33.4	0.71	0.8
	EGPRS 2TX		25.5	35.5	34.8	0.83	0.7	31.1	30.4	0.83	0.7	30.4	0.71	0.8
	EGPRS 3TX		24.5	33.7	33.0	0.83	0.7	29.3	28.6	0.83	0.7	28.6	0.71	0.8
	EGPRS 4TX		23.5	32.5	31.8	0.83	0.7	28.1	27.4	0.83	0.7	27.4	0.71	0.8
GSM1900	GSM 1TX	ANT0	29.4	43.1	42.4	0.79	0.67	28.3	27.6	0.79	0.67	24.4	0.68	1.0
	GPRS 1TX		29.4	43.1	42.4	0.79	0.67	28.3	27.6	0.79	0.67	24.4	0.68	1.0
	GPRS 2TX		27.9	40.1	39.4	0.79	0.67	25.3	24.6	0.79	0.67	21.4	0.68	1.0
	GPRS 3TX		27.4	38.3	37.6	0.79	0.67	23.5	22.8	0.79	0.67	19.6	0.68	1.0
	GPRS 4TX		26.4	37.1	36.4	0.79	0.67	22.3	21.6	0.79	0.67	18.4	0.68	1.0
	EGPRS 1TX		25.4	43.1	42.4	0.79	0.67	28.3	27.6	0.79	0.67	24.4	0.68	1.0
	EGPRS 2TX		24.4	40.1	39.4	0.79	0.67	25.3	24.6	0.79	0.67	21.4	0.68	1.0
	EGPRS 3TX		23.4	38.3	37.6	0.79	0.67	23.5	22.8	0.79	0.67	19.6	0.68	1.0
	EGPRS 4TX		22.4	37.1	36.4	0.79	0.67	22.3	21.6	0.79	0.67	18.4	0.68	1.0
	GSM 1TX	ANT2	29.5	35.5	34.8	0.81	0.69	32.3	31.6	0.81	0.69	31.6	0.69	0.9
	GPRS 1TX		29.5	35.5	34.8	0.81	0.69	32.3	31.6	0.81	0.69	31.6	0.69	0.9
	GPRS 2TX		28.0	32.5	31.8	0.81	0.69	29.3	28.6	0.81	0.69	28.6	0.69	0.9
	GPRS 3TX		27.5	30.7	30.0	0.81	0.69	27.5	26.8	0.81	0.69	26.8	0.69	0.9
	GPRS 4TX		26.5	29.5	28.8	0.81	0.69	26.3	25.6	0.81	0.69	25.6	0.69	0.9
	EGPRS 1TX		25.5	35.5	34.8	0.81	0.69	32.3	31.6	0.81	0.69	31.6	0.69	0.9
	EGPRS 2TX		24.5	32.5	31.8	0.81	0.69	29.3	28.6	0.81	0.69	28.6	0.69	0.9
	EGPRS 3TX		23.5	30.7	30.0	0.81	0.69	27.5	26.8	0.81	0.69	26.8	0.69	0.9
	EGPRS 4TX		22.5	29.5	28.8	0.81	0.69	26.3	25.6	0.81	0.69	25.6	0.69	0.9

Plimit (dBm)														
Technology	Mode	Antenna	Index 1	Index 2	Index 3	Index 2 Head SAR Design_Target (W/kg)	Index 3 Head SAR Design_Target (W/kg)	Index 5	Index 6	Index 5 Body SAR Design_Target (W/kg)	Index 6 Body SAR Design_Target (W/kg)	Index 4	Index 4 Hotspot SAR Design_Target (W/kg)	Uncertainty (dB)
WCDMA B5	R99	ANT0	24.3	27.4	26.7	0.76	0.64	23.6	22.9	0.76	0.64	22.9	0.64	1.2
	HSDPA		24.3	27.4	26.7	0.76	0.64	23.6	22.9	0.76	0.64	22.9	0.64	1.2
	HSUPA		24.3	27.4	26.7	0.76	0.64	23.6	22.9	0.76	0.64	22.9	0.64	1.2
	DC-HSDPA		24.3	27.4	26.7	0.76	0.64	23.6	22.9	0.76	0.64	22.9	0.64	1.2
	R99	ANT1	24.1	20.9	20.2	0.72	0.61	26.4	25.7	0.72	0.61	24.1	0.62	1.4
	HSDPA		24.1	20.9	20.2	0.72	0.61	26.4	25.7	0.72	0.61	24.1	0.62	1.4
	HSUPA		24.1	20.9	20.2	0.72	0.61	26.4	25.7	0.72	0.61	24.1	0.62	1.4
	DC-HSDPA		24.1	20.9	20.2	0.72	0.61	26.4	25.7	0.72	0.61	24.1	0.62	1.4
WCDMA B4	R99	ANT0	23.8	33.3	32.6	0.68	0.57	18.8	18.1	0.68	0.57	16.3	0.57	1.7
	HSDPA		23.8	33.3	32.6	0.68	0.57	18.8	18.1	0.68	0.57	16.3	0.57	1.7
	HSUPA		23.8	33.3	32.6	0.68	0.57	18.8	18.1	0.68	0.57	16.3	0.57	1.7
	DC-HSDPA		23.8	33.3	32.6	0.68	0.57	18.8	18.1	0.68	0.57	16.3	0.57	1.7
	R99	ANT2	24	28.8	28.1	0.71	0.6	22.3	21.6	0.71	0.6	21.6	0.60	1.5
	HSDPA		24	28.8	28.1	0.71	0.6	22.3	21.6	0.71	0.6	21.6	0.60	1.5
	HSUPA		24	28.8	28.1	0.71	0.6	22.3	21.6	0.71	0.6	21.6	0.60	1.5
	DC-HSDPA		24	28.8	28.1	0.71	0.6	22.3	21.6	0.71	0.6	21.6	0.60	1.5
WCDMA B2	R99	ANT0	23.8	33.5	32.8	0.68	0.57	17.8	17.1	0.68	0.57	14.3	0.57	1.7
	HSDPA		23.8	33.5	32.8	0.68	0.57	17.8	17.1	0.68	0.57	14.3	0.57	1.7
	HSUPA		23.8	33.5	32.8	0.68	0.57	17.8	17.1	0.68	0.57	14.3	0.57	1.7
	DC-HSDPA		23.8	33.5	32.8	0.68	0.57	17.8	17.1	0.68	0.57	14.3	0.57	1.7
	R99	ANT2	24	26.7	26.0	0.71	0.6	22.1	21.4	0.71	0.6	21.4	0.60	1.5
	HSDPA		24	26.7	26.0	0.71	0.6	22.1	21.4	0.71	0.6	21.4	0.60	1.5
	HSUPA		24	26.7	26.0	0.71	0.6	22.1	21.4	0.71	0.6	21.4	0.60	1.5
	DC-HSDPA		24	26.7	26.0	0.71	0.6	22.1	21.4	0.71	0.6	21.4	0.60	1.5

Plimit (dBm)															
Technology	Band	Power Class	Antenna	Index 1	Index 2	Index 3	Index 2 Head SAR Design_Target (W/kg)	Index 3 Head SAR Design_Target (W/kg)	Index 5	Index 6	Index 5 Body SAR Design_Target (W/kg)	Index 6 Body SAR Design_Target (W/kg)	Index 4	Index 4 Hotspot SAR Design_Target (W/kg)	Uncertainty (dB)
LTE	B71	PC3	ANT0	24.3	29.5	28.8	0.85	0.72	28.0	27.3	0.85	0.72	25.6	0.72	0.7
LTE	B71	PC3	ANT1	24.1	22.5	21.8	0.81	0.69	29.6	28.9	0.81	0.69	27.5	0.69	0.9
LTE	B12	PC3	ANT0	24.3	29.9	29.2	0.85	0.72	26.4	25.7	0.85	0.72	25.7	0.72	0.7
LTE	B12	PC3	ANT1	24.1	21.1	20.4	0.81	0.69	28.3	27.6	0.81	0.69	27.5	0.69	0.9
LTE	B17	PC3	ANT0	24.3	29.9	29.2	0.85	0.72	26.4	25.7	0.85	0.72	25.7	0.72	0.7
LTE	B17	PC3	ANT1	24.1	21.1	20.4	0.81	0.69	28.3	27.6	0.81	0.69	27.5	0.69	0.9
LTE	B13	PC3	ANT0	24.3	28.7	28.0	0.85	0.72	25.0	24.3	0.85	0.72	24.1	0.72	0.7
LTE	B13	PC3	ANT1	24.1	21.5	20.8	0.81	0.69	27.9	27.2	0.81	0.69	27.1	0.69	0.9
LTE	B14	PC3	ANT0	24.3	28.3	27.6	0.85	0.72	25.6	24.9	0.85	0.72	24.8	0.72	0.7
LTE	B14	PC3	ANT1	24.1	22.0	21.3	0.81	0.69	26.6	25.9	0.81	0.69	25.9	0.69	0.9
LTE	B26	PC3	ANT0	24.3	27.5	26.8	0.85	0.72	23.5	22.8	0.85	0.72	22.8	0.72	0.7
LTE	B26	PC3	ANT1	24.1	21.0	20.3	0.81	0.69	27.7	27.0	0.81	0.69	27.0	0.69	0.9
LTE	B5	PC3	ANT0	24.3	27.5	26.8	0.85	0.72	23.5	22.8	0.85	0.72	22.8	0.72	0.7
LTE	B5	PC3	ANT1	24.1	21.0	20.3	0.81	0.69	27.7	27.0	0.81	0.69	27.0	0.69	0.9
LTE	B66	PC3	ANT0	23.9	32.4	31.7	0.78	0.66	16.9	16.2	0.78	0.66	16.2	0.66	1.1
LTE	B66	PC3	ANT2	24.0	28.6	27.9	0.79	0.67	23.6	22.9	0.79	0.67	22.9	0.68	1.0
LTE	B4	PC3	ANT0	23.9	32.4	31.7	0.78	0.66	16.9	16.2	0.78	0.66	16.2	0.66	1.1
LTE	B4	PC3	ANT2	24.0	28.6	27.9	0.79	0.67	25.8	25.1	0.79	0.67	24.5	0.68	1.0
LTE	B25	PC3	ANT0	23.9	35.6	34.9	0.78	0.66	16.6	15.9	0.78	0.66	15.9	0.66	1.1
LTE	B25	PC3	ANT2	24.0	26.9	26.2	0.79	0.67	22.2	21.5	0.79	0.67	21.5	0.68	1.0
LTE	B2	PC3	ANT0	23.9	35.6	34.9	0.78	0.66	16.6	15.9	0.78	0.66	15.9	0.66	1.1
LTE	B2	PC3	ANT2	24.0	26.9	26.2	0.79	0.67	22.6	21.9	0.79	0.67	21.9	0.68	1.0
LTE	B30	PC3	ANT0	23.8	33.2	32.5	0.79	0.67	19.2	18.5	0.79	0.67	18.5	0.68	1.0
LTE	B30	PC3	ANT2	24.0	27.1	26.4	0.81	0.69	20.3	19.6	0.81	0.69	19.6	0.69	0.9
LTE	B7	PC3	ANT0	23.9	36.1	35.4	0.79	0.67	20.4	19.7	0.79	0.67	18.4	0.68	1.0
LTE	B7	PC3	ANT2	24.1	24.1	23.4	0.81	0.69	22.5	21.8	0.81	0.69	20.5	0.69	0.9
LTE	B41	PC3	ANT0	21.9	36.9	36.2	0.79	0.67	23.4	22.7	0.79	0.67	19.5	0.68	1.0
LTE	B41	PC2	ANT0	22.2	36.9	36.2	0.79	0.67	23.4	22.7	0.79	0.67	19.5	0.68	1.0
LTE	B41	PC3	ANT2	22.1	26.0	25.3	0.81	0.69	24.7	24.0	0.81	0.69	20.6	0.69	0.9
LTE	B41	PC2	ANT2	22.4	26.0	25.3	0.81	0.69	24.7	24.0	0.81	0.69	20.6	0.69	0.9
LTE	B38	PC3	ANT0	21.9	36.9	36.2	0.79	0.67	23.4	22.7	0.79	0.67	19.5	0.68	1.0
LTE	B38	PC2	ANT0	22.2	36.9	36.2	0.79	0.67	23.4	22.7	0.79	0.67	19.5	0.68	1.0
LTE	B38	PC3	ANT2	22.1	26.0	25.3	0.81	0.69	24.7	24.0	0.81	0.69	20.6	0.69	0.9
LTE	B38	PC2	ANT2	22.4	26.0	25.3	0.81	0.69	24.7	24.0	0.81	0.69	20.6	0.69	0.9
LTE	B48	PC3	ANT6	20.1	28.2	27.5	0.79	0.67	22.2	21.5	0.79	0.67	21.5	0.68	1.0
LTE	B48	PC3	ANT7	20.8	28.7	28.0	0.79	0.67	22.0	21.3	0.79	0.67	21.3	0.68	1.0

