Testing and Certification

TEST REPORT

FCC PART 2: RF Exposure Compliance Test for SM-X528U
Certification

APPLICANT
SAMSUNG Electronics Co., Ltd.

REPORT NO.
HCT-SR-2502-FC008

DATE OF ISSUE
February 12, 2025

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PART 2 RF Exposure Compliance Test for certification

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FCC ID
A3LSMX528U

Applicant	SAMSUNG Electronics Co., Ltd 129, Samsung-ro, Yeongtong-gu, Suwon-Si, Gyeonggi-do, 16677, Korea
Product Name Model Name	Tablet SM-X528U
FCC Rule Part(s):	CFR § 2.1093
Date of Test	Feb. 03, 2025 – Feb. 10, 2025
Location of Test	■ Permanent Testing Lab ☐ On Site Testing Lab (Address: 74, Seoicheon-ro 578beon-gil, Majang-myeon, Icheon-si, Gyeonggi-do, 17383 KOREA)
Results	Pass

REVISION HISTORY

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

Revision No.	Date of Issue	Description
0	Feb. 12, 2025	Initial Release

Notice

Content
The results shown in this test report only apply to the sample(s), as received, provided by the applicant, unless otherwise stated. The test results have only been applied with the test methods required by the standard(s). The laboratory is not accredited for the test results marked *. Information provided by the applicant is marked **. Test results provided by external providers are marked ***. When confirmation of authenticity of this test report is required, please contact www.hct.co.kr The test results in this test report are not associated with the ((KS Q) ISO/IEC 17025) accreditation by KOLAS (Korea Laboratory Accreditation Scheme) / A2LA (American Association for Laboratory Accreditation) that are under the ILAC (International Laboratory Accreditation Cooperation) Mutual Recognition Agreement (MRA).

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1. RF Exposure Limits

1.1RF Exposure Limits for Frequencies < 6 GHz

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

NOTES:

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

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

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

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be mad fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e.as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. This exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

1.2 RF Exposure Limits for Frequencies from 6 GHz - 300 GHz

Per October 2023 TCB Workshop Notes, the below time-averaging windows can be used for assessing time-averaged exposures for devices that are capable of actively monitoring and adjusting power output over timeto comply with exposure limits.

Frequency (GHz):	< 3	3–6	6–10	10-16	16-24	24-42	42-95
Max. Averaging Time (s):	100	60	30	14	8	4	2
From: Oct. 2018 TCBC Workshop, "RF Exposure Order/NPRM Issues"							

Note:
S.LSI's TAS algorithm applies an overall average time of 60 seconds for communication modes below 6 GHz frequency to control the output in the worst case.

2. Test Location

2.1 Test Laboratory

Company Name	HCT Co., Ltd.
Address	74, Seoicheon-ro 578beon-gil, Majang-myeon, Icheon-si, Gyeonggi-do, 17383 KOREA
Telephone	031-645-6300
Fax.	031-645-6401

2.2 Test Facilities

Our laboratories are accredited and approved by the following approval agencies according to ISO/IEC 17025.

Korea	National Radio Research Agency (Designation No. KR0032)
	KOLAS (Testing No. KT197) CAB identifier by FCC:KR0032

2.3 General Information of the EUT

Model Name	SM-X528U
Equipment Type	Tablet
FCC ID	A3LSMX528U
Application Type	Certification
Applicant	SAMSUNG Electronics Co., Ltd.

3. Information of the DUT

Device Wireless specification overview		
Band & Mode	Band & Mode	Band & Mode
UMTS Band 2	Data	1 852.4 MHz ~ 1 907.6 MHz
UMTS Band 4	Data	1 712.4 MHz ~ 1 752.6 MHz
UMTS Band 5	Data	826.4 MHz ~ 846.6 MHz
LTE FDD Band 2 (PCS)	Data	1 850.7 MHz ~ 1 909.3 MHz
LTE FDD Band 4 (AWS)	Data	1 710.7 MHz ~ 1 754.3 MHz
LTE FDD Band 5 (Cell)	Data	824.7 MHz ~ 848.3 MHz
LTE FDD Band 7	Data	2 502.5 MHz ~ 2 567.5 MHz
LTE FDD Band 12	Data	699.7 MHz ~ 715.3 MHz
LTE FDD Band 13	Data	779.5 MHz ~ 784.5 MHz
LTE FDD Band 14	Data	790.5 MHz ~ 795.5 MHz
LTE FDD Band 25	Data	1 850.7 MHz ~ 1 914.3 MHz
LTE FDD Band 26	Data	814.7 MHz ~ 848.3 MHz
LTE FDD Band 30	Data	2 307.5 MHz ~ 2 312.5 MHz
LTE TDD Band 38	Data	2 572.5 MHz ~ 2 617.5 MHz
LTE TDD Band 41	Data	2 498.5 MHz ~ 2 687.5 MHz
LTE TDD Band 48	Data	3 552.5 MHz ~ 3 697.5 MHz
LTE FDD Band 66 (AWS)	Data	1 710.7 MHz ~ 1 779.3 MHz
LTE FDD Band 71	Data	665.5 MHz ~ 695.5 MHz
NR FDD Band n2 (PCS)	Data	1 852.5 MHz ~ 1 907.5 MHz
NR FDD Band n5	Data	826.5 MHz ~ 846.5 MHz
NR FDD Band n25 (PCS)	Data	1 852.5 MHz ~ 1 912.5 MHz
NR FDD Band n30	Data	2 307.5 MHz ~ 2 312.5 MHz
NR TDD Band n41	Data	2 501.01 MHz ~ 2 685 MHz
NR TDD Band n48	Data	3 555 MHz ~ 3 695.01 MHz
NR FDD Band n66	Data	1 712.5 MHz ~ 1 777.5 MHz
NR FDD Band n70	Data	1 697.5 MHz ~ 1 707.5 MHz
NR FDD Band n71	Data	665.5 MHz ~ 695.5 MHz
NR TDD Band n77	Data	3 705 MHz ~ 3 975 MHz
NR TDD Band n77 DoD	Data	3 445.01 MHz ~ 3 544.98 MHz
NR TDD Band n78	Data	3 705 MHz ~ 3 795 MHz
NR TDD Band n78 DoD	Data	3 455.01 MHz ~ 3 544.98 MHz
U-NII-1	Data	5 180 MHz ~ 5 240 MHz
U-NII-2A	Data	5 260 MHz ~ 5 320 MHz
U-NII-2C	Data	5 500 MHz ~ 5 720 MHz
U-NII-3	Data	5 745 MHz ~ 5 825 MHz
U-NII-4	Data	5 845 MHz ~ 5 885 MHz
2.4 GHz WLAN	Data	2 412 MHz ~ 2 462 MHz
Bluetooth / LE 5.3	Data	2 402 MHz ~ 2 480 MHz
S-Pen	Data	531.25 kHz, 562.5 kHz, 593.75 kHz

Device Description		
Battery	EB-BX526ABY (ATL, SDI)	
Cover	EF-DX720(Variant 1), EF-DX725(Variant 2)	
S Pen	EJ-PX510	
	Test Case Descriptions	Serial Number
Device Serial Numbers	TC 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13	XLB0669M
	The manufacturer has confirmed that the devices tested have the same physical, mechanical and thermal characteristics are within operational tolerances expected for production units.	

Measurement Results Summary Table

TC#	Test scenario	Tech	Band	Antenna	RSI	Measured 1g SAR (W/kg)	Max averaged time 1g SAR (W/kg)	Test Result
1	Time varying Tx power Seqeunce 1	LTE	7	M1	2	0.397	0.412	Verified
2		SA/FR1	n77	M2	4	0.425	0.442	Verified
3		UMTS	4	M1	2	0.429	0.480	Verified
4	Time varying Tx power Seqeunce 2	LTE	7	M1	2	0.397	0.380	Verified
5		SA/FR1	n77	M2	4	0.425	0.403	Verified
6		UMTS	4	M1	2	0.429	0.457	Verified
7	Change in Call	LTE	7	M1	2	0.397	0.371	Verified
8	Modulation Chage	LTE	7	M1	2	0.397	0.381	Verified
9	Re-selection in call	SA/FR1	n41	M1	2	0.477	0.423	Verified
		LTE	7	M1		0.397		Verified
10	SAR exposure switch	LTE	12	M1	2	0.350	0.536	Verified
		NSA/FR1	n41	M1		0.477		Verified
11	Change in RSI	SA FR1	n77	M2	0	0.414	0.409	Verified
					4	0.425		Verified
12	NSA antenna switching with Spatial TAS	LTE	12	M1	0	0.411	0.615	Verified
		NSA/FR1	n66	M1		0.526		Verified
		NSA/FR1	n77	M2		0.419		Verified
13	Intra-band ULCA	LTE	66	M1	2	0.333	0.298	Verified
								Verified

Note:

1. The output power for SAR test in WWAN mode of this device is characterized as Free [RSI=0] Grip Sensor #1 [RSI=1], Grip Sensor #2 [RSI=2], Grip Sensor #3 [RSI=3], Grip Sensor #4 [RSI=4] and Grip Sensor #5 [RSI=5].

2. This device's main chipset use S.LSI TAS Algorithm which based on [OEM][Samsung S.LSI_S5300] Time-averaged SAR algorithm (FCC)v.3.3. and also the latest version [OEM [Samsung+S.LSI_S5400]+Time-averaged SAR algorithm+(FCC)_v1.1] has been applied to the TAS test

3. FCC SAR Limit [W/kg]: 1.6W/kg,1g, The SAR Design Target for Main Band is 1.0W/kg. Uncertainty of 1dB is applied to WWAN mode.

4. The range of change in the output Power of the Plimit of the TAS operation of this DUT is limited by the manufacturer to operate within a range of +6 dB ~-3dB.