Plimit (dBm)															
Technology	Band	Power Class	Antenna	Index 1	Index 2	Index 3	Index 2 Head SAR Design_Target (W/kg)	Index 3 Head SAR Design_Target (W/kg)	Index 5	Index 6	Index 5 Body SAR Design_Target (W/kg)	Index 6 Body SAR Design_Target (W/kg)	Index 4	Index 4 Hotspot SAR Design_Target (W/kg)	Uncertainty (dB)
NR	N71	PC3	ANT0	24.3	30.1	29.4	0.85	0.72	27.5	26.8	0.85	0.72	25.8	0.72	0.7
NR	N71	PC3	ANT1	24.1	23.8	23.1	0.81	0.69	27.3	26.6	0.81	0.69	26.6	0.69	0.9
NR	N12	PC3	ANT0	24.3	28.9	28.2	0.85	0.72	28.8	28.1	0.85	0.72	25.8	0.72	0.7
NR	N12	PC3	ANT1	24.1	22.8	22.1	0.81	0.69	26.0	25.3	0.81	0.69	25.3	0.69	0.9
NR	N14	PC3	ANT0	24.3	29.0	28.3	0.85	0.72	25.4	24.7	0.85	0.72	24.7	0.72	0.7
NR	N14	PC3	ANT1	24.1	22.7	22.0	0.81	0.69	25.8	25.1	0.81	0.69	25.1	0.69	0.9
NR	N26	PC3	ANT0	24.3	28.5	27.8	0.85	0.72	25.1	24.4	0.85	0.72	24.4	0.72	0.7
NR	N26	PC3	ANT1	24.1	21.1	20.4	0.81	0.69	26.4	25.7	0.81	0.69	25.7	0.69	0.9
NR	N5	PC3	ANT0	24.3	28.5	27.8	0.85	0.72	25.1	24.4	0.85	0.72	24.4	0.72	0.7
NR	N5	PC3	ANT1	24.1	21.1	20.4	0.81	0.69	26.4	25.7	0.81	0.69	25.7	0.69	0.9
NR	N70	PC3	ANT0	24.1	34.2	33.5	0.81	0.69	18.1	17.4	0.81	0.69	17.4	0.69	0.9
NR	N70	PC3	ANT2	24.2	30.3	29.6	0.83	0.7	23.7	23.0	0.83	0.7	23.0	0.71	0.8
NR	N66	PC3	ANT0	23.9	35.1	34.4	0.78	0.66	18.7	18.0	0.78	0.66	17.7	0.66	1.1
NR	N66	PC3	ANT2	24.0	29.3	28.6	0.79	0.67	26.5	25.8	0.79	0.67	22.8	0.68	1.0
NR	N25	PC3	ANT0	23.9	34.1	33.4	0.78	0.66	19.9	19.2	0.78	0.66	17.0	0.66	1.1
NR	N25	PC3	ANT2	24.0	27.5	26.8	0.79	0.67	22.7	22.0	0.79	0.67	22.0	0.68	1.0
NR	N2	PC3	ANT0	23.9	34.1	33.4	0.78	0.66	19.9	19.2	0.78	0.66	17.0	0.66	1.1
NR	N2	PC3	ANT2	24.0	27.5	26.8	0.79	0.67	22.7	22.0	0.79	0.67	22.0	0.68	1.0
NR	N30	PC3	ANT0	23.8	32.8	32.1	0.79	0.67	19.0	18.3	0.79	0.67	18.3	0.68	1.0
NR	N30	PC3	ANT2	24.0	26.2	25.5	0.81	0.69	21.7	21.0	0.81	0.69	21.0	0.69	0.9
NR	N7	PC3	ANT0	23.9	34.7	34.0	0.79	0.67	22.3	21.6	0.79	0.67	19.5	0.68	1.0
NR	N7	PC3	ANT2	24.1	23.8	23.1	0.81	0.69	21.3	20.6	0.81	0.69	20.6	0.69	0.9
NR	N41	PC3	ANT0	23.9	35.2	34.5	0.79	0.67	21.0	20.3	0.79	0.67	19.4	0.68	1.0
NR	N41	PC2	ANT0	22.8	35.2	34.5	0.79	0.67	21.0	20.3	0.79	0.67	19.4	0.68	1.0
NR	N41	PC1P5	ANT0	19.8	35.2	34.5	0.79	0.67	21.0	20.3	0.79	0.67	19.4	0.68	1.0
NR	N41	PC3	ANT1	24.1	18.3	17.6	0.81	0.69	26.5	25.8	0.81	0.69	25.0	0.69	0.9
NR	N41	PC2	ANT1	23.0	18.3	17.6	0.81	0.69	26.5	25.8	0.81	0.69	25.0	0.69	0.9
NR	N41	PC1P5	ANT1	20.0	18.3	17.6	0.81	0.69	26.5	25.8	0.81	0.69	25.0	0.69	0.9
NR	N41	PC3	ANT2	24.1	23.7	23.0	0.81	0.69	21.7	21.0	0.81	0.69	20.2	0.69	0.9
NR	N41	PC2	ANT2	23.0	23.7	23.0	0.81	0.69	21.7	21.0	0.81	0.69	20.2	0.69	0.9
NR	N41	PC1P5	ANT2	20.0	23.7	23.0	0.81	0.69	21.7	21.0	0.81	0.69	20.2	0.69	0.9
NR	N41	PC3	ANT5	23.9	17.7	17.0	0.79	0.67	23.9	23.2	0.79	0.67	23.2	0.68	1.0
NR	N41	PC2	ANT5	22.8	17.7	17.0	0.79	0.67	23.9	23.2	0.79	0.67	23.2	0.68	1.0
NR	N41	PC1P5	ANT5	19.8	17.7	17.0	0.79	0.67	23.9	23.2	0.79	0.67	23.2	0.68	1.0
NR	N38	PC3	ANT0	23.9	35.2	34.5	0.79	0.67	21.0	20.3	0.79	0.67	19.4	0.68	1.0
NR	N38	PC3	ANT1	24.1	18.3	17.6	0.81	0.69	26.5	25.8	0.81	0.69	25.0	0.69	0.9
NR	N38	PC3	ANT2	24.1	23.7	23.0	0.81	0.69	21.7	21.0	0.81	0.69	20.2	0.69	0.9
NR	N38	PC3	ANT5	23.9	17.7	17.0	0.79	0.67	23.9	23.2	0.79	0.67	23.2	0.68	1.0
NR	N78	PC3	ANT1	24.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	23.3	0.68	1.0
NR	N78	PC2	ANT1	22.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	24.5	0.68	1.0
NR	N78	PC1P5	ANT1	19.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	24.5	0.68	1.0
NR	N78	PC3	ANT5	23.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N78	PC2	ANT5	21.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N78	PC1P5	ANT5	18.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N78	PC3	ANT6	24.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N78	PC2	ANT6	22.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N78	PC1P5	ANT6	19.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N78	PC3	ANT7	23.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0
NR	N78	PC2	ANT7	21.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0
NR	N78	PC1P5	ANT7	18.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0
NR	N48	PC3	ANT1	22.1	18.3	17.6	0.79	0.67	25.4	24.7	0.79	0.67	23.3	0.68	1.0

NR	N48	PC3	ANT5	22.9	18.0	17.3	0.79	0.67	27.0	26.3	0.79	0.67	24.5	0.68	1.0
NR	N48	PC3	ANT6	22.1	28.4	27.7	0.79	0.67	23.2	22.5	0.79	0.67	22.4	0.68	1.0
NR	N48	PC3	ANT7	22.9	27.5	26.8	0.79	0.67	22.5	21.8	0.79	0.67	21.6	0.68	1.0
NR	N77	PC3	ANT1	24.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	23.3	0.68	1.0
NR	N77	PC2	ANT1	22.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	24.5	0.68	1.0
NR	N77	PC1P5	ANT1	19.0	16.2	15.5	0.79	0.67	25.2	24.5	0.79	0.67	24.5	0.68	1.0
NR	N77	PC3	ANT5	23.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N77	PC2	ANT5	21.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N77	PC1P5	ANT5	18.0	18.0	17.3	0.79	0.67	24.9	24.2	0.79	0.67	24.2	0.68	1.0
NR	N77	PC3	ANT6	24.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N77	PC2	ANT6	22.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N77	PC1P5	ANT6	19.0	28.9	28.2	0.79	0.67	21.1	20.4	0.79	0.67	19.7	0.68	1.0
NR	N77	PC3	ANT7	23.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0
NR	N77	PC2	ANT7	21.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0
NR	N77	PC1P5	ANT7	18.0	28.1	27.4	0.79	0.67	19.9	19.2	0.79	0.67	19.2	0.68	1.0

Plimit (dBm)						
Technology	**Band**	**Antenna**	**Index 1**	**Index 5**	**Body SAR Design_Target (W/kg)**	**Uncertainty (dB)**
NTN	Band 23	ANT1	22.5	22	0.79	1.0
NTN	Band 255	ANT5	22.7	25.35	0.79	1.0

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 5.2.1 Sub-6GHz TAS validation test case list

No.	Test Scenario	Test case	Test configuration
1	Time-varying Tx power transmission	UMTS_Time_Varying_Tx_Power_Case_1	WCDMA B5
2		UMTS_Time_Varying_Tx_Power_Case_1	WCDMA B2
3		LTE_Time_Varying_Tx_Power_Case_1	LTE B66
4		LTE_Time_Varying_Tx_Power_Case_1	LTE B25
5		SA_FR1_Time_Varying_Tx_Power_Case_1	n7 (SA Mode)
6		SA_FR1_Time_Varying_Tx_Power_Case_1	n25 (SA Mode)
7	Time-varying Tx power transmission	UMTS_Time_Varying_Tx_Power_Case_2	WCDMA B5
8		UMTS_Time_Varying_Tx_Power_Case_2	WCDMA B2
9		LTE_Time_Varying_Tx_Power_Case_2	LTE B66
10		LTE_Time_Varying_Tx_Power_Case_2	LTE B25
11		SA_FR1_Time_Varying_Tx_Power_Case_2	n7 (SA Mode)
12		SA_FR1_Time_Varying_Tx_Power_Case_2	n25 (SA Mode)
13	Change operate states	SA_FR1_RF_SAR_Index_Change	n25 (SA Mode) index 4 to index 5
14	Wireless technology Handover	LTE_to_WCDMA_H.O.	LTE B48 pc3 , WCDMA B2
15	Drop call	Call_Disconnect_Reestablishment	LTE B25
16	SAR exposure switch	NSA_FR1_Dominant_Power_Switching	LTE B25 , n77 pc3 (NSA Mode)
17	Re-selection in call	NR_TO_LTE_IRAT_HO	n25 pc3 (SA Mode) to LTE B48
18	UL CA	LTE Uplink CA	LTE B66

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

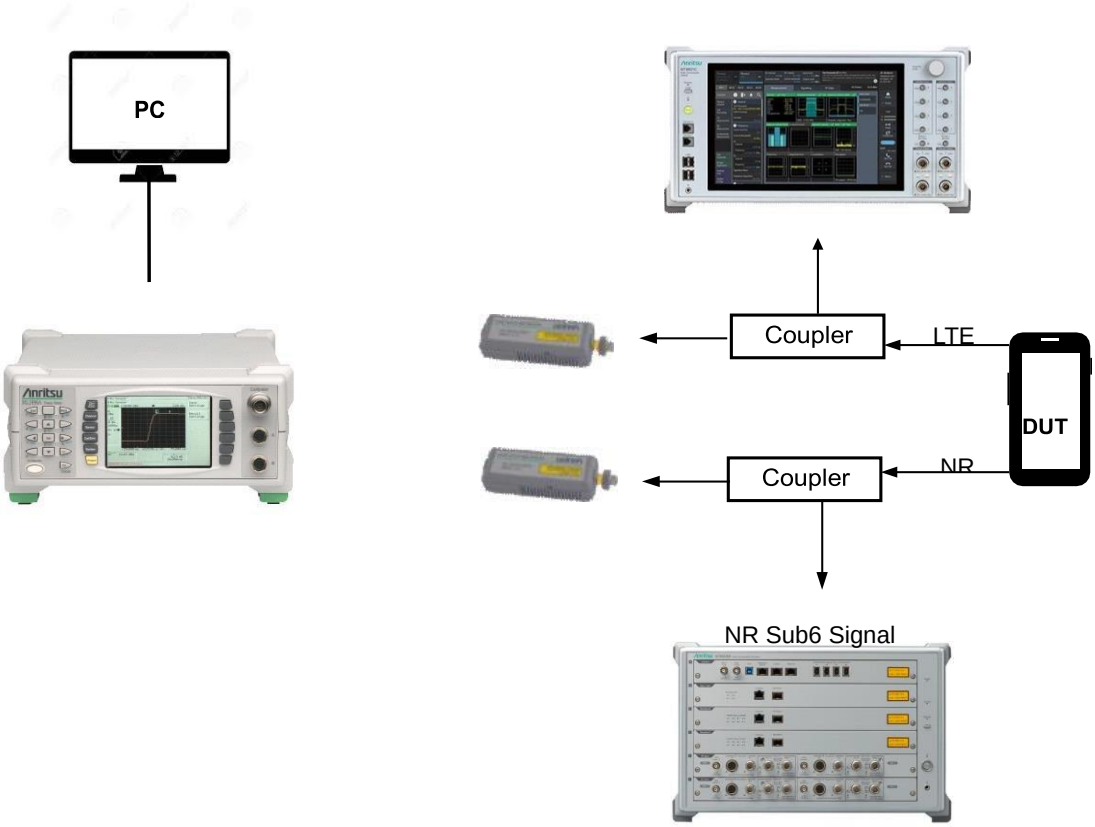


Figure 7.1-1 Test set-up for legacy and sub 6GHz

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.

Table 7.2.1 Measured *Plimit* and *Pmax* of selected radio configurations

TC#	Test Scenario	Antenna	Power Index	Test band	Configuration	Pmax Setting (dBm)	measured Pmax (dBm)	Plimit Setting (dBm)	Measured Plimit (dBm)	Total Uncertainty (dB)
1	Time varying Tx power case 1	TX2_Ant 0	4	WCDMA B5	RMC 12.2Kbps	24.3	23.69	22.9	22.48	1.2
2		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	23.8	20.39	14.3	14.28	1.7
3		TX0_Ant 2	4	LTE B66	20M/QPSK/1/99	24	23.66	22.9	22.87	1.1
4		TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	23.9	21.56	15.9	15.54	1.1
5		TX10_Ant 2	3	n7 (SA Mode)	40M/BPSK/135/67	24.1	23.91	23.1	22.68	0.9
6		TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	23.9	23.29	17	17.16	1.1
7	Time varying Tx power case 2	TX2_Ant 0	4	WCDMA B5	RMC 12.2Kbps	24.3	23.69	22.9	22.48	1.2
8		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	23.8	20.39	14.3	14.28	1.7
9		TX0_Ant 2	4	LTE B66	20M/QPSK/1/99	24	23.66	22.9	22.87	1.1
10		TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	23.9	21.56	15.9	15.54	1.1
11		TX10_Ant 2	3	n7 (SA Mode)	40M/BPSK/135/67	24.1	23.91	23.1	22.68	0.9
12		TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	23.9	23.29	17	17.16	1.1
13	Change in operating state	TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	23.9	23.29	17	17.16	1.1
		TX1_Ant 0	5	n25 (SA Mode)	40M/BPSK/1/1	23.9	23.29	19.9	19.94	1.1
14	LTE_to_WCDMA_H.O.	TX0_Ant 6	4	LTE B48pc3	20M/QPSK/1/49	20.1	20.68	21.5	20.68	1
		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	23.8	20.39	14.3	14.28	1.7
15	Call_Disconnect_Reestablishment	TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	23.9	21.56	15.9	15.54	1.1
16	NSA_FR1_Dominant_Power_Switching	TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	23.9	21.56	15.9	15.54	1.1
		TX0_Ant 6	4	n77 pc3 (NSA Mode)	100M/BPSK/135/69	24	24.22	19.7	19.38	1
17	NR_TO_LTE_IRAT_HO	TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	23.9	23.29	17	17.16	1.1
		TX0_Ant 6	4	LTE B48pc3	20M/QPSK/1/49	20.1	20.68	21.5	20.68	1
18	UL CA	TX1_Ant 0	4	LTE B66_PCC	20M/QPSK/100/0	23.9	23.55	16.2	16.39	1.1
				LTE B66 _PCC + SCC	20M/QPSK/1/99 + 20M/QPSK/1/0	23.9	21.16		15.26	

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.