4. Tx Varying Transmission Test Cases and Test Proposal.

In order to validate the TAS algorithm, we propose many test cases to confirm that TAS can ensure the compliance for different operation scenarios. In this section, we explain the reasoning for the selection of test cases and how the performance is validated.

As described in Section 4 the RF exposure is proportional to the Tx power for both sub-6GHz, and WLAN technologies. Thus, we rely on conducted power measurements for sub-6GHz RATs (such as 2G, UMTS, LTE and FR1), WLAN and Bluetooth power measurements in each dynamic case to demonstrate that overall RF exposure is within the FCC limit. Detailed test case numbering, procedures and test configurations are covered in Sections 5,7 and 8. The final performance validation results for all test cases are then provided in Sections 8 and 9. Here we provide a general explanation of how the tests carried out and some examples of the way results will be presented.

The overall procedure for validating any test case is summarized below:

1. Measure conducted power for any sub-6GHz RAT (such as LTE and FR1), WLAN and Bluetooth over time, denoted as $TxPower_{sub6GHz}(t)$, and radiated Power EIRP(FR2) over time, denoted $EIRP_{FR2}(t)$, with time index (t). These are measured values reported by the power meter referenced back to the UE antenna planes.
2. Convert measured powers to RF exposure values using linear relationship shown below. In below expression, $P_{limit,sub6GHz}$,would be the measured power at which the sub-6GHz technology meets measured SAR level of SAR_design_target. Similarly,$P_{limit,FR2}$ would be the measured EIRP at which FR2 technology meets the measured PD level of PD_desin_targets

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

Eqn. (1)

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

Eqn. (2)

3. Compute the total RF exposure over the most recent measurement duration which are denoted as $T_{SAR,2G}, T_{SAR,WCDMA}, T_{SAR,LTE}, T_{SAR,FR1}$ and T_{PD} for 2G, UMTS, LTE, FR1 and FR2, respectively. The maximum values for these durations are as specified by FCC. As an example, this total exposure within the measurement duration is given by adding up $SAR_{inst,sub6GHz}(u)$ and $PD_{inst,FR2}(u)$ for different RATs and bands for all time instances u within time intervals such as $[t - T_{SAR,LTE}. t]$, $[t - T_{SAR,FR1}. t]$ and $[t - T_{PD}. t]$ for LTE, FR1 and FR2, respectively.
4. Divide the total RF exposure for sub-6GHz RATs and FR2 by corresponding FCC limit and ensure the sum denoted as $TER(t)$ (or total exposure ratio at time t) is less than 1 for all t. Please refer to the equations in Algorithm operation which describes the detailed calculation of TER and its target constraint.

$$TER(t) = \frac{\sum_{l_{SAR}=0}^{L_{SAR}-1} SAR_{avg,l_{SAR}}(t)}{SAR_{limit,FCC}} + \frac{\sum_{l_{PD}=0}^{L_{PD}-1} PD_{avg,l_{PD}}(t)}{PD_{limit,FCC}} \leq 1$$ Eqn. (3)

Since TAS is implemented for different technologies (LTE, NR, UMTS, and 2G), separate test cases are chosen to show that TAS guarantees the compliance for all supported technologies. We have chosen

the test scenarios such that each technology is represented by at least one test case (or a part of a test) that shows its standalone operation using different requested power sequences in a single band. Usually, the maximum transmit power request at long durations will exercise the TAS algorithm fully to restrict allowed maximum power per window (when Plimit<Pmax).
However, some requested transmit power change sequences (in FR1) or beam change (in FR2) are also included to show that TAS maintains SAR/PD usage history in dynamic cases.

Additionally, tests cases are provided for different operations that can occur while still being connected to the same technology (rather than power request change). For example, TC involves inter-Band ULCA operation for FR1, which shows how TAS can handle the different operations of transmitting over two bands simultaneously and the addition/removal of a band/cell.
Other cases that are included to confirm the UE maintains and tracks SAR usage history are call disconnect/re-establishment and also RSI change tests (where Plimit can be changed during operation due to device state change). Moreover, UL-MIMO tests are included for rank 2 transmission over two antennas in addition to tests that include switching of operating bands.

Other scenarios include multi-RAT operations where two technologies can transmit simultaneously (such as EN-DC) or there is dynamic switching between each other (during inter-RAT handover). These scenarios include transitions when switching happens between technologies or a RAT/band is added or removed. LTE and NR are chosen with some specific bands to verify TER compliance in different scenarios which have multi-radio operations. Since the TAS operation is band/technology agnostic, only a few combinations are sufficient for testing. As an example, inter-RAT represents a switch of operation from one technology to another while both are not operating simultaneously. For simultaneous transmission of technologies, the EN-DC operation between LTE and FR1 and the NR-DC operation between FR1 and FR2, respectively.
These cases include the different scenarios such as addition/removal of a technology and the simultaneous operation between the two RATs.

Please note that these multi-technology/transmitters operations are the considered as the worst-case scenarios specially during the transitions of operations. To allow a separate TAS for each RAT, the SAR adjustment algorithm that handles the splitting of SAR budget between the RATs should control the increase of SAR allocation at any RAT in a very conservative manner such that compliance is ensured at any moment. In addition, sometime this algorithm enforces harsher actions (like setting lower power levels) if one RAT is consuming high amount SAR or even if this RAT is reducing its consumed SAR slower than the intended rate of SAR reduction. In addition, while ensuring compliance, the SAR adjustment algorithm aims to optimize the operation during transitions to allow a reasonable power level of transmission for both RATs.
In addition, our TAS algorithm supports another feature that can deal with the spatial properties of the antennas which we call Spatial TAS(S-TAS). This feature could boost the transmitted power as it takes into consideration the coupling between the different antennas and bands.
Spatial TAS allows each of two simultaneous transmitters that use two uncoupled antennas to transmit at an average power equal to their Plimit values. This means that the total power is doubled while ensuring the compliance. In addition, Spatial TAS has a major benefit for a single transmitter when switching between antennas.
If the antennas are uncoupled, then if the transmission was happening at Ant1 and switched to Ant2, Spatial TAS will start transmission at Ant2 without taking into consideration the consumed SAR at Ant1. This will enhance the capability of the transmitter at Ant2 to transmit with more power while ensuring that the TER/SAR is below the compliance limit at any time.
Please note that, coupling between antennas depends on the OEM device used. So, the OEM has to construct a coupling matrix that includes the coupling between each two antennas/antenna groups.

For this feature, the test cases are mainly chosen to show how the transmission on uncoupled antennas enhances the transmit power performance while still ensuring RF exposure compliance. The tests are chosen mainly to include multiple antennas transmissions (simultaneous transmission or switching between antennas) with different operations such as EN-DC and inter-band ULCA. For spatial TAS, several test cases are shown where multiple antennas are used for transmission.
In summary, 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 switch in SAR exposure-to prove that TAS feature can handle multi-RAT transmission with transitions in operation.

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

7. During UL MIMO-to prove that TAS feature can handle Tx power variations with Rank2 transmission.

8. During usage of Spatial TAS with uncoupled antennas for two transmit scenarios.

9. During usage of 60s averaging in <3GHz FR1 bands in addition to the previously supported 100s duration.

5. SAR Time Averageing Validation Test Procedures

Test Plan and test procedure for validating Samsung S.LSI TAS algorithm for FR1, WLAN and Bluetooth scenarios.

5.1 Test sequence determination for validation

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

1. Test sequence A which is generated with one or two levels where one of the levels (Pmax) which is appied at least for 150s. The other level is set at the target power level plus 2dB(Plimi(dBm)+2dB) and it lasts for at least 200s.

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

5.2. Test configuration selection for Validation TAS

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

5.2.1 Test configuration selection for time-varying Tx power transmission

The Samsung S.LSI TAS algorithm is independent of band, modes or channel of any technology. Hence, we can validate using one or two combinations of band/mode/channel per technology. The criteria for selecting these would be based on the relative value of Plimit and Pmax as determined in SAR PART 0 Report. Essentially, we need to pick this combination such that Plimit is less than Pmax so that the TAS algorithm will enforce power restriction.

5.2.2 Test configuration selection for change in call

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

5.2.3 Test configuration for change in RSI (Radio SAR index)

The criteria for selecting test case to demonstrate compliance across RSI change within a radio. The two RSI states are chosen by pick a technology/band from SAR Part 0 Report such that Plimit is less than Pmax for both states. However, to show the performance of the TAS algorithm in this document, the case of low Plimit is considered, which is shown in Table 8.2-1.

5.2.4 Test configuration for change in modulation

The criteria for selecting test case to demonstrate compliance across modulation change within a radio. The two module states are chosen by pick a technology/band from SAR PART 0 Report such that Plimit is less than Pmax for both states. However, to show the performance of the TAS algorithm in this document, the case of low Plimit is considered, which is shown in Table 8.2-1.

5.2.5 Test configuration for SAR exposure switching

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

5.2.6 Test configuration for change in technology/band/antenna

FCC specifies different measurement durations for time averaging based on operating frequency. The criteria for selecting test case to demonstrate compliance is to pick a technology/band/antenna corresponding to antenna groups from SAR PART 0 Report such that Plimit is less than Pmax.

5.2.7 Test configuration for Uplink CA

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

5.2.8 Test configuration for Uplink MIMO

The criteria for selecting test case is to demonstrate the compliance of the TAS algorithm when a rank2 SA FR1 transmission is done over 2 Tx antennas. This test shows that the TAS algorithm compliance by ensuring a total average SAR below the designated compliance level.

5.2.9 Test configuration for NSA antenna 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 change the antenna at maximum power for LTE and NR.

5.2.10 Test configuration for NTN

The criteria of selecting this test configuration is to demonstrate that Samsung S.LSI algorithm is independent of bands or technology used. We will show that the algorithm can control the transmitted power of an NTN transmission when a maximum power is requested.

5.2.11 Test configuration for WLAN & Bluetooth

The criteria for selecting test case to demonstrate compliance across RSI change within a radio. The two RSI states are chosen by pick a technology/band from Table 6-1 such that Plimit is less than Pmax for both states. However, to show the performance of the TAS algorithm in this document, the case of low Plimit is considered, which is shown in Table 8.2-1.

5.3 Test procedures for conducted power measurements

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

5.3.1 Time-varying Tx power transmission scenario

This test is performed with two pre-defined test sequences as described in Section 5.1 for all technologies operating on sub-6GHz applying to GSM, UMTS, LTE and FR1. 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.

5.3.1.1 Test procedure

1. Using the Pmax and Plimit obtained in Table 8.2.1, generate the test sequence of power levels for each selected technology/band. Both test sequences A and B are generated. Maximum power can be changed according to DUT test results.

2. Establish the connection of the DUT to the call box in the selected RAT, with the call box requesting the DUT Tx power to be according to the sequence determined in Step 1. An initial value of Tx power will be set to 0dBm for 60s 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

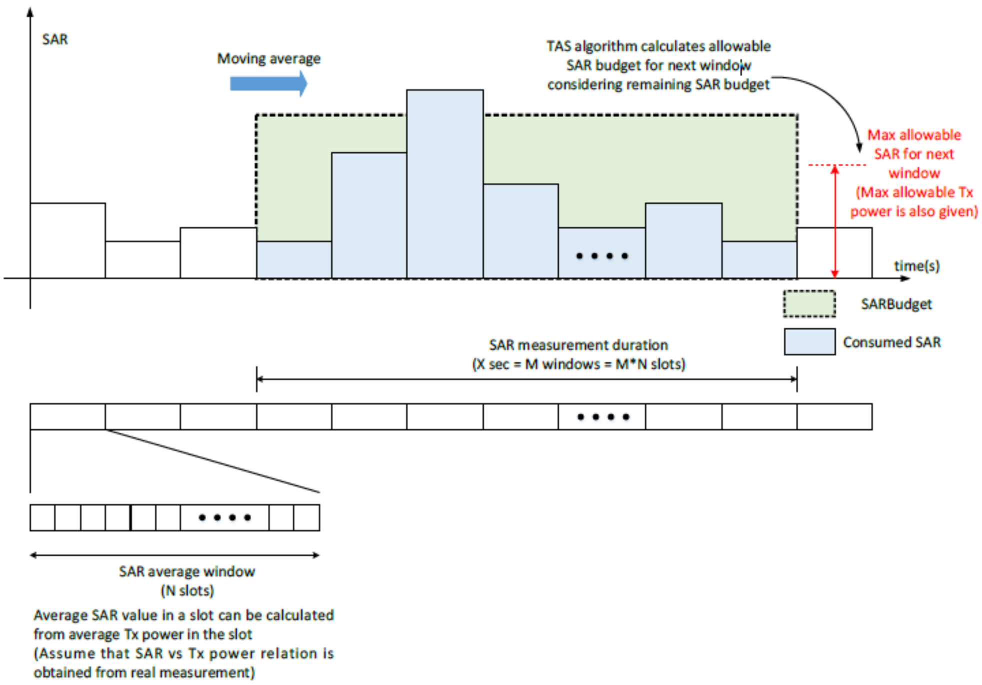

Figure 5.3-1 SAR measurement from Tx power using block-wise processing

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 60s using instantaneous values from Step 2
   D. Power level Plimit which is determined as meeting SAR target in Table 8.2.1(Pmax Plimit Table)

5. Make a second plot containing the following information:
   A. Computed time-averaged 1gSAR versus time determined in Step 2
   B. 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.

5.3.2 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.

5.3.2.1 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 0dBm for 60s.
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 150s 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 and continue for 140s
6. Release LTE connection.
7. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Requested Tx power versus time (c) Time-averaged power over 100s using instantaneous values and (d) Power level Plimit which is determined as meeting SAR target
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time and (b) FCC 1gSAR limit of 1.6W/kg.

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

5.3.3 Change in technology/band

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

$$SAR_1(t) = \frac{TxPower_1(t)}{P_{limit,1,FR1}} * SAR\_design\_target_1 \quad (5.3\text{-}1)$$

$$SAR_2(t) = \frac{TxPower_2(t)}{P_{limit,2,FR1}} * SAR\_design\_target_2 \quad (5.3\text{-}2)$$

where $P_{limit,1,FR1}$ would correspond to measured power at which first technology/band meets measured SAR level of SAR_design_target as described in Table 8.2.1 with time-averaging duration of T_{1SAR} . Similarly, the quantities $P_{limit,2,FR1}$, SAR_$design_target_{2,}T_{2,SAR}$ are defined for the second technology/band/antenna/ In this document, 60s is considered for all sub 6GHz including below 3GHz.

5.3.3.1 Test procedure for handover between two TAS RATs

1. Establish radio connection of DUT with call box e.g. using 5G FR1 NR technology
2. Configure call box to set DUT Tx power to a low value of 0dBm for 60s.
3. Configure call box to send “ALL UP” power control commands and continue SA FR1 transmission from DUT so that maximum power of Pmax is achieved. Continue transmission at the maximum power for 150s.
4. Change RAT from NR to LTE and configure call box to send “ALL UP” power control commands in LTE
5. Continue call in LTE at maximum power for 150s.
6. Release LTE connection
7. After the completion of the test, prepare one plot with the following information for each RAT (a)Instantaneous Tx power versus time (b) Time-averaged power for each RAT over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each RAT (b) Sum of time-averaged SAR computed according to Eqn. (5.3-1) and (5.3-2), and (c) FCC1g SAR limit of 1.6W/kg

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

5.3.3.2 Test procedure for band/antenna change

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 0dBm for 60s.

3. Configure call box to send “ALL UP” power control commands and continue LTE Band A transmission from DUT so that maximum power of Pmax is achieved. Continue transmission for 150s.

4. Change band from LTE Band A to LTE Band B and configure call box to send “ALL UP” power control commands in LTE for another 150s.

5. Release LTE connection.

6. After the completion of the test, prepare one plot with the following information for each RAT (a) Instantaneous Tx power versus time (b) Time-averaged power for each RAT over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.

7. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time for each RAT (b) Sum of time-averaged SAR computed according to Eqn. (5.3-1) and (5.3-2), 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/antenna change occurs in-between.

5.3.4 Change in RSI

This test is to demonstrate that Samsung S.LSI TAS feature can properly handle change of RSI resulting from different SAR index state detected by host platform software. It involves changing the Plimit value during the test for the same technology to emulate RSI change, while the SAR_design_target remains the same. Note that the DUT has a Hotspot mode to manage body exposure, which is represented using RSI = 0, the head exposure can be distinguished through audio receiver mode, represented as RSI = 1.

5.3.4.1 Test procedure for change in RSI

1. Establish radio connection of DUT with call box e.g. using NR SA FR1
2. Configure DUT to send at low Tx power of 0 dBm for 60s and set the RSI index corresponding to Plimit.
3. Configure call box to send “ALL UP” power control commands and continue SA FR 1 transmission from DUT so that maximum power of Pmax is achieved. Continue the transmission for 150s.
4. Change the RSI index corresponding to lower value and continue the transmission for another 150s
5. Release the SA FR1 connection.
6. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target
7. 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 1.6 W/kg throughout the test duration. It is required to check if power limiting enforcement is operated as expected when RSI index is changed during the test.

5.3.5 SAR exposure switching

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

5.3.5.1 Test procedure for SAR exposure switching

1. Establish LTE and NR radio connection in NSA case with both call boxes, e.g. LTE and NR FR1 Technology.
2. Configure the LTE and NR call box to set DUT Tx power to a low value of 0dBm for 60s.
3. Configure the NR call box to send “ALL UP” power control commands and continues transmission from DUT so that maximum power of Pmax is achieved. Continue transmission for 150s
4. In the second part of test configure the LTE call box to send “ALL UP” power control commands and all transmissions are continued, resulting in maximum power requested from DUT for both LTE and NR. This stage of test is continued for another 150s.
5. In the third part of test, configure the NR call box to send “ALL DOWN” power control commands so that LTE becomes the dominant SAR radio. This stage is continued for another 150s.
6. Release the both LTE and NR connections.
7. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time and (b) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate 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 dominant power is changed in EN-DC.

5.3.6 Test procedure for NSA antenna switching

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

5.3.6.1 Test procedure

1. Establish LTE and NR radio connection in NSA case with both call boxes, e.g. LTE and NR FR1 Technology.
2. Configure the LTE and NR call box to set DUT Tx power to a low value of 0dBm for 60s.
3. Configure the LTE call box to send “ALL UP” power control commands and continues transmission from DUT so that maximum power of Pmax is achieved. Continue transmission for 150s.
4. In the second part of test, configure the NR call box to send “ALL UP” power control commands and all transmissions are continued, resulting in maximum power requested from DUT for both LTE and NR. This stage of test is continued for another 150s.
5. In the third part of test, change band from NR SA FR1 on AG0 to AG1 and configure call box to send “ALL UP” power control commands in NR for another 150s.
6. Release the both LTE and NR connections.
7. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.
8. Make a second plot containing the following information (a) Computed time-averaged 1gSAR versus time and (b) FCC 1gSAR limit of 1.6W/kg.

Pass condition is to demonstrate 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 Tx antenna is changed in EN-DC

5.3.7 Uplink CA

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

5.3.7.1 Test procedure for intra-band uplink CA

1. Establish LTE connection of DUT with call box over Cell 1 E.g. one cell of the band Combo CA.
2. Configure the call box to set DUT Tx power to a low value of 0dBm for 60s.
3. Configure Call box to send "ALL UP" power control commands and continue transmission from DUT so that maximum power of Pmax is achieved. Continue transmission for 150s
4. Establish LTE connection of DUT with call box over Cell 2 E.g. other cell of the band Combo CA and configure call box to send "ALL UP" power control command on cell 2 for 150s.
5. Release LTE connection for both cells
6. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.
7. 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 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 intra-band change occurs.