Table 7.2.2 Sub-6 summary test results

TC#	Test Scenario	Antenna	Power Index	Test band	Configuration	Total Uncertainty (dB)	1g SAR design target (W/kg)	1g Time average SAR (W/kg)	deviation (dB)
1	Time varying Tx power case 1	TX0_Ant 2	4	WCDMA B5	RMC 12.2Kbps	1.2	0.64	0.515	-0.94
2		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	1.7	0.57	0.473	-0.81
3		TX0_Ant 0	4	LTE B66	20M/QPSK/1/99	1.1	0.68	0.624	-0.37
4		TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	1.1	0.66	0.566	-0.67
5		TX0_Ant 2	3	n7 (SA Mode)	40M/BPSK/135/67	0.9	0.69	0.567	-0.85
6		TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	1.1	0.66	0.633	-0.18
7	Time varying Tx power case 2	TX0_Ant 2	4	WCDMA B5	RMC 12.2Kbps	1.2	0.64	0.54	-0.74
8		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	1.7	0.57	0.483	-0.72
9		TX0_Ant 0	4	LTE B66	20M/QPSK/1/99	1.1	0.68	0.595	-0.58
10		TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	1.1	0.66	0.538	-0.89
11		TX0_Ant 2	3	n7 (SA Mode)	40M/BPSK/135/67	0.9	0.69	0.576	-0.78
12		TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	1.1	0.66	0.606	-0.37
13	Change in operating state	TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	1.1	0.66	0.734	0.46
		TX1_Ant 0	5	n25 (SA Mode)	40M/BPSK/1/1	1.1	0.77	0.734	-0.21
14	LTE_to_WCDMA_H.O.	TX0_Ant 6	4	LTE B48pc3	20M/QPSK/1/49	1	0.68	0.616	-0.43
		TX1_Ant 0	4	WCDMA B2	RMC 12.2Kbps	1.7	0.57	0.616	0.34
15	Call_Disconnect_Reestablishment	TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	1.1	0.66	0.572	-0.62
16	NSA_FR1_Dominant_Power_Switching	TX1_Ant 0	4	LTE B25	20M/QPSK/50/0	1.1	0.66	0.594	-0.46
		TX0_Ant 6	4	n77 pc3 (NSA Mode)	100M/BPSK/135/69	1	0.68	0.594	-0.59
17	NR_TO_LTE_IRAT_HO	TX1_Ant 0	4	n25 (SA Mode)	40M/BPSK/108/54	1.1	0.66	0.636	-0.16
		TX0_Ant 6	4	LTE B48pc3	20M/QPSK/1/49	1	0.68	0.636	-0.29
18	UL CA	TX1_Ant 0	4	LTE B66_PCC	20M/QPSK/100/0	1.1	0.66	0.659	-0.01
				LTE B66 _PCC + SCC	20M/QPSK/1/99 + 20M/QPSK/1/0				

7.3 Time-varying Tx power measurement results

Following the test procedure in Section 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 - 12 in Table 7.2.1 by generating the test sequence A or B given in Appendix.

7.3.1 TC01: WCDMA B5_Time_Varying_Tx_Power_Case_1

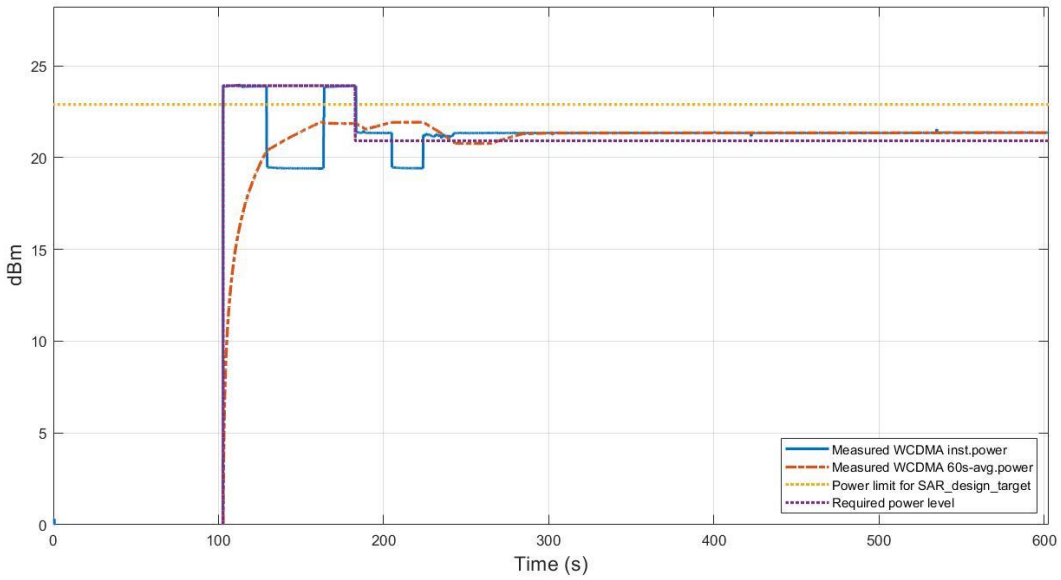


Figure 7.3-1 Time average conducted power

Figure 7.3-1 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 7.3-1, 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 7.3-2 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

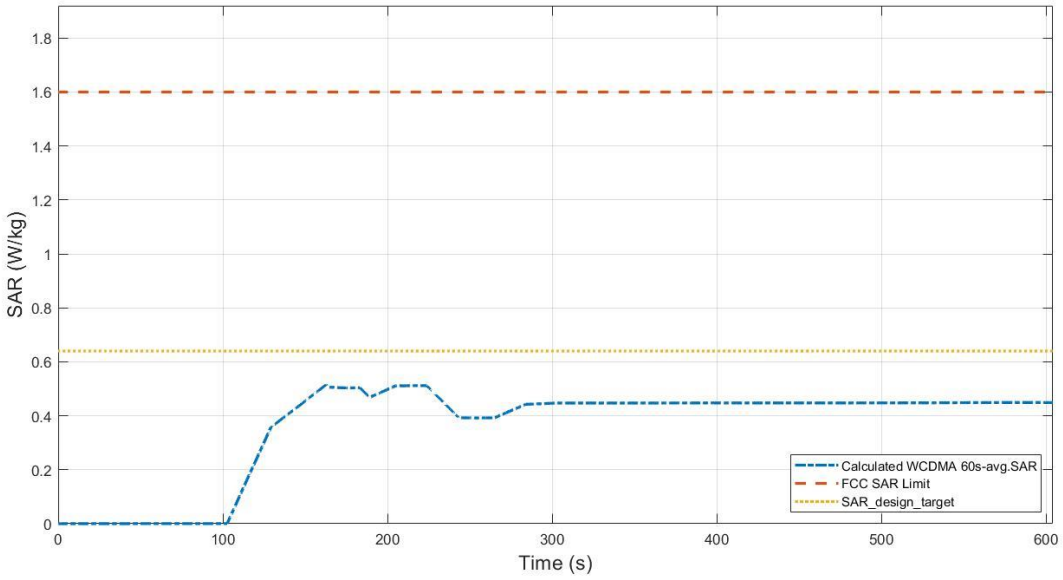


Figure 7.3-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.515 W/kg
Device uncertainty	1.2 dB

7.3.2 TC02: WCDMA B2_Time_Varying_Tx_Power_Case_1

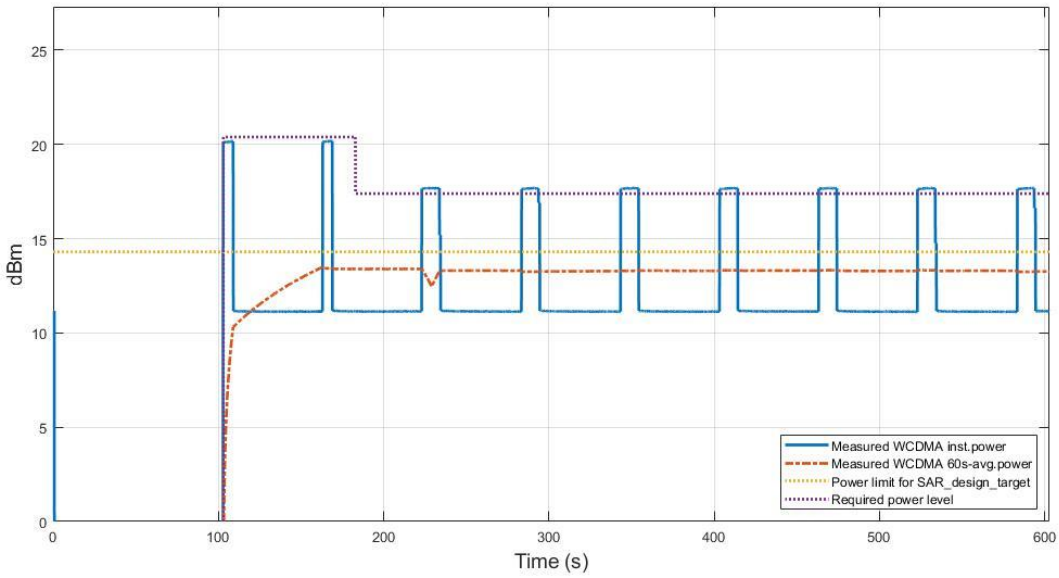


Figure 7.3-3 Time-average conducted power

Figure 7.3-3 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 7.3-3, 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 7.3-4 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

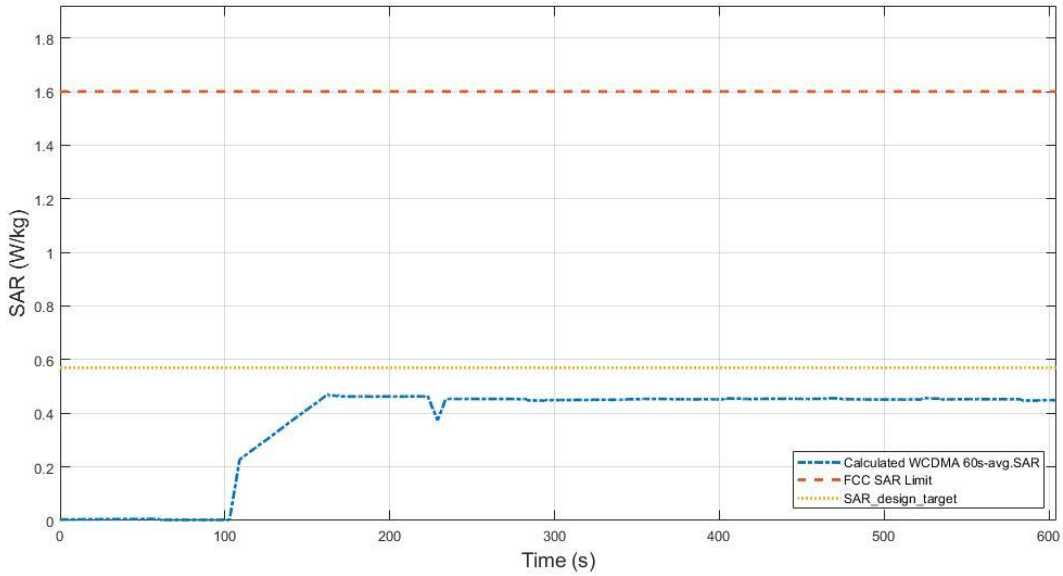


Figure 7.3-4 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.473 W/kg
Device uncertainty	1.7 dB

7.3.3 TC03: LTE Band 66_Time_Varying_Tx_Power_Case_1

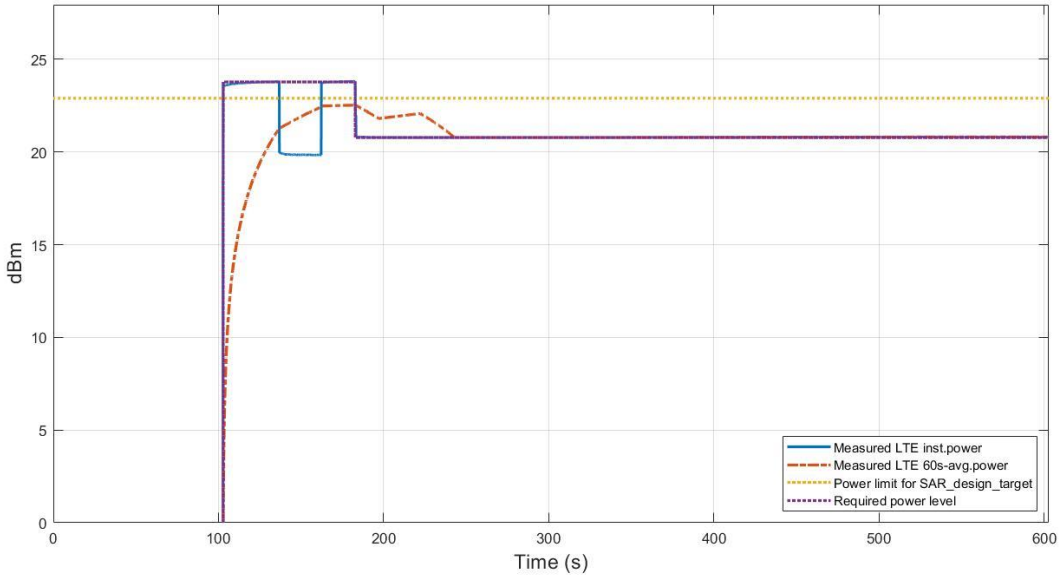


Figure 7.3-5 Time-average conducted power

Figure 7.3-5 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 7.3-5, 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 7.3-6 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