5.3.7.2 Test procedure for inter-band uplink CA

1. Establish LTE/NR connection of DUT with callbox PCC
2. Configure call box to set DUT Tx power to a low value of 0dBm for 60s.
3. Configure call box to send "ALL UP" power control commands and continue transmission from DUT so that maximum power of Pmax is achieved. Continue transmission for 150s.
4. Establish an inter-band ULCA connection by attaching a secondary cell connection SCC and configure call box to send "ALL UP" power control commands for 150s.
5. Release the LTE/NR connection
6. After the completion of the test, prepare one plot with the following information (a)Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.
7. 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 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 inter-band change occurs.

5.3.8 Change in modulation change 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.

5.3.8.1 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 below 0dBmfor 60s.
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 the transmission for 150s.
4. Change the modulation from QPSK to 16QAM from call box and continued the transmission for another 150s.
5. Release LTE connection.
6. After the completion of the test, prepare one plot with the following information (a) Instantaneous Tx power versus time (b) Time-averaged power over 60s using instantaneous values and (c) Power level Plimit which is determined as meeting SAR target.
7. 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 modulation change. Current TAS algorithm software makes the UE estimate the exact amount of Tx power and average SAR even during modulation change event.

5.4 Spatial TAS

For the test cases with spatial TAS, we will consider 2 antennas (Main 1 and Main2) with two antenna groups where each antenna group consists of two antennas and multiple bands as in Table 5.4-1.

Table 5.4-1 Antennas and bands used in the spatial TAS conducted tests

AG#	Antenna	Band
AG0	Main 1	UMTS 4, LTE 7, LTE 12, LTE 66 NR n66
AG1	Main 2	NR n77

The coupling matrix considered during the tests is

$$R = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

6. Test Configurations

Plim values in green indicate Plimit < Pmax			Plim values in green indicate Plimit > Pmax						
Plimit corresponding to 1 W/kg (1g) SAR_Design_target									Pmax
SAR Exposure Position			Free RSI = 0	Grip (#1) RSI = 1	Grip (#2) RSI = 2	Grip (#3) RSI = 3	Grip (#4) RSI = 4	Grip (#5) RSI = 5	Maximum Tune-up Output Power (Frame Averaged Power) [dBm]
Averaging volume			1g	1g	1g	1g	1g	1g	
seperation Distance			0,10,18,19 mm	0 mm	0 mm	0 mm	0 mm	0 mm	
Mode	Band	Antenna	Free	Grip	Grip	Grip	Grip	Grip	
UMTS	2	Main1	27.1	16.5	12.5	16.5	N/A	N/A	24.0
UMTS	4	Main1	27.1	20.0	13.0	20.0	N/A	N/A	24.0
UMTS	5	Main1	27.3	21.5	15.0	21.5	N/A	N/A	24.0
LTE FDD	7	Main1	26.8	21.5	9.0	21.5	N/A	N/A	24.0
LTE FDD	7	Sub1	26.2	N/A	N/A	N/A	N/A	11.0	23.0
LTE FDD	25 (2)	Main1	27.1	17.5	11.5	17.5	N/A	N/A	24.0
LTE FDD	25 (2)	Sub1	29.1	N/A	N/A	N/A	N/A	10.5	23.0
LTE FDD	66 (4)	Main1	27.5	21.0	11.5	21.0	N/A	N/A	24.0
LTE FDD	66 (4)	Sub1	31.5	N/A	N/A	N/A	N/A	10.5	24.0
LTE FDD	30	Main1	28.4	20.5	11.5	20.5	N/A	N/A	23.0
LTE FDD	30	Sub1	27.5	N/A	N/A	N/A	N/A	13.5	23.0
LTE FDD	12	Main1	27.7	N/A	14.0	N/A	N/A	N/A	24.0
LTE FDD	13	Main1	25.7	N/A	12.5	N/A	N/A	N/A	24.0
LTE FDD	14	Main1	26.0	N/A	13.0	N/A	N/A	N/A	24.0
LTE FDD	26 (5)	Main1	26.3	23.0	14.0	23.0	N/A	N/A	24.0
LTE TDD	41 PC3 (38)	Main1	25.3	N/A	10.0	N/A	N/A	N/A	22.0
LTE TDD	41 PC2	Main1	25.6	N/A	10.0	N/A	N/A	N/A	22.4
LTE TDD	48	Sub2	7.5	7.5	7.5	7.5	7.5	7.5	21.0
LTE FDD	71	Main1	30.5	N/A	15.5	N/A	N/A	N/A	24.0
NR FDD	n5	Main1	27.2	23.0	14.0	23.0	N/A	N/A	24.0
NR FDD	n25 (2)	Main1	27.5	17.5	11.5	17.5	N/A	N/A	24.0
NR FDD	n30	Main1	28.2	20.5	11.5	20.5	N/A	N/A	23.0
NR FDD	n66	Main1	27.1	21.0	11.5	21.0	N/A	N/A	24.0
NR TDD	n41 PC3	Main1	18.0	N/A	11.0	N/A	N/A	N/A	24.0
NR TDD	n41 PC2	Main1	18.0	N/A	11.0	N/A	N/A	N/A	26.5
NR TDD	n48 SRS0	Sub2	9.0	9.0	9.0	9.0	9.0	9.0	23.0
NR TDD	n48 SRS1	Sub4	9.0	N/A	N/A	2.5	N/A	N/A	14.0
NR TDD	n48 SRS2	Main2	18.0	N/A	N/A	N/A	10.5	N/A	23.0
NR TDD	n48 SRS3	Sub3	4.0	4.0	4.0	4.0	4.0	4.0	16.0
NR FDD	n70	Main1	26.5	18.5	12.5	18.5	N/A	N/A	24.0
NR FDD	n71	Main1	30.6	N/A	15.5	N/A	N/A	N/A	24.0
NR TDD	n77 (78) PC3 SRS0	Main2	18.0	N/A	N/A	N/A	8.5	N/A	24.0
NR TDD	n77 (78) PC3 SRS1	Sub3	5.0	5.0	5.0	5.0	5.0	5.0	18.0
NR TDD	n77 (78) PC3 SRS2	Sub2	12.0	12.0	12.0	12.0	12.0	12.0	24.0
NR TDD	n77 (78) PC3 SRS3	Sub4	10.5	N/A	N/A	1.5	N/A	N/A	16.0
NR TDD	n77 (78) PC2 SRS0	Main2	18.0	N/A	N/A	N/A	8.5	N/A	27.0
NR TDD	n77 (78) PC2 SRS1	Sub3	5.0	5.0	5.0	5.0	5.0	5.0	19.0
NR TDD	n77 (78)PC2 SRS2	Sub2	12.0	12.0	12.0	12.0	12.0	12.0	27.0
NR TDD	n77 (78) PC2 SRS3	Sub4	10.5	N/A	N/A	1.5	N/A	N/A	17.0
NR TDD	n77(78) PC3 DoD SRS0	Main2	18.0	N/A	N/A	N/A	8.5	N/A	24.0
NR TDD	n77(78) PC3 DoD SRS1	Sub3	5.0	5.0	5.0	5.0	5.0	5.0	18.0
NR TDD	n77(78) PC3 DoD SRS2	Sub2	12.0	12.0	12.0	12.0	12.0	12.0	24.0
NR TDD	n77(78) PC3 DoD SRS3	Sub4	10.5	N/A	N/A	1.5	N/A	N/A	16.0
NR TDD	n77(78) PC2 DoD SRS0	Main2	18.0	N/A	N/A	N/A	8.5	N/A	27.0
NR TDD	n77(78) PC2 DoD SRS1	Sub3	5.0	5.0	5.0	5.0	5.0	5.0	19.0
NR TDD	n77(78) PC2 DoD SRS2	Sub2	12.0	12.0	12.0	12.0	12.0	12.0	27.0
NR TDD	n77(78)PC2 DoD SRS3	Sub4	10.5	N/A	N/A	1.5	N/A	N/A	17.0

Table 6-1

Note:

1. Radio SAR indicator (RSI) in the table above means the SAR test configuration of each mobile communication technology.
2. Plimit and Tune up output power Pmax above table correspond to average power level accounting for duty cycle in the case of TDD Modulation schemes (LTE TDD)
3. Maximum tune up output Power Pmax is used to configure DUT during RF tune up procedure. The maximum allowed output power is equal to Tune up power +1 dB device design uncertainty.
4. Compared with the Plimit (Tune up Powers) declared in each RSI by the manufacturer and the Plimit (calculation) calculated by the SAR measurement of each RSI, the lower power is applied to the DUT as the Plimit at each RSI configurations.