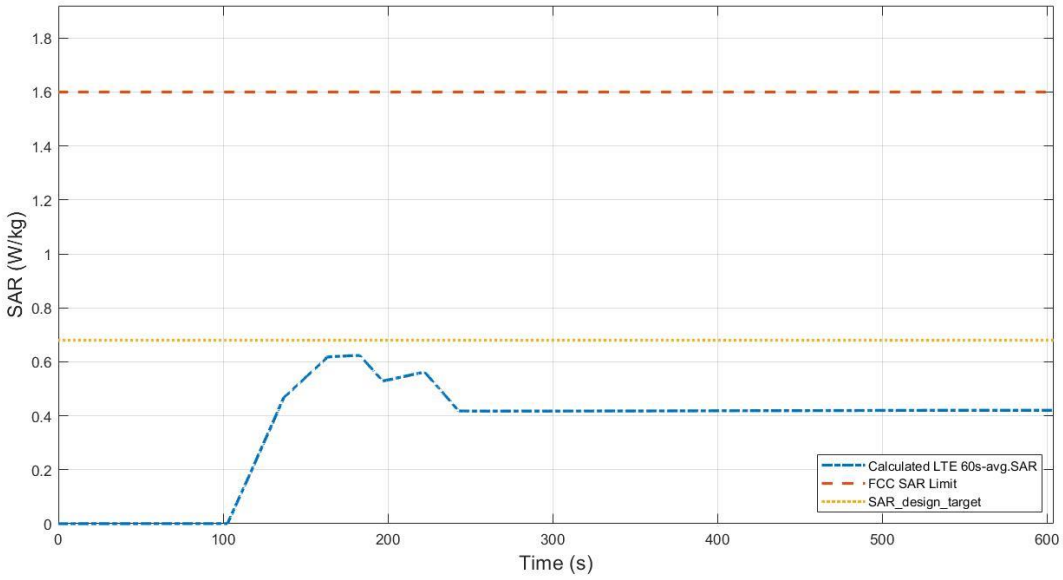


Figure 7.3-6 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.624 W/kg
Device uncertainty	1.1 dB

7.3.4 TC04: LTE Band 25_Time_Varying_Tx_Power_Case_1

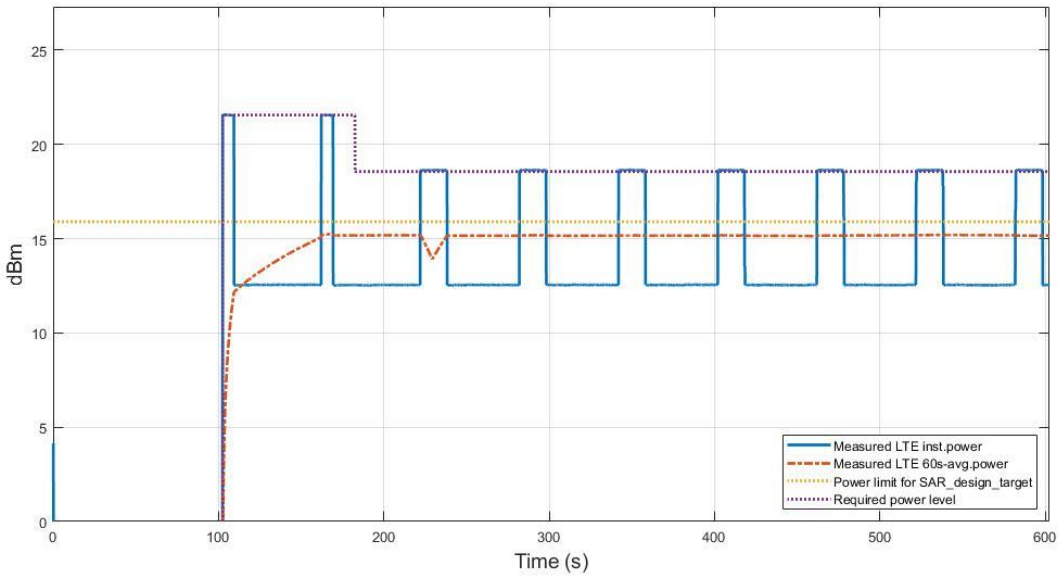


Figure 7.3-7 Time-average conducted power

Figure 7.3-7 shows the instantaneous and time-averaged Tx power for this test. As shown in Figure 7.3-7, 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 7.3-8 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

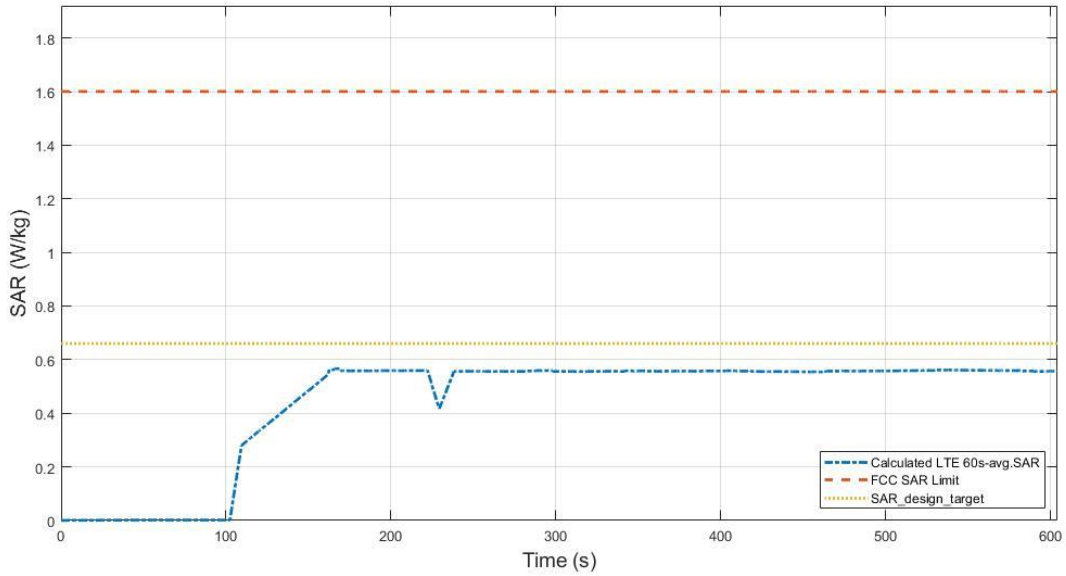


Figure 7.3-8 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.566 W/kg
Device uncertainty	1.1 dB

7.3.5 TC05: FR1 n7 SA mode_Time_Varying_Tx_Power_Case_1

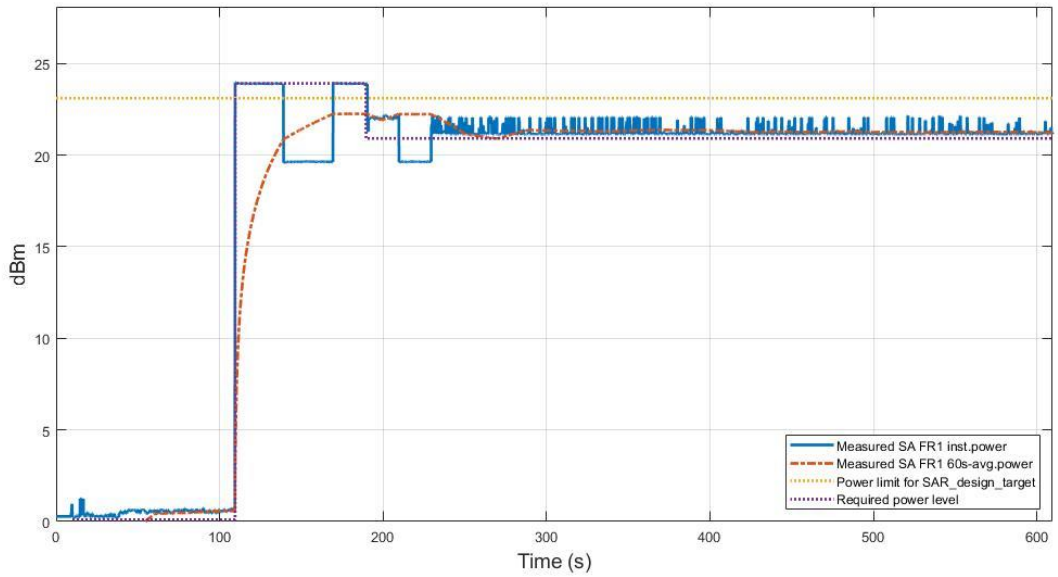


Figure 7.3-9 Conducted Tx power

Figure 7.3-9 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-10 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

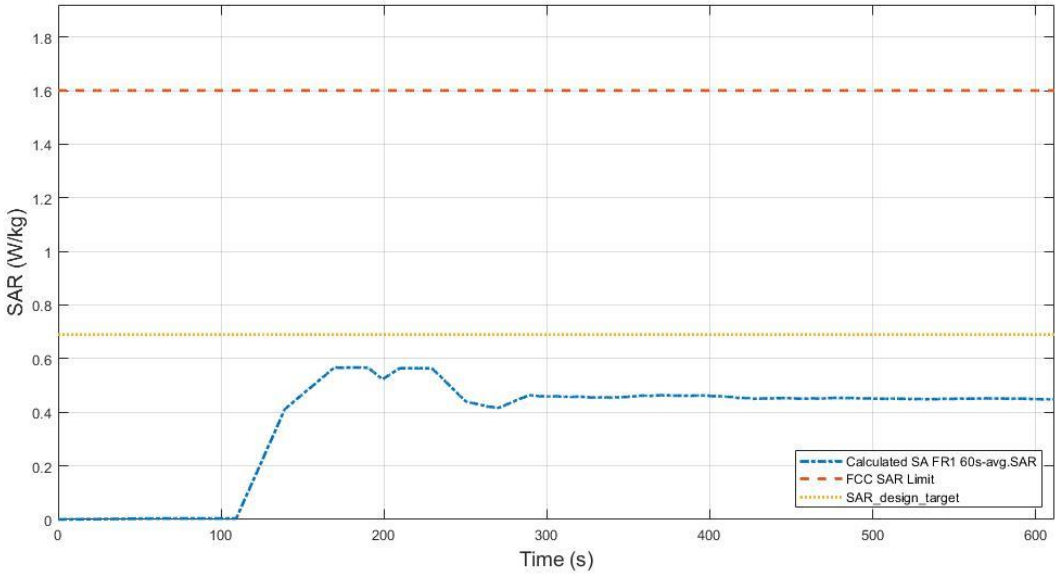


Figure 7.3-10 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.567 W/kg
Device uncertainty	0.9 dB

7.3.6 TC06: FR1 n25 SA mode_Time_Varying_Tx_Power_Case_1

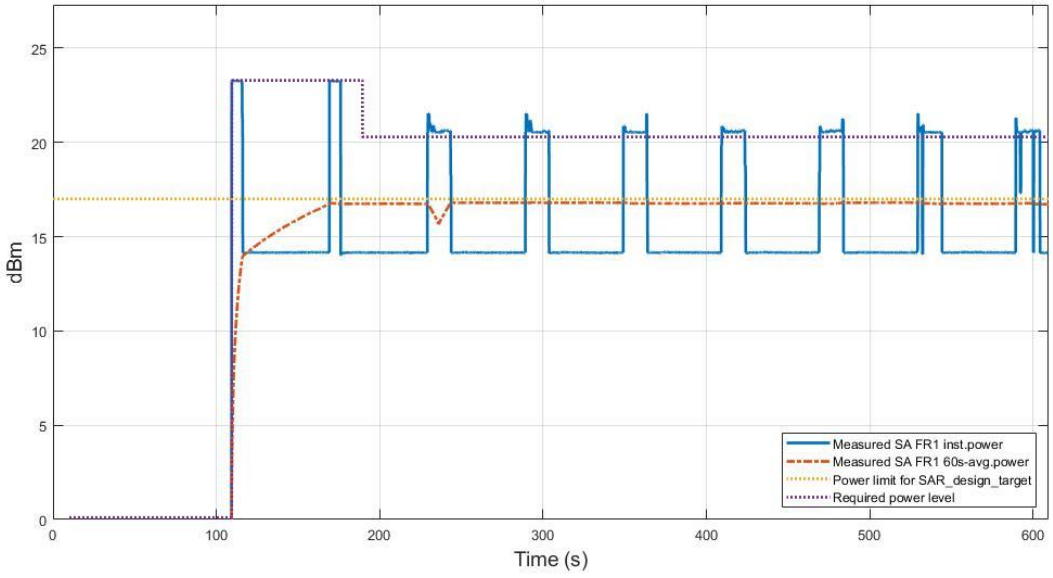


Figure 7.3-11 Conducted Tx power

Figure 7.3-11 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-12 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

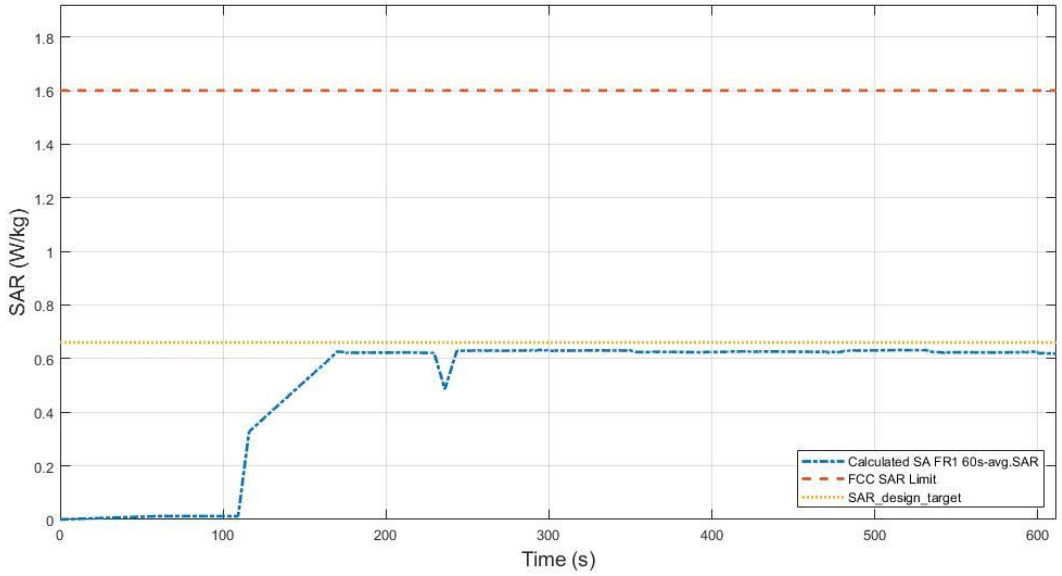


Figure 7.3-12 Total time-averaged SAR in F_TC04

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.633 W/kg
Device uncertainty	1.1 dB

7.3.7 TC07: WCDMA B5_Time_Varying_Tx_Power_Case_2

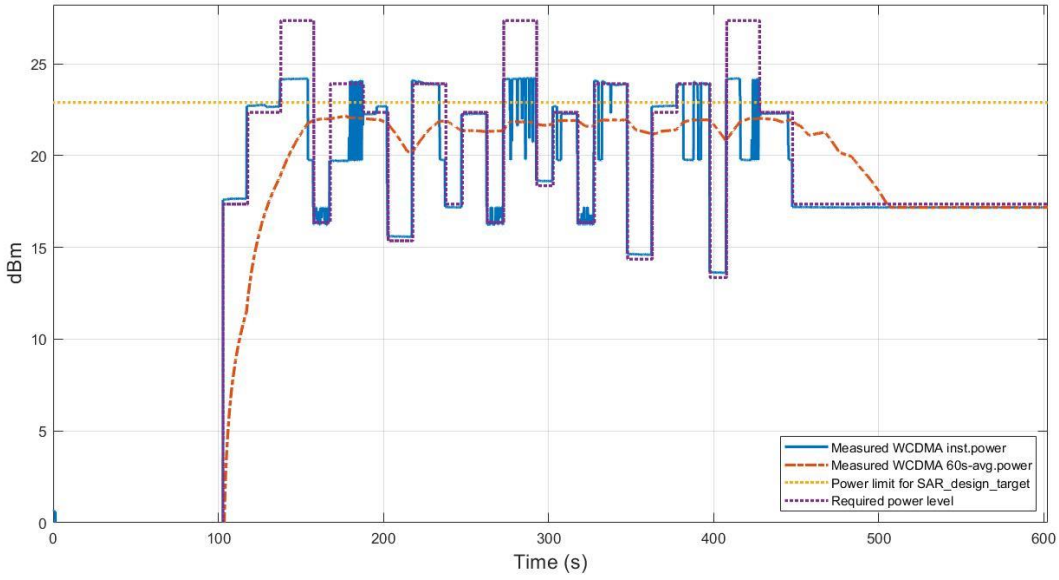


Figure 7.3-13 Conducted Tx power

Figure 7.3-13 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-14 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

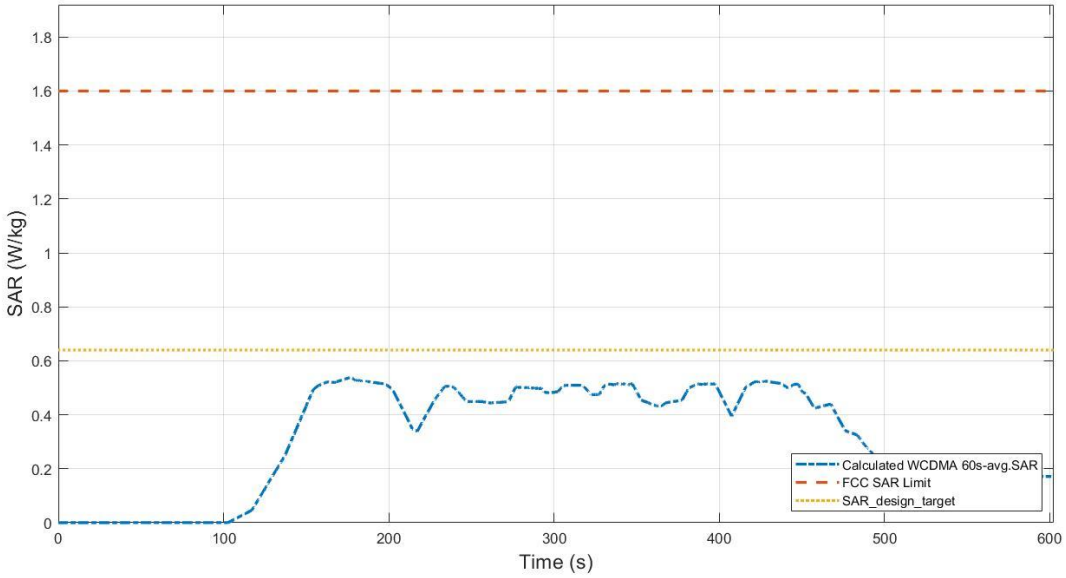


Figure 7.3-14 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.540 W/kg
Device uncertainty	1.2 dB

7.3.8 TC08: WCDMA B2_Time_Varying_Tx_Power_Case_2

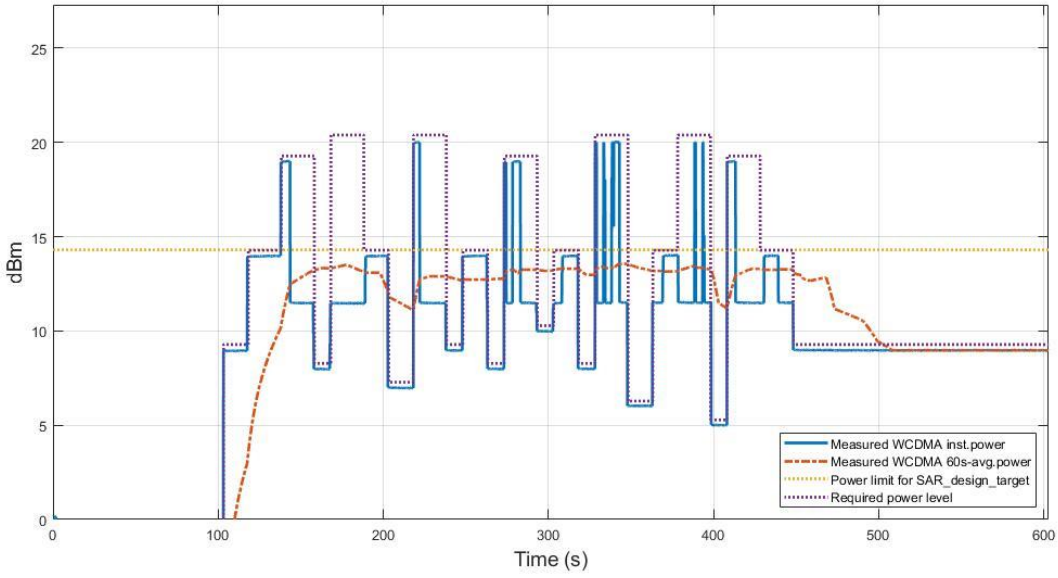


Figure 7.3-15 Conducted Tx power

Figure 7.3-15 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-16 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

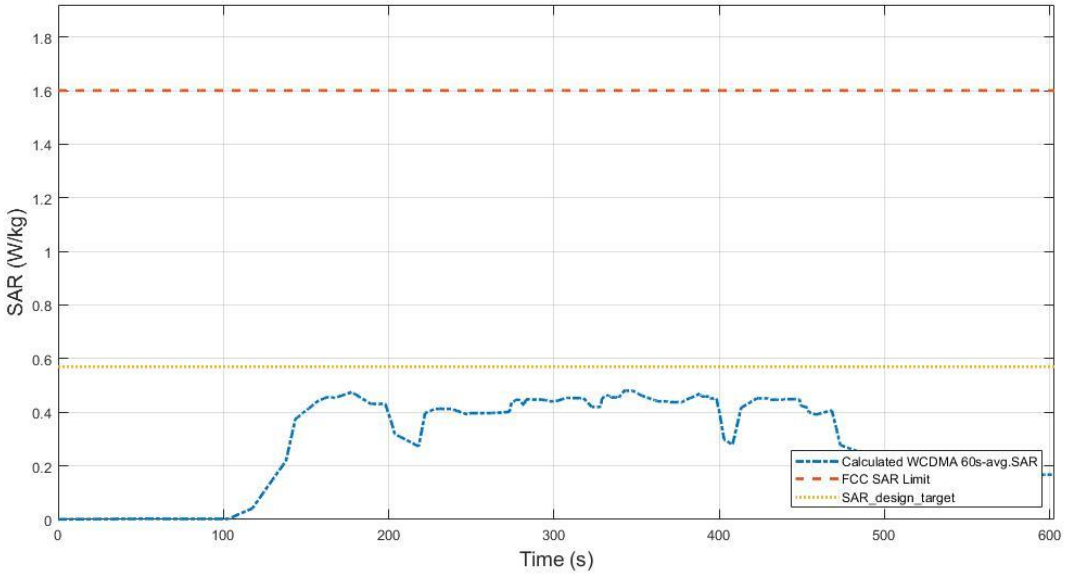


Figure 7.3-16 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.483 W/kg
Device uncertainty	1.7 dB

7.3.9 TC09: LTE Band 66_Time_Varying_Tx_Power_Case_2

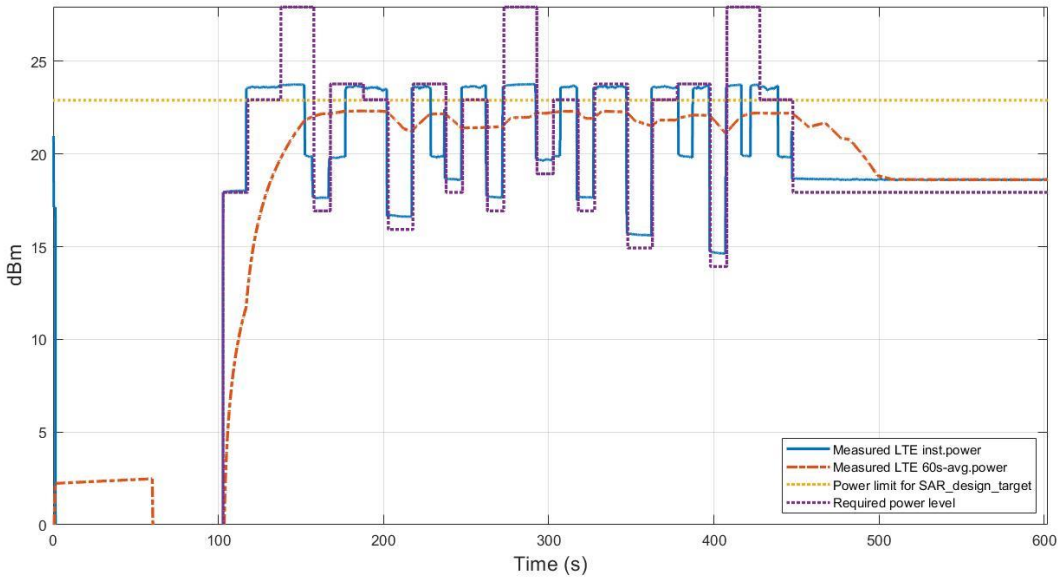


Figure 7.3-17 Conducted Tx power

Figure 7.3-17 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-18 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

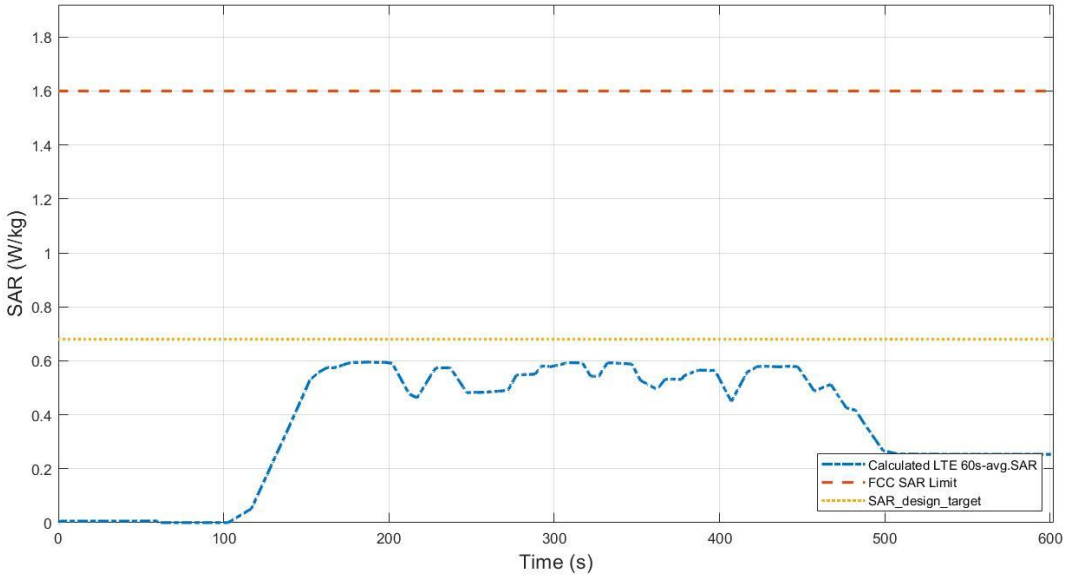


Figure 7.3-18 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.595 W/kg
Device uncertainty	1.1 dB