7. Test case list

7.1 Test case list for sub-6GHz transmissions

To validate TAS algorithm in various sub-6GHz conditions, the chosen TC(Test Case) list is defined as in Table 7.1-1

TC#	Test scenario	Tech	Band	Antenna	RSI	RB/offset/BW	Mode	Congfiguration
1	Time varying Tx power Seqeunce 1	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body
2		SA/FR1	n77	M2	4	1/1/100MHz	DFT-s QPSK	0mm/Body
3		UMTS	4	M1	2	-		0mm/Body
4	Time varying Tx power Seqeunce 2	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body
5		SA/FR1	n77	M2	4	1/1/100MHz	DFT-s QPSK	0mm/Body
6		UMTS	4	M1	2	-	0	0mm/Body
7	Change in Call	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body
8	Modulation Chage	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body
							16QAM	
9	Re-selection in call	SA/FR1	n41	M1	2	1/1/100MHz	DFT-s QPSK	0mm/Body
		LTE	7	M1		1/1/20MHz	QPSK	0mm/Body
10	SAR exposure switch	LTE	12	M1	2	1/1/10MHz	QPSK	0mm/Body
		NSA/FR1	n41	M1		1/1/100MHz	DFT-s QPSK	0mm/Body
11	Change in RSI	SA FR1	n77	M2	0	1/1/100MHz	DFT-s QPSK	0mm/Body
					4			0mm/Body
12	NSA antenna switching with Spatial TAS	LTE	12	M1	0	1/1/10MHz	QPSK	0mm/Body
		NSA/FR1	n66	M1		1/1/40MHz	DFT-s QPSK	0mm/Body
		NSA/FR1	n77	M2		1/1/100MHz		0mm/Body
13	Intra-band ULCA	LTE	66	M1	2	50/0/20MHz	PCC(QPSK)	0mm/Body
						50/49/20MHz	SCC(QPSK)	0mm/Body

Table 7.1-1 Sub-6GHz TAS validation test case list

8. Conducted Power Test Results for sub-6 TAS validation

8.1 Measurement set-up

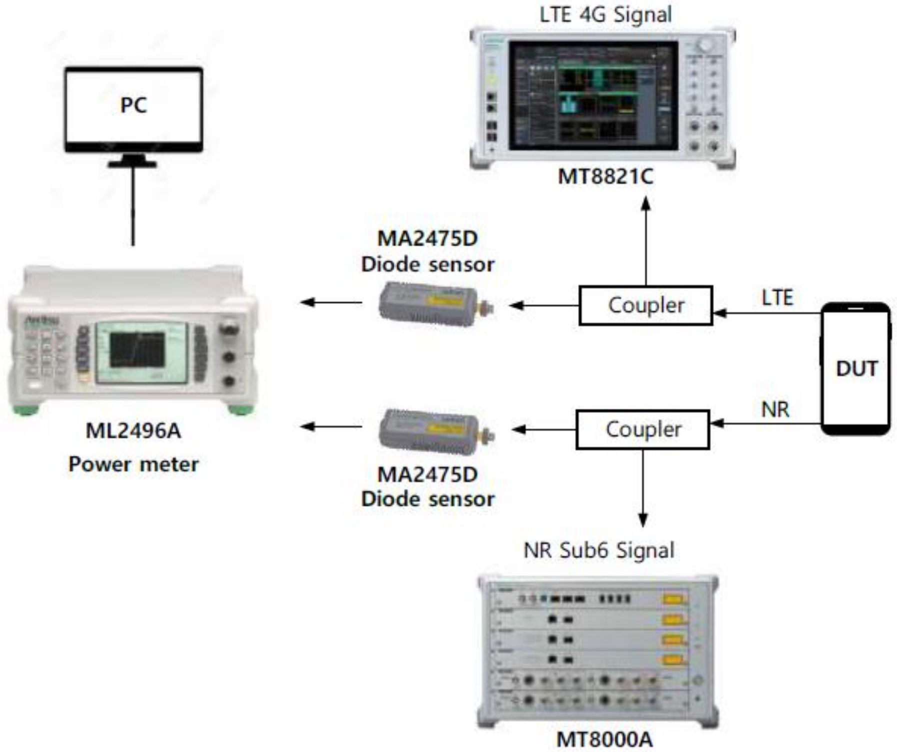

Figure 8.1-1 Test set-up for legacy and sub 6GHz

8.1.1 Test set-up for legacy and sub 6GHz

The test setup for TAS validation with sub-6GHz RATs only is shown in Figure 8.1-1. Normally, a power sensor would measure total power in the entire frequency of its specification e.g. 10MHz to 50GHz for the MA2475D unit. However, when two radios are active, we need to measure their powers separately for using the corresponding SAR mapping table. Therefore, this test setup considers scenarios where two radios would be transmitting from different ports of the DUT so that separate power sensors measure them individually. A common power meter is able to display and record the readings for each sensor at the same time for post processing at a PC. The signaling call boxes MT8000A and MT8821C are used to establish the call and data connection to the DUT on those same ports for NR and LTE, respectively.

The couplers are able to provide the transmit signal from DUT to power sensors while uplink and downlink signaling messages exchanged with the call boxes on the same paths. We can build scripts to program a certain sequence of power control commands from the call boxes to the DUT which can essentially instruct the DUT to change its transmit power.

Thus, if we want DUT to transmit at maximum power in LTE, then continuous power up commands are sent by MT8821C. Similarly, continuous power up commands from MT8000A will try to increase NR power up to its maximum limit. Other power control scenarios which mimic real field behavior such as sequence of power up followed by power down are also possible as described in Section 4. All the path losses from RF port of DUT to the callbox and the power meters are calibrated and automatically entered as offsets in the callbox and power meter, which are also connected to the control PC used in the test setup. We use an Anritsu AMS tool, which is capable of executing the entire test sequence including requested power variation over time and call setup/disconnect scenarios based on pre-configured test case definition.
Power readings for each active technology are recorded every 100ms and dumped in an excel file. A post processing tool is used to extract data from the excel file and plot the required metrics such as time-averaged power, SAR values versus time as described in Section 4.

In summary, the tests have to be executed as following procedure.

1. Measure conduction sub 6GHz Tx power corresponds to SAR regulation.

2. Set sub 6GHz power level with some margin. And start the test

3. Execute time-varying test scenarios. And record sub 6GHz power using sub 6GHz power meter equipment.

4. Plot the recorded results over measurement time. And evaluate the results for validation.

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

9. Test Results for sub-6 TAS validation

9.1 p_{limit} and p_{max} measurement results

Table 9-1 shows the Pmax and Plimit settings for each test for all RATs/bands/cells within the test. In addition, it shows the actual Pmax and steady state maximum average power measurements achieved during the test which should depend on the test type and procedure. Please note although this table only shows the maximum average power at steady state, TAS will always ensure the compliance at any time

TC#	Test scenario	Tech	Band	Antenna	RSI	RB/offset/BW	Mode	Congfiguration	Plimit setting (dBm)	Pmax setting (dBm)	measured Plimit (dBm) Sensor	measured Pmax (dBm) Sensor
1	Time varying Tx power Seqeunce 1	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body	9.0	24.0	9.13	23.31
2		SA/FR1	n77	M2	4	1/1/100MHz	DFT-s QPSK	0mm/Body	8.5	24.0	7.71	24.84
3		UMTS	4	M1	2	-		0mm/Body	13.0	24.0	12.68	24.23
4	Time varying Tx power Seqeunce 2	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body	9.0	24.0	9.13	23.31
5		SA/FR1	n77	M2	4	1/1/100MHz	DFT-s QPSK	0mm/Body	8.5	24.0	7.71	24.84
6		UMTS	4	M1	2	-	0	0mm/Body	13.0	24.0	12.68	24.23
7	Change in Call	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body	9.0	24.0	9.13	23.31
8	Modulation Chage	LTE	7	M1	2	1/1/20MHz	QPSK	0mm/Body	9.0	24.0	9.13	23.31
							16QAM		9.0	23.0	9.13	22.48
9	Re-selection in call	SA/FR1	n41	M1	2	1/1/100MHz	DFT-s QPSK	0mm/Body	11.0	24.0	10.94	23.45
		LTE	7	M1		1/1/20MHz	QPSK	0mm/Body	9.0	24.0	9.13	23.31
10	SAR exposure switch	LTE	12	M1	2	1/1/10MHz	QPSK	0mm/Body	14.0	24.0	14.29	23.60
		NSA/FR1	n41	M1		1/1/100MHz	DFT-s QPSK	0mm/Body	11.0	24.0	10.94	23.45
11	Change in RSI	SA FR1	n77	M2	0	1/1/100MHz	DFT-s QPSK	0mm/Body	18.0	24.0	17.44	24.84
					4			0mm/Body	8.5		7.71	24.84
12	NSA antenna switching with Spatial TAS	LTE	12	M1	0	1/1/10MHz	QPSK	0mm/Body	24.0	24.0	23.60	23.60
		NSA/FR1	n66	M1		1/1/40MHz	DFT-s QPSK	0mm/Body	24.0	24.0	24.30	24.30
		NSA/FR1	n77	M2		1/1/100MHz		0mm/Body	18.0	24.0	18.1	24.84
13	Intra-band ULCA	LTE	66	M1	2	50/0/20MHz	PCC(QPSK)	0mm/Body	11.5	24.0	11.8	23.57
						50/49/20MHz	SCC(QPSK)	0mm/Body				

(steady state and transient)

Table 9-1 Measured p_{limit} and p_{max} of selected radio configurations

9.2 Time-varying Tx power transmission results

Following the test procedure in Section 5.1, the conducted Tx power measurement results for all selected test cases are listed in this Section. In all conducted Tx power plots, the blue line shows the measured instantaneous power using the power meter, the red line shows the time-averaged Tx power and yellow line shows the Plimit value corresponding to design target. In all SAR plots, the dotted blue line shows the time-averaged 1gSAR while the red line shows the corresponding FCC limit of 1.6W/Kg. Time-varying Tx power measurements were conducted for sequence 1,2 TC #1-6 in Table 9-1 by generating the test sequence 2 in Appendix A

9.2.1 TC01 : Time_Varying_Tx_Power_Case_1 [LTE B7]

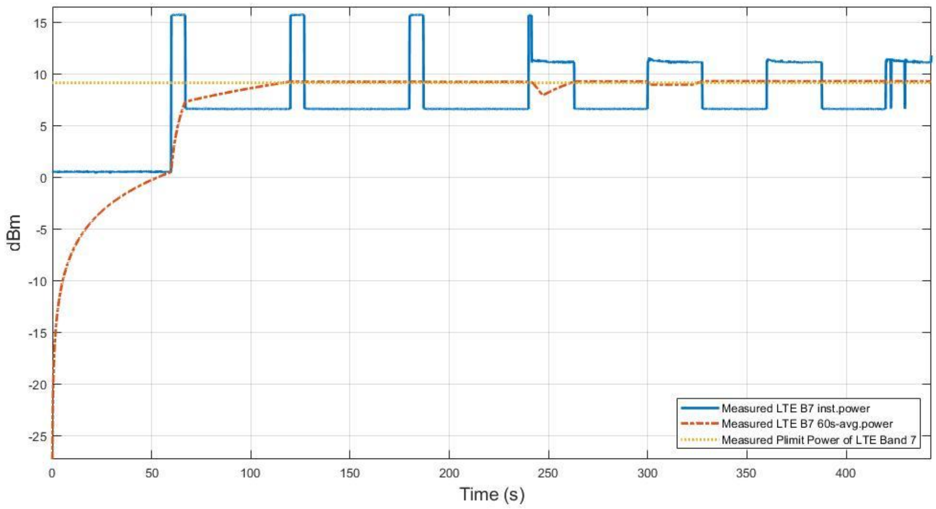

Figure 9.2-1 Time average conducted power of LTE B7 in TC01

In this test, measured 1g SAR would be 0.397 W/kg at 9.0 dBm. Figure 9.2-1 shows the instantaneous and time-averaged Tx power with test sequence 1 for LTE B7 with Plimit 9.0 dBm. In addition, Figure 9.2-1 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-2 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

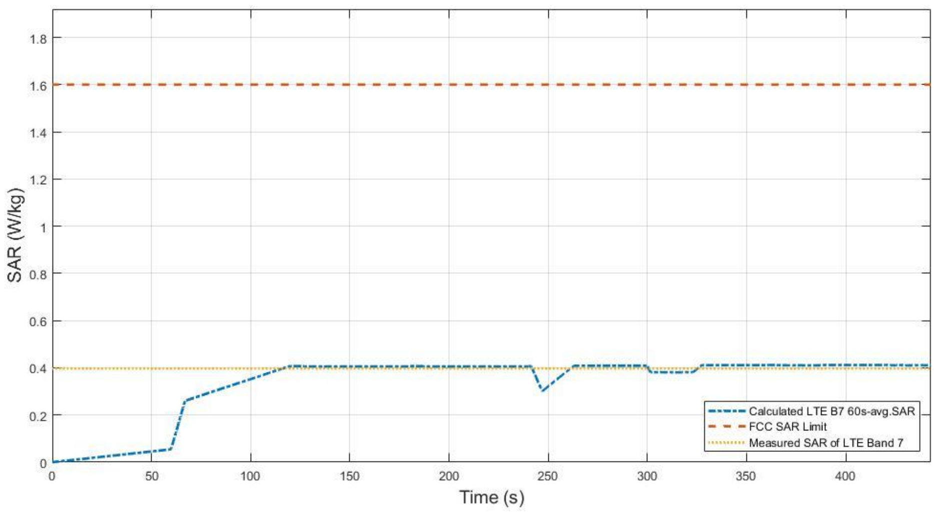

Figure 9.2-2 Total time-averaged SAR in TC01

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.412 W/kg
Device uncertainty	1 dB

9.2.2 TC02 : Time_Varying_Tx_Power_Case_1 [NR n77]

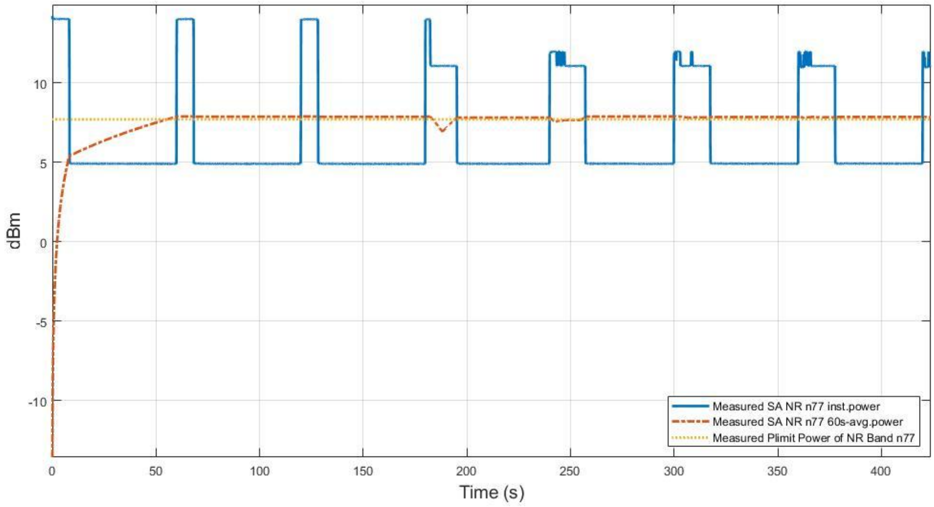

Figure 9.2-3 Time average conducted power of NR n77 in TC02

In this test, measured 1g SAR would be 0.425 W/kg at 8.5 dBm. Figure 9.2-3 shows the instantaneous and time-averaged Tx power with test sequence 1 for NR n77 with Plimit 8.5 dBm. In addition, Figure 9.2-3 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-4 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

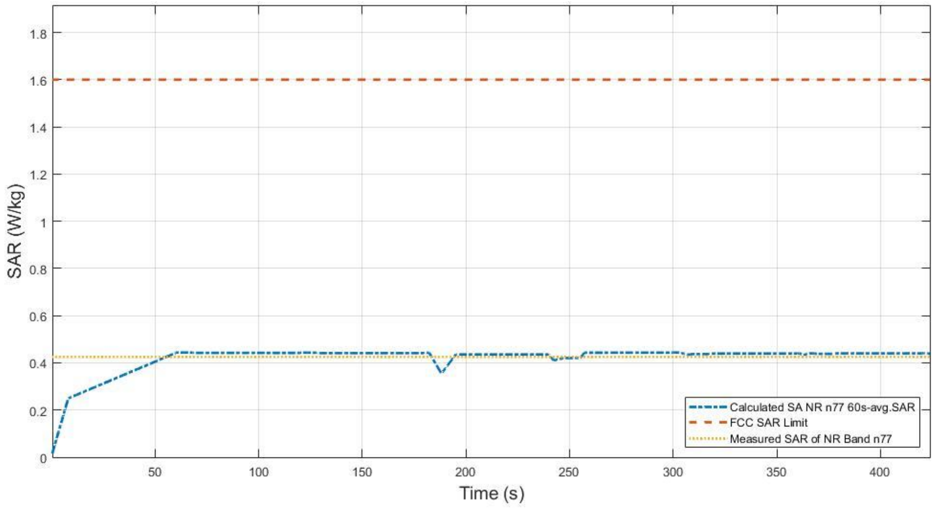

Figure 9.2-4 Total time-averaged SAR in TC02

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.442 W/kg
Device uncertainty	1 dB

9.2.3 TC03 : Time_Varying_Tx_Power_Case_1 [UMTS B4]

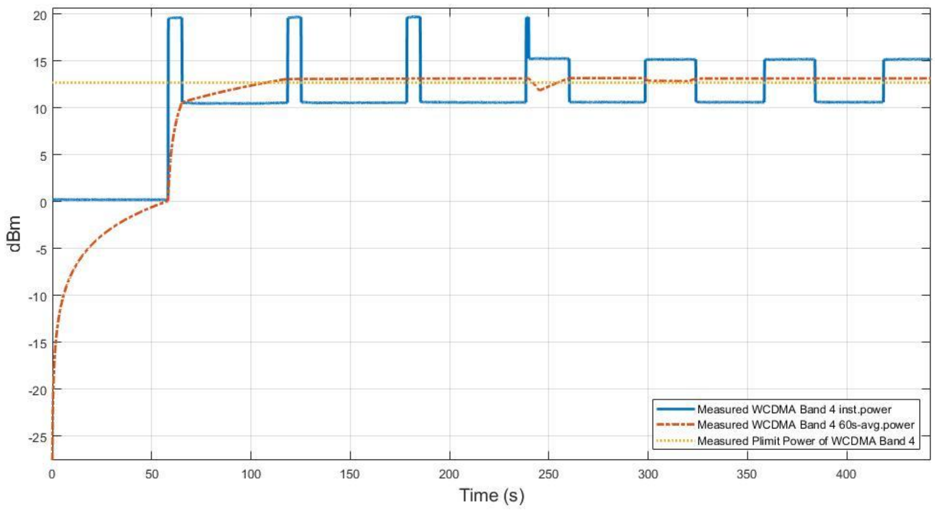

Figure 9.2-5 Time-average conducted power of UMTS B4 in TC03

In this test, measured 1g SAR would be 0.429 W/kg at 13.0dBm. Figure 9.2-5 shows the instantaneous and time-averaged Tx power with test sequence 1 for UMTS B4 with Plimit 13.0 dBm. In addition, Figure 9.2-5 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-6 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

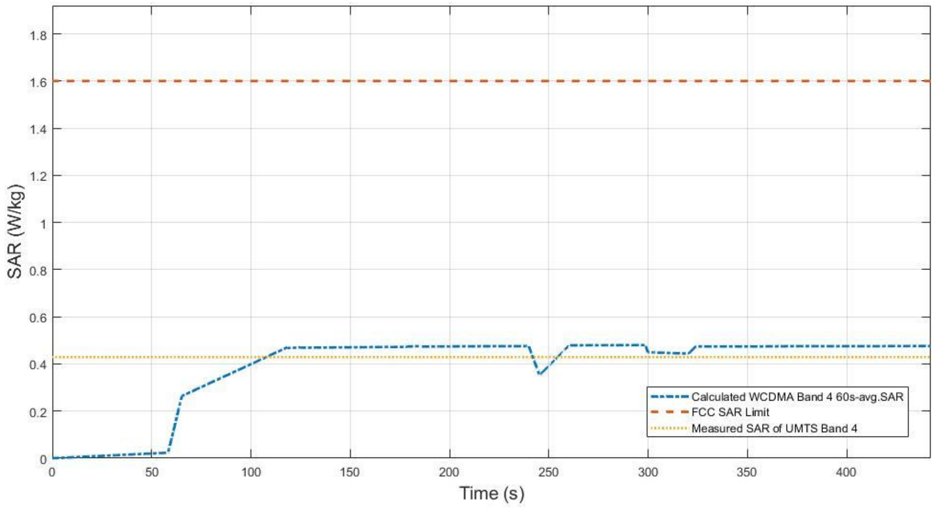

Figure 9.2-6 Total time-averaged SAR in TC03

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.480 W/kg
Device uncertainty	1 dB