7.3.10 TC10: LTE Band 25_Time_Varying_Tx_Power_Case_2

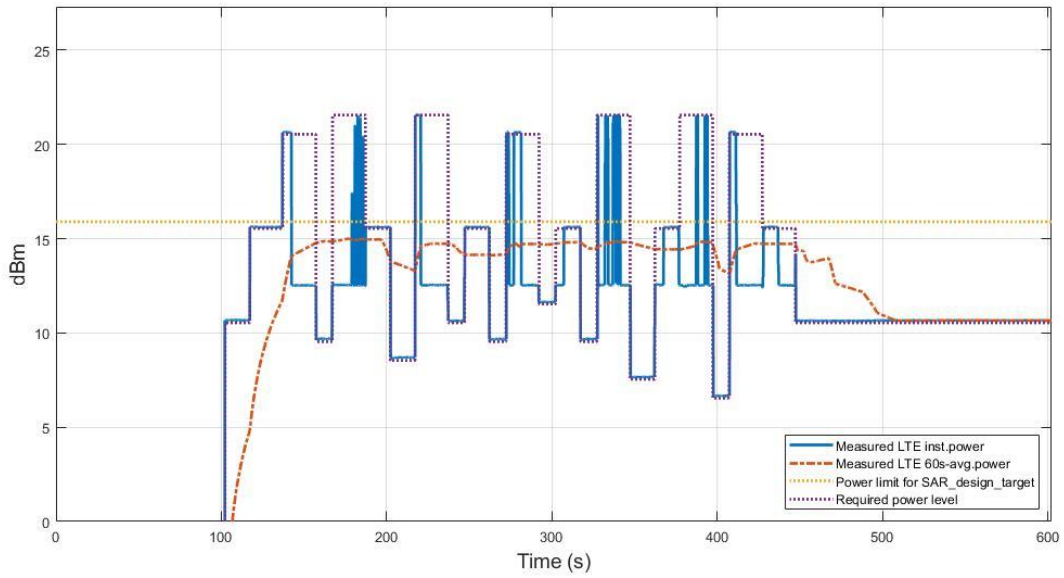


Figure 7.3-19 Conducted Tx power

Figure 7.3-19 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-20 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

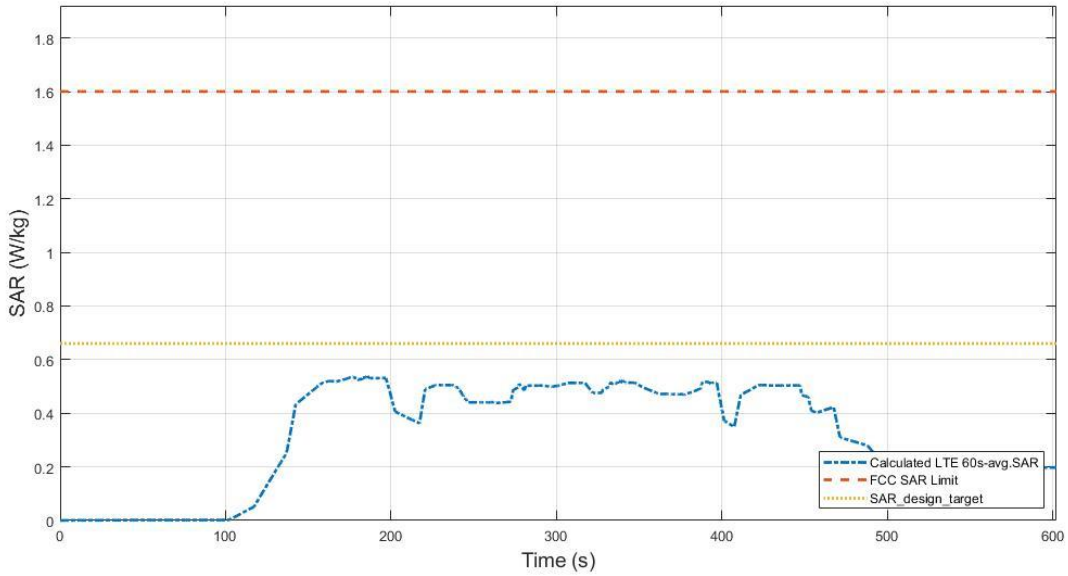


Figure 7.3-20 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.538 W/kg
Device uncertainty	1.25 dB

7.3.11 TC11: FR1 n7 SA mode _Time_Varying_Tx_Power_Case_2

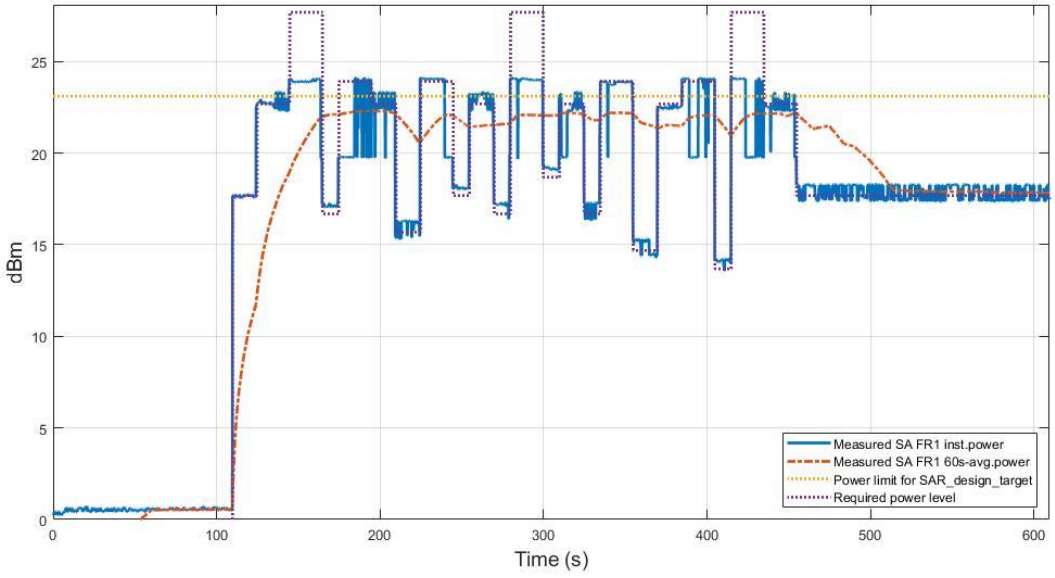


Figure 7.3-21 Conducted Tx power

Figure 7.3-21 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-22 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

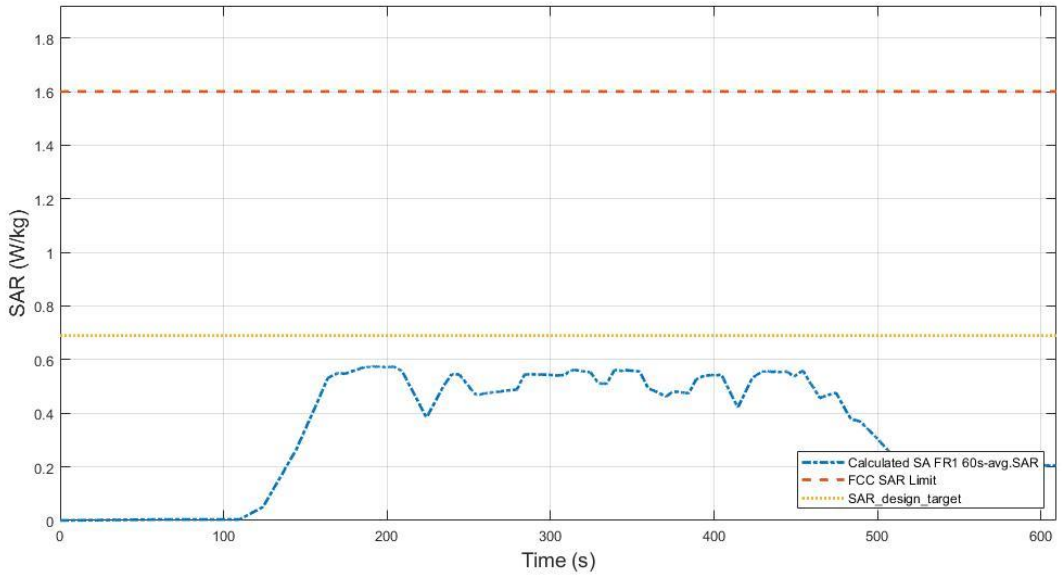


Figure 7.3-22 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.576 W/kg
Device uncertainty	0.9 dB

7.3.12 TC12: FR1 n25 SA mode_Time_Varying_Tx_Power_Case_2

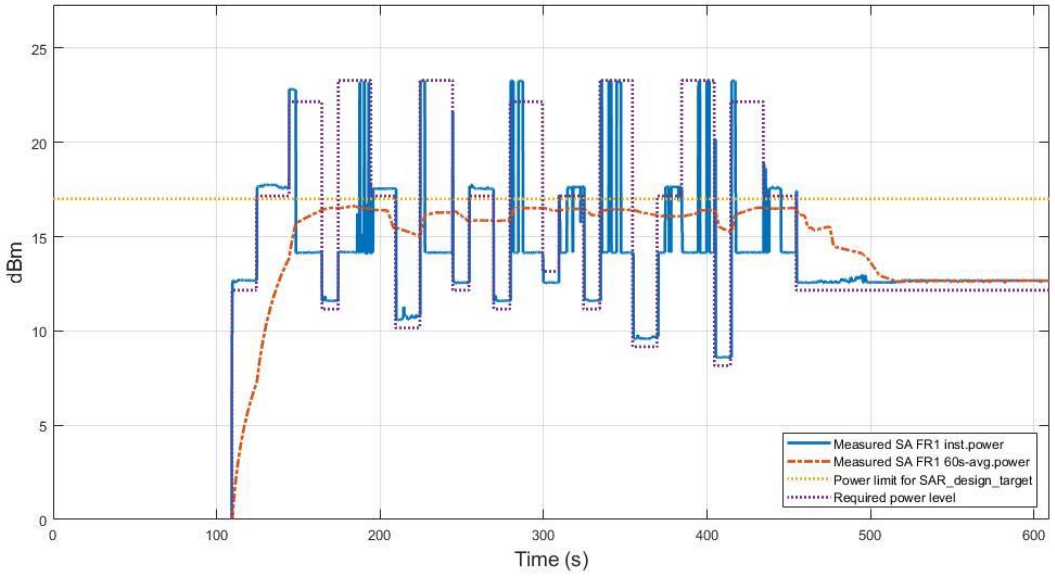


Figure 7.3-23 Conducted Tx power

Figure 7.3-23 shows the instantaneous and time-averaged Tx power with test sequence B. Figure 7.3-24 shows the plot of calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/Kg.

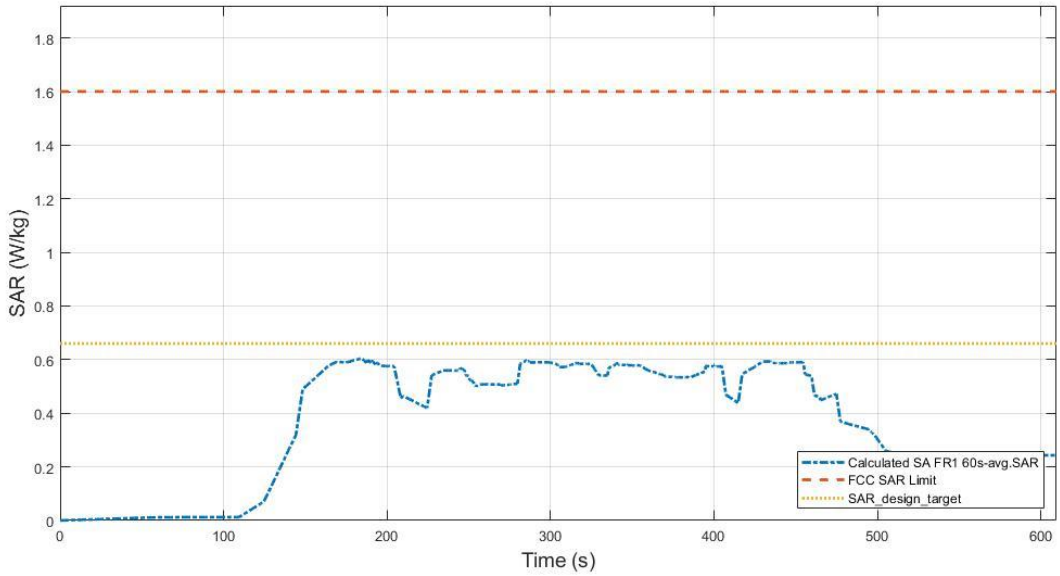


Figure 7.3-24 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.606 W/kg
Device uncertainty	1.15 dB

7.4 Change operate states

The test results in this section are obtained following the procedure in Section 3. The test cases correspond to TC#13 in Table 7.2.1.

7.4.1 TC13: SA_FR1 n25_RF_SAR_Index_Change

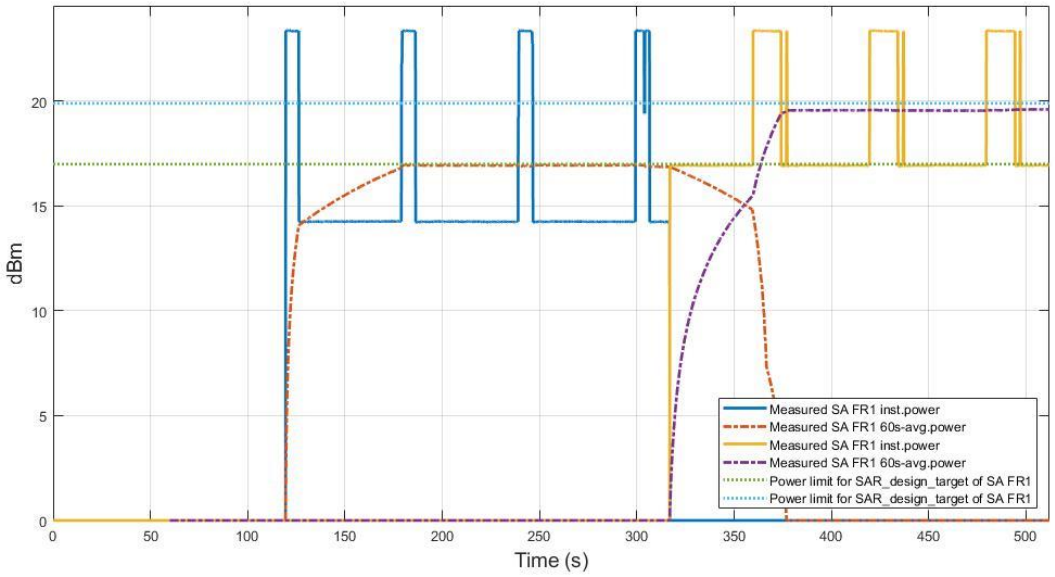


Figure 7.4-1 Conducted Tx power for SAR states change

Figure 7.4-1 shows the instantaneous and time-averaged conducted Tx power for both SA FR1 n25 for the duration of the test. Around time stamp of ~330s, the RFI value is changed from index 4 to index 5, resulting in reduction of target time-averaged power of SA FR1 n25. It can be seen that Plimit value of index 5 is lower than that of index 4, so in index 5 region, more Tx power is limited compared to index 4 region. Figure 7.4-2 shows the time-averaged 1gSAR value for each of index 5 and index 4 value, as well as the total SAR value.

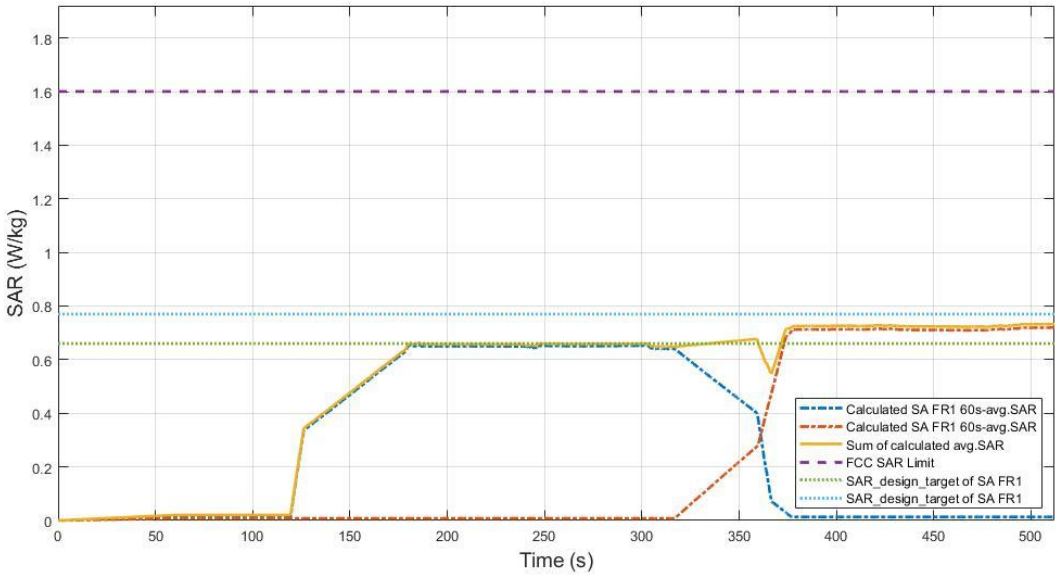


Figure 7.4-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.734 W/kg
Device uncertainty	1.1 dB

7.5 LTE Handover WCDMA results

The test results in this section are obtained following the procedure in Section 3. The test cases correspond to TC#14 in Table 7.2.1.

7.5.1 TC14: Wireless technology Handover

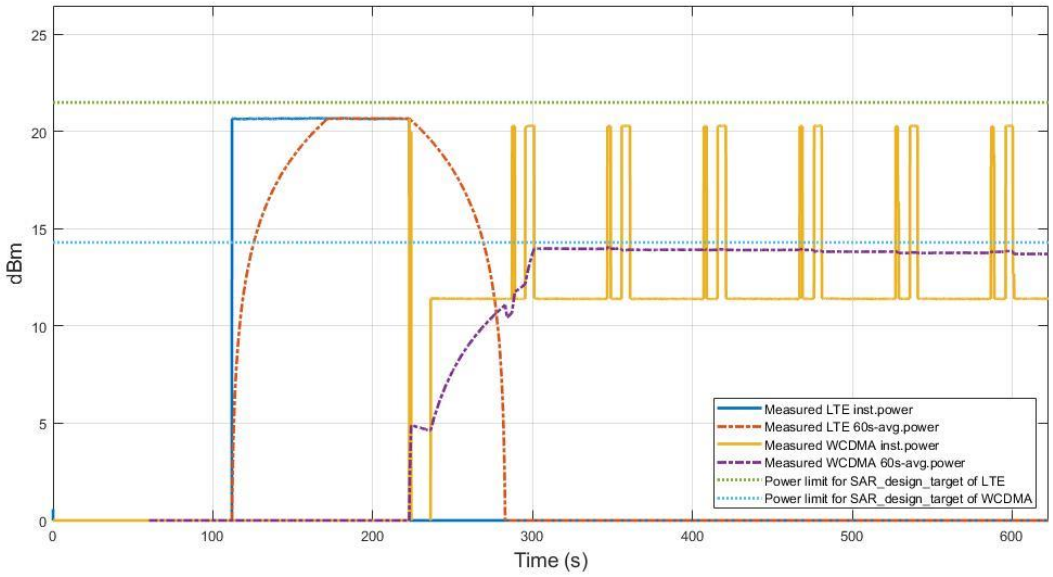


Figure 7.5-1 Conducted Tx power for Wireless technology Handover

Figure 7.5-1 shows the instantaneous and time-averaged conducted Tx power for both LTE B48 and WCDMA B2 for the duration of the test. Around time stamp of ~220s, a handover from LTE B48 to WCDMA B2 was executed, resulting in reduction of time-averaged power of LTE B48 and simultaneous increase in time- averaged power of WCDMA B2. Figure 7.5-2 shows the time-averaged 1gSAR value for each of LTE B48 and WCDMA B2, as well as the total SAR value.

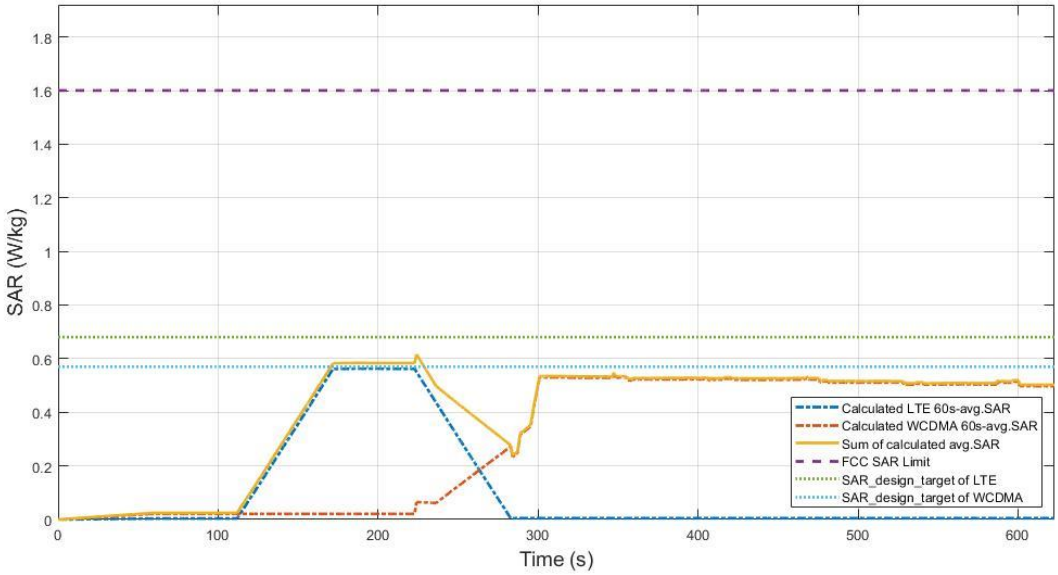


Figure 7.5-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.616 W/kg
Device uncertainty	1.7 dB

7.6 Change in call test results

The test results in this section are obtained following the procedure in Section 3. The test case corresponds to TC#15 in Table 7.2.1.

7.7.1 TC17: LTE Band 7_Call_Disconnect_Reestablishment

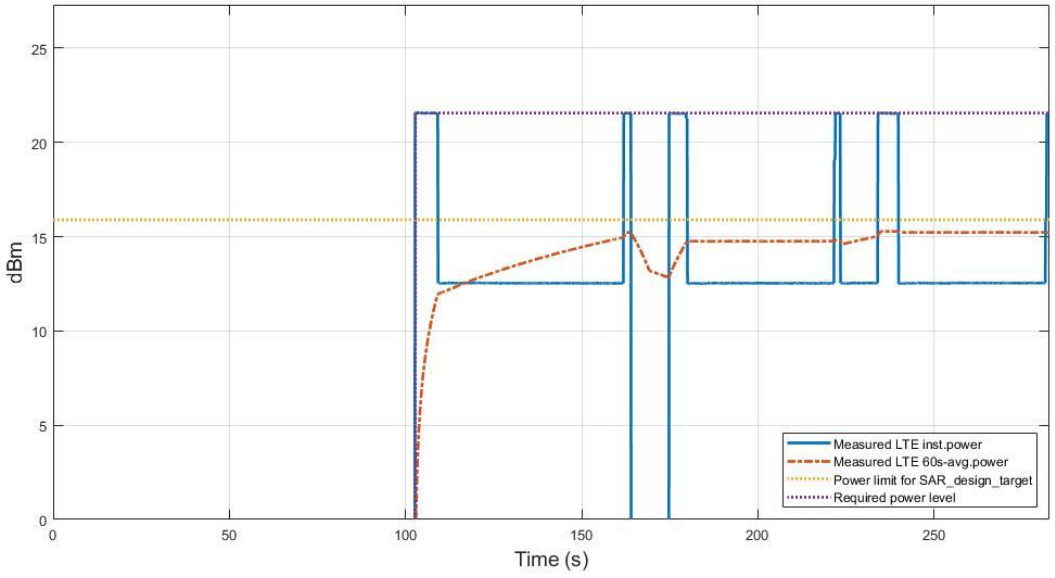


Figure 7.7-1 Conducted Tx power in Call_Disconnect_Reestablishment

Figure 7.7-1 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 7.7-2 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.

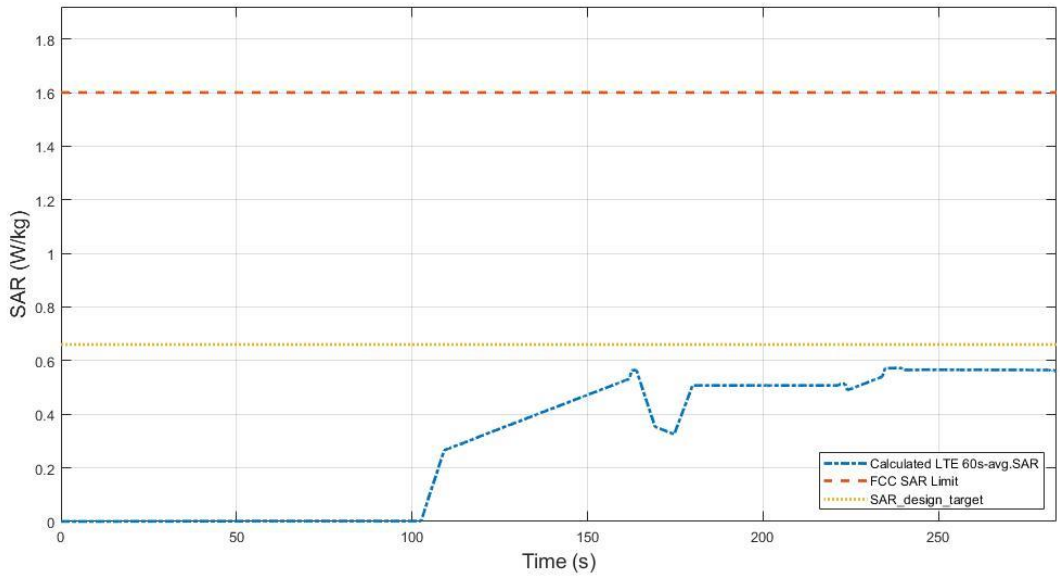


Figure 7.7-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max time average 1gSAR (blue curve)	0.572 W/kg
Device uncertainty	1.1 dB

7.7 Switch in SAR exposure test results

The test results in this section are obtained following the procedure in Section 3. The test cases correspond to TC#16 in Table 7.2.1.

7.8.1 TC18: NSA_FR1_Dominant_Power_Switching (ENDC LTE B25_FR1 n77)

In this LTE B25+FR1 n77 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.