9.2.4 TC04 : Time_Varying_Tx_Power_Case_2 [LTE B7]

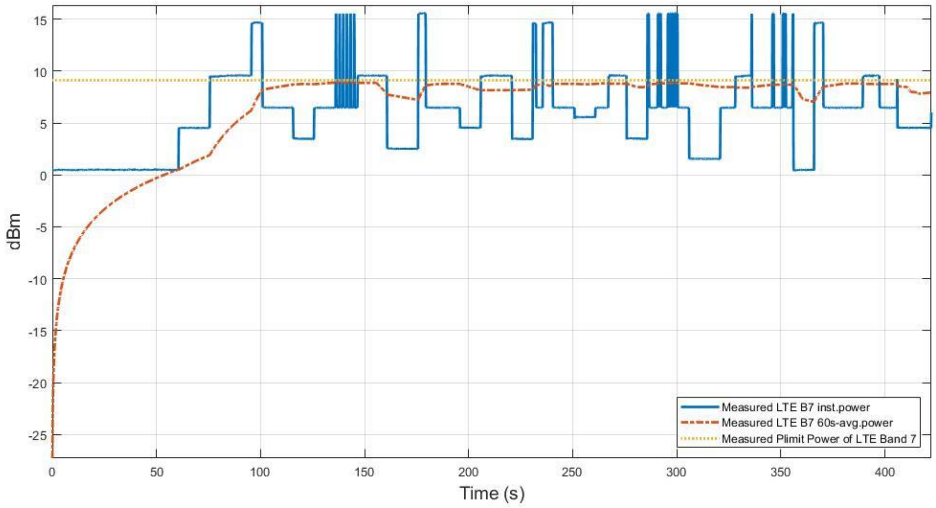

Figure 9.2-7 Conducted Tx power of LTE B7 in TC04

In this test, measured 1g SAR would be 0.397 W/kg at 9.0 dBm. Figure 9.2-7 shows the instantaneous and time-averaged Tx power with test sequence 2 for LTE B7 with Plimit 9.0 dBm. In addition, Figure 9.2-7 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-8 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

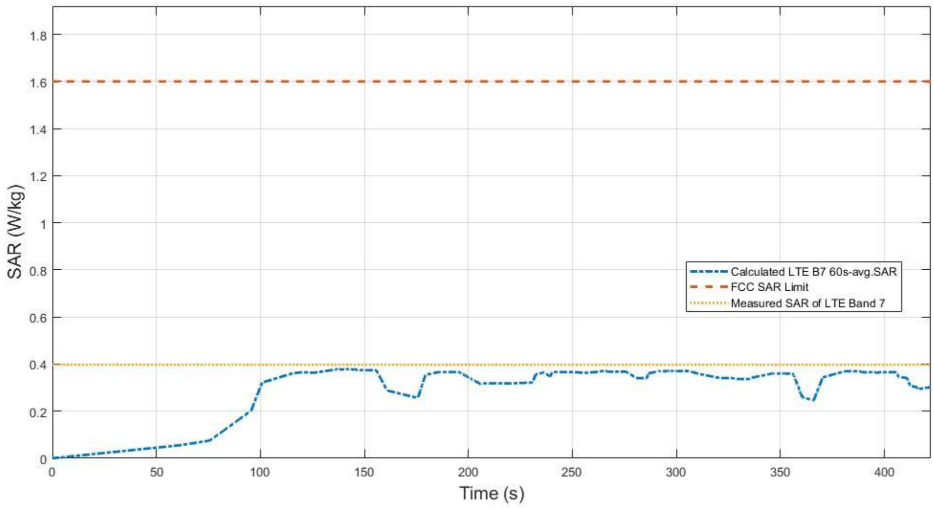

Figure 9.2-8 Total time-averaged SAR in TC04

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.380 W/kg
Device uncertainty	1 dB

9.2.5 TC05 : Time_Varying_Tx_Power_Case_2 [NR n77]

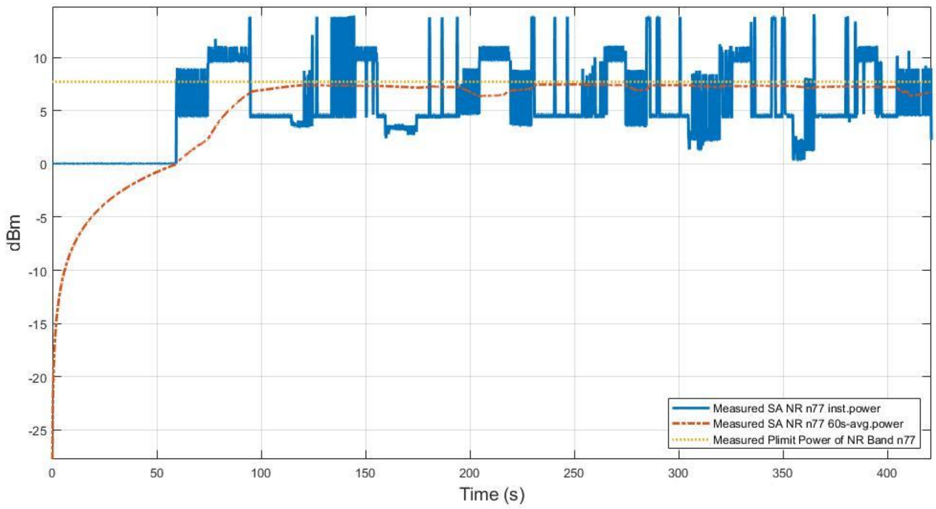

Figure 9.2-9 Conducted Tx power of NR n77 in TC05

In this test, measured 1g SAR would be 0.425 W/kg at 8.5 dBm. Figure 9.2-9 shows the instantaneous and time-averaged Tx power with test sequence 2 for NR n77 with Plimit 8.5 dBm. In addition, Figure 9.2-9 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-10 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

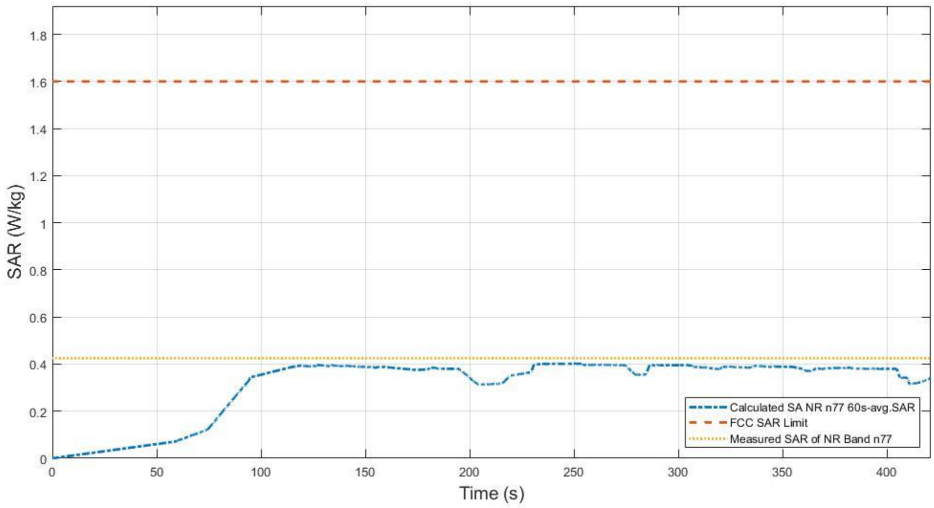

Figure 9.2-10 Total time-averaged SAR in TC05

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.403 W/kg
Device uncertainty	1 dB

9.2.6 TC06 : Time_Varying_Tx_Power_Case_2 [UMTS B4]

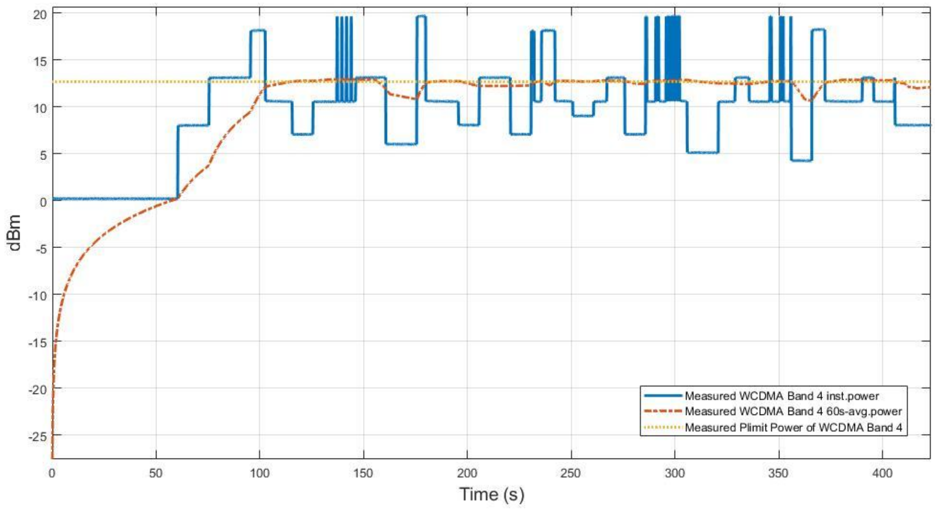

Figure 9.2-11 Conducted Tx power for UMTS B4 in TC06

In this test, measured 1g SAR would be 0.429 W/kg at 13.0 dBm. Figure 9.2-11 shows the instantaneous and time-averaged Tx power with test sequence 2 for UMTS B4 with Plimit 13.0 dBm. In addition, Figure 9.2-11 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.2-12 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