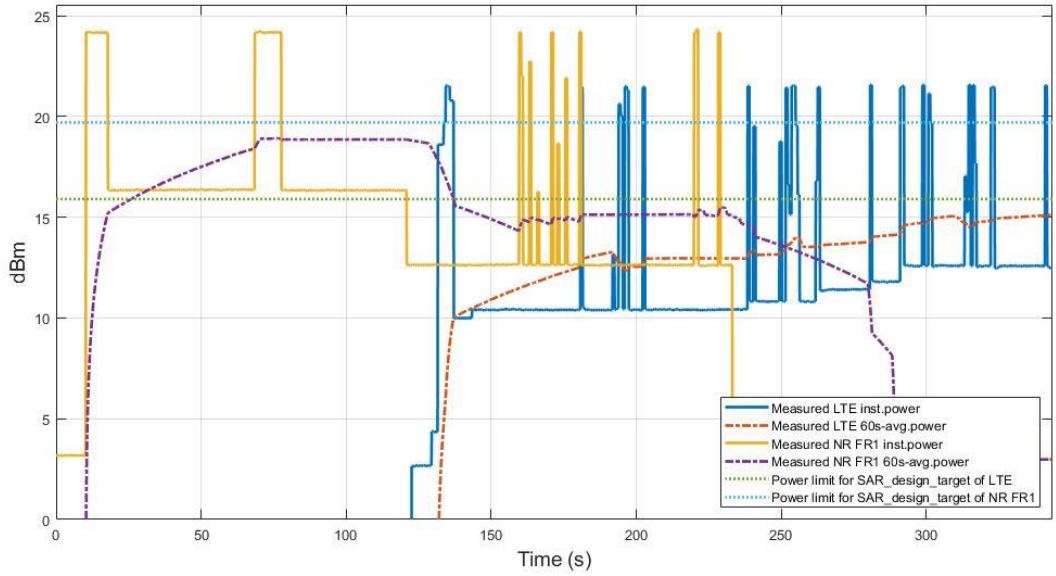


Figure 7.8-1 Time average SAR of LTE B25 and FR1 n77 in EN-DC case

Figure 7.8-1 shows the instantaneous and time-averaged Tx power for both LTE band B25 and NR FR1 band n77 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 7.8-2 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.

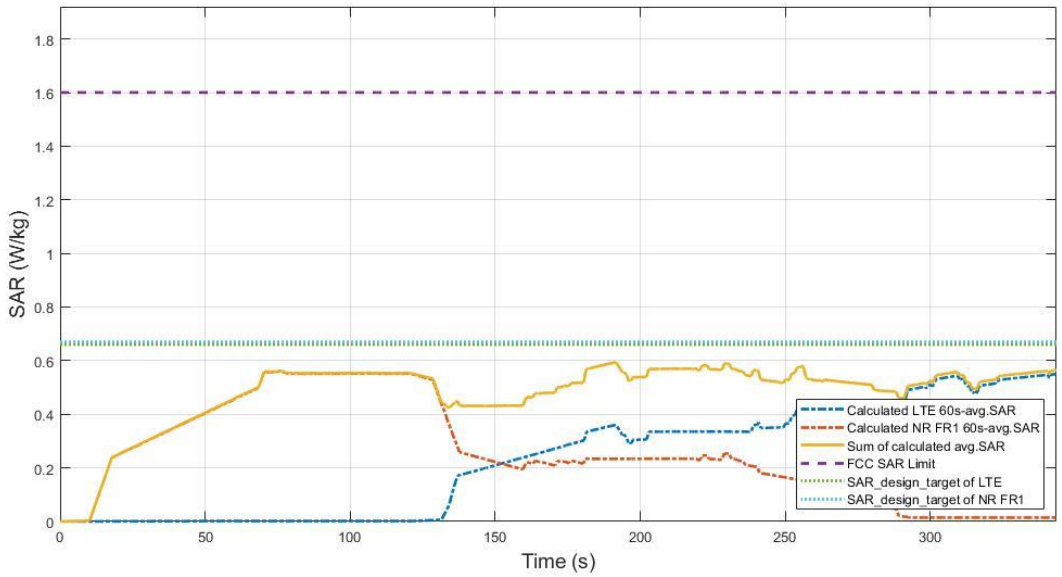


Figure 7.8-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.594 W/kg
Device uncertainty	1.1 dB

7.8 Re-selection in call test results

The test results in this section are obtained following the procedure in Section 3. The test cases correspond to TC#17 in Table 7.2.1.

7.9.1 TC19: FR1 n25 to LTE Band 48 IRAT Re-selection

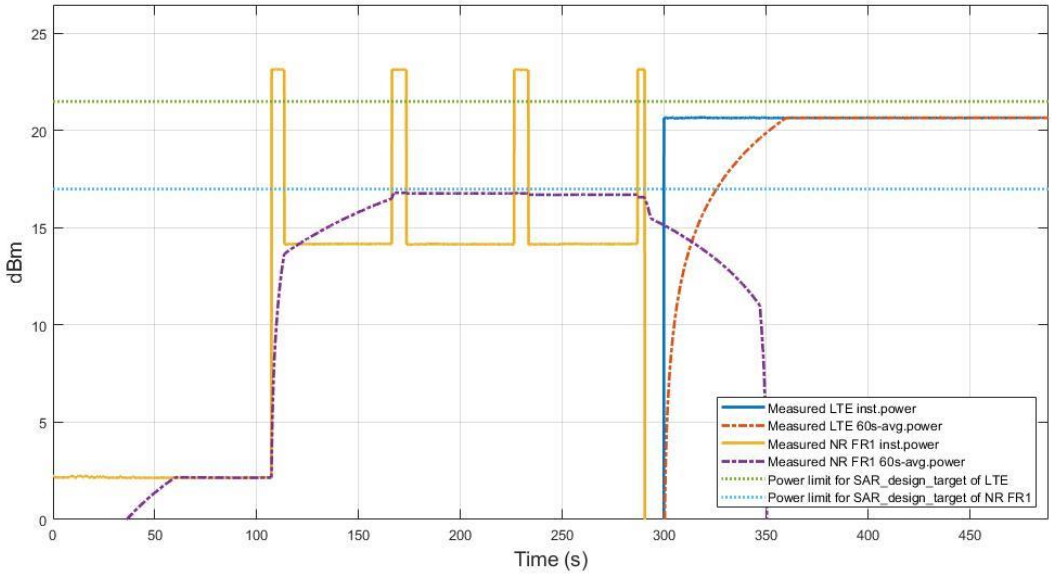


Figure 7.9-1 Conducted Tx power for SAR IRAT re-selection

Figure 7.9-1 shows the instantaneous and time-averaged conducted Tx power for both LTE Band 48 and NR FR1 n25 for the duration of the test. Around time stamp of ~310s, a RAT re-selection from LTE Band 48 to NR FR1 n25 was executed, resulting in reduction of time-averaged power of Band 48 and simultaneous increase in time-averaged power of n25. Figure 7.9-2 shows the time-averaged 1gSAR value for each of LTE Band 48 and NR FR1 n25, as well as the total SAR value.

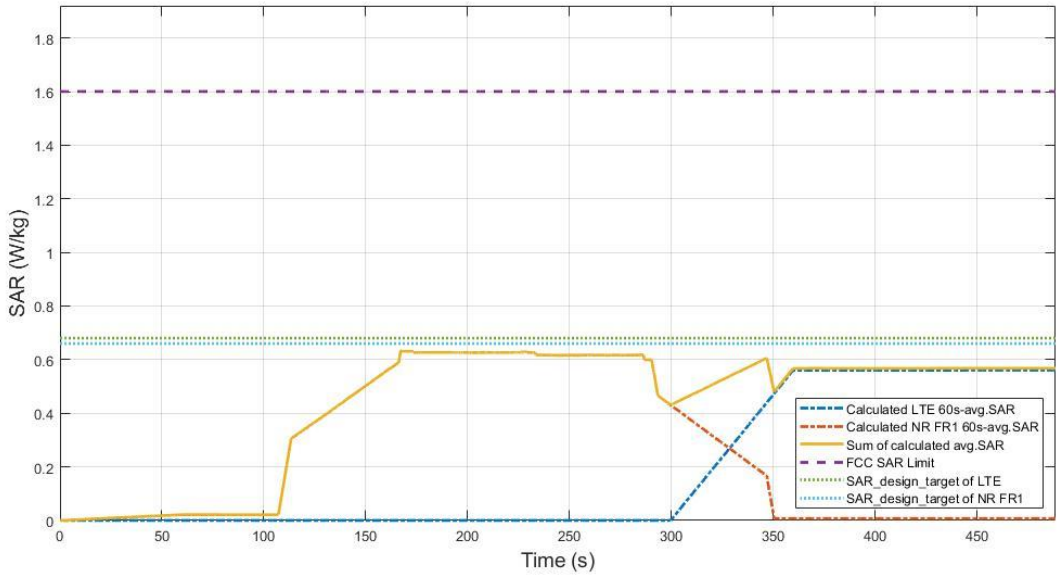


Figure 7.9-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.636 W/kg
Device uncertainty	1.1 dB

7.9 LTE Uplink CA

The test results in this section are obtained following the procedure in Section 3. The test cases correspond to TC#18 in Table 7.2.1.

7.10.1 TC20: LTE_UL_CA (LTE Band 66)

Figure 7.10-1 shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCC Limit value. In this test, SAR_design_target would be 0.66W/kg at 16.2dBm. The setting value and measured values are described in Table 7.2.1. An MPR of 2dB is configured within this band so with 100% duty cycle the maximum power should be reaching 23.9dBm.

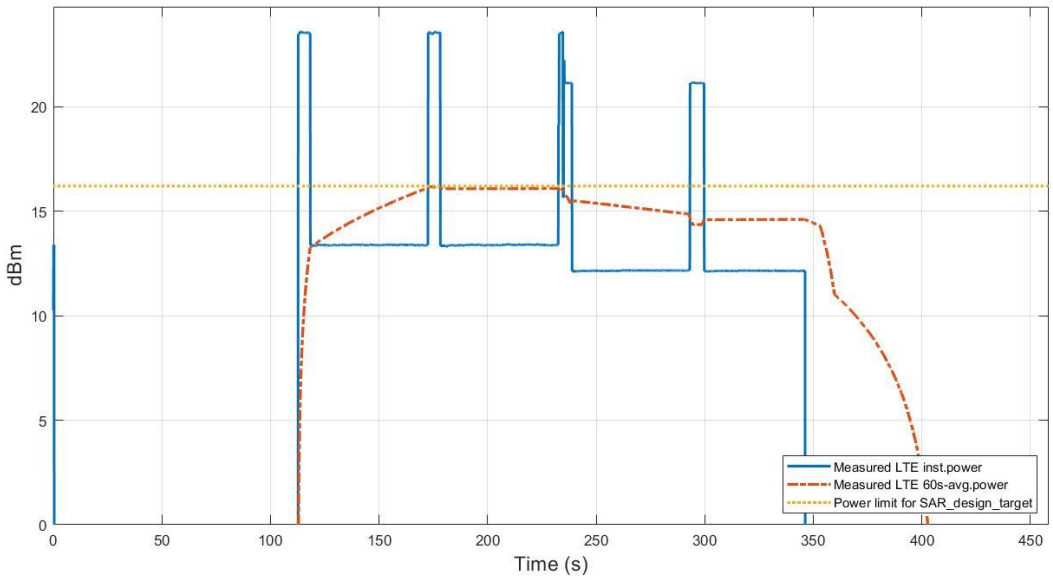


Figure 7.10-1 Conducted transmitted power of LTE Band 66 in UL CA

Next after 120s, an intra-band CA is configured (CA_66C) where a new CC is added and the transmission is continued for another 120s. As shown in Figure 7.10-1, the total power of the two CC is kept almost the same as in the single CC transmission. Average power in Figure 7.10-1 assures the compliance of the average power of the transmitted signal which is below 16.2dBm and consequently the average SAR in Figure 7.10-2 is below 1W/kg which is below the FCC limit of 1.6W/kg

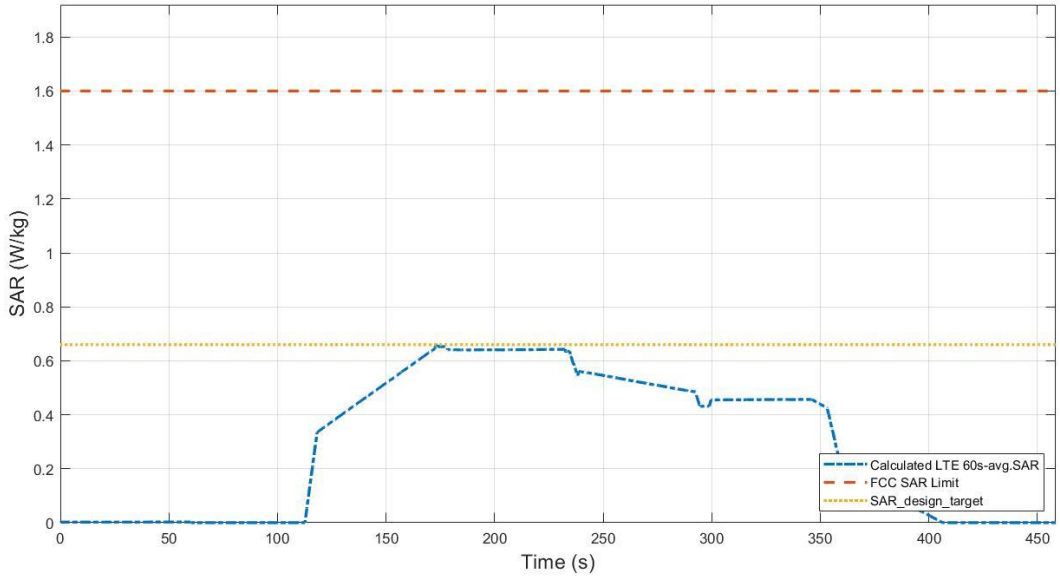


Figure 7.10-2 Total time-averaged SAR

FCC 1gSAR limit	1.6 W/kg
Max sum of calculated average SARs (yellow curve)	0.659 W/kg
Device uncertainty	1.1 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	Base Station	MT8821	6201074414	Aug. 23, 2023	Aug. 22, 2024
Anritsu	Base Station	MT8000	6262208374	Jan. 03, 2024	Jan. 02, 2025
Testo	Hygro meter	608-H1	45196600	Nov. 02, 2023	Nov. 01, 2024
Anritsu	Signal Generator	MG3710A	6201502524	Sep. 27, 2023	Sep. 26, 2024
Anritsu	Power Meter	ML2496A	2119003	Jul. 19, 2023	Jul. 18, 2024
Anritsu	Power Sensor	MA2411B	1911333	Jul. 19, 2023	Jul. 18, 2024
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.