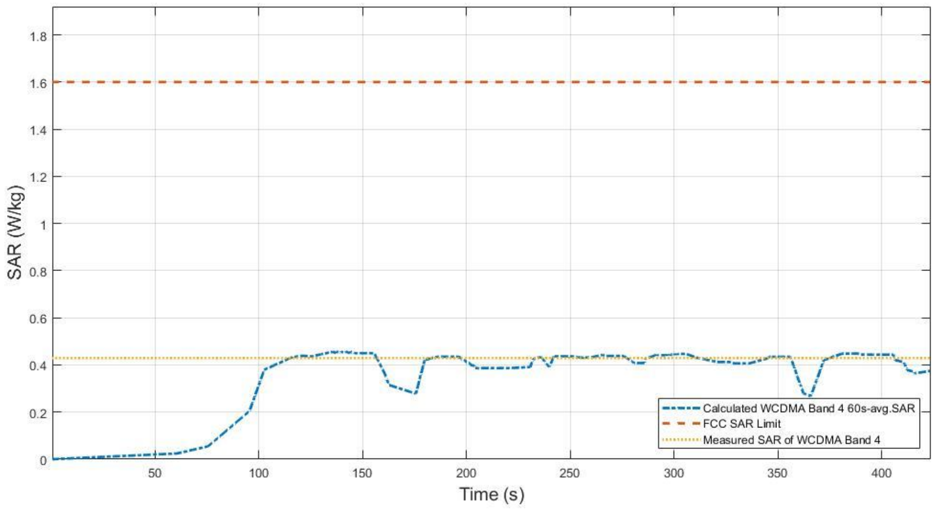

Figure 9.2-12 Total time-averaged SAR in TC06

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.457 W/kg
Device uncertainty	1 dB

9.3 Change in call test results

The test results in this Section are obtained following the procedure in Section 5.3.2. The test case corresponds to TC#7 in Table 9-1.

9.3.1 TC07 : LTE_Call_Disconnect_Reestablishment

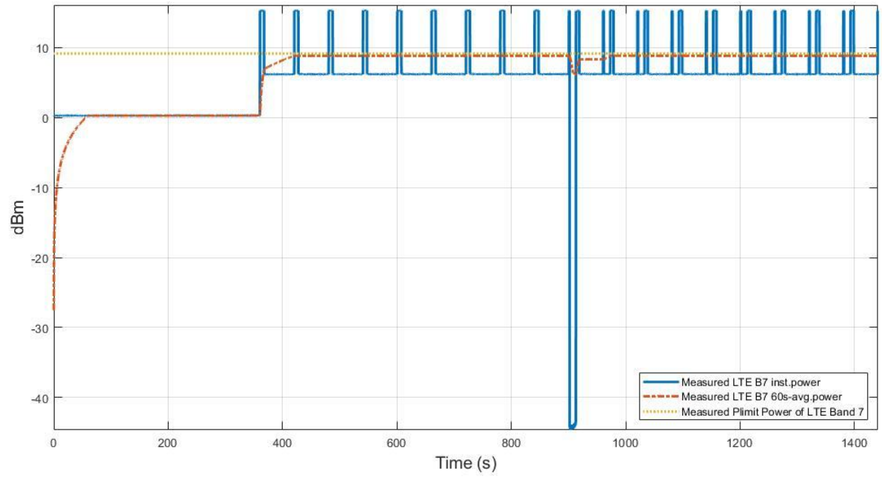

Figure 9.3-1 Conducted Tx power in Call_Disconnect_Reestablishment LTE Band 7 case TC07

In this test, measured 1g SAR would be 0.397 W/kg at 9.0 dBm. Figure 9.3-1 shows the instantaneous and time-averaged Tx power for this test. The call disconnected around 900s and resumed after 10s. It is confirmed for time-average Tx power that the FCC limit was not exceeded, and observed averaging power is around power limit with an uncertainty. Figure 9.3-2 shows the 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.

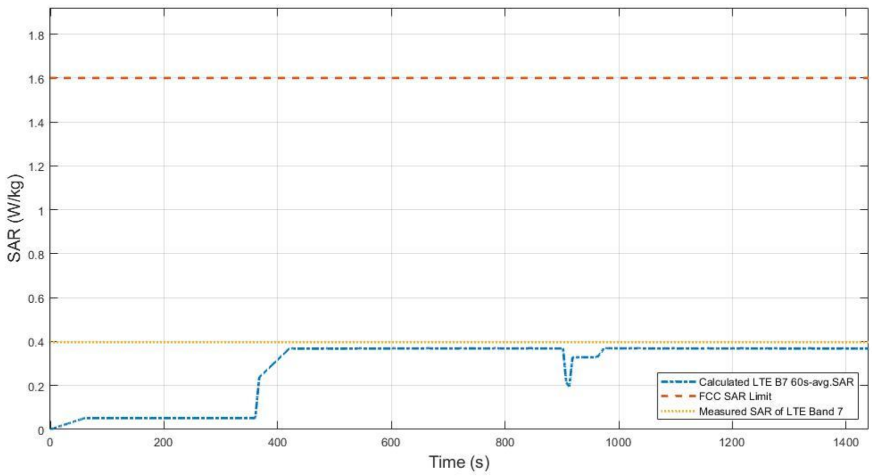

Figure 9.3-2 Total time-averaged SAR in TC07

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.371 W/kg
Device uncertainty	1 dB

9.4 Modulation scheme change test case

The test results in this Section are obtained following the procedure in Section 5.3.8 The test cases correspond to TC#8 in Table 9-1

9.4.1 TC08: LTE_Modulation_change

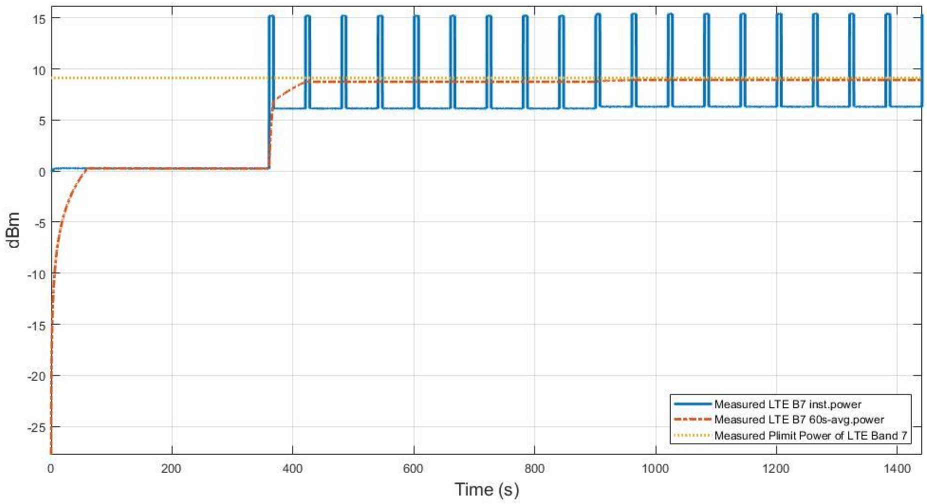

Figure 9.4-1 Conducted Tx power for SAR Modulation Change in test TC08 [LTE Band 7]

In this test, measured 1g SAR would be 0.397 W/kg at 9.0 dBm. Figure 9.4-1 shows the instantaneous and time-averaged Tx power with Plimit 9.0 dBm. The nominal maximum power is set at 24 dBm and a switch of modulation is happening from QPSK to 16QAM at 900s where an increase in the MPR value from 0dB to 1dB happens. The measured power meter reading is 23 dBm at maximum output power.

Figure 9.4-1 shows that the moving-average Tx power is around the targeted Plimit value but it is acceptable result due to uncertainty. Also Figure 9.4-2 shows the calculated time-averaged 1gSAR for this test demonstrating that exposure is well below the FCC limit of 1.6W/kg.

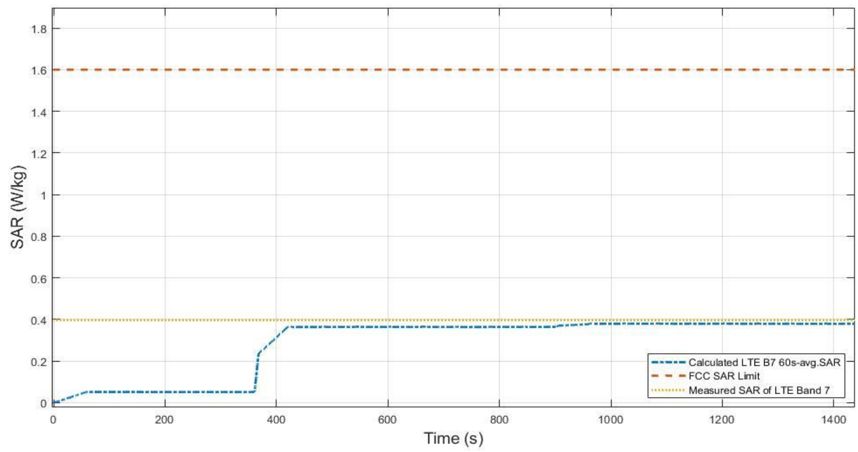

Figure 9.4-2 Total time-averaged SAR in TC08

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.381 W/kg
Device uncertainty	1 dB

9.5 Re-selection in call test results

The test results in this Section are obtained following the procedure in Section 5.3.3.1 The test cases correspond to TC#9 in Table 9-1.

9.5.1 TC09: FR1 to LTE IRAT Re-selection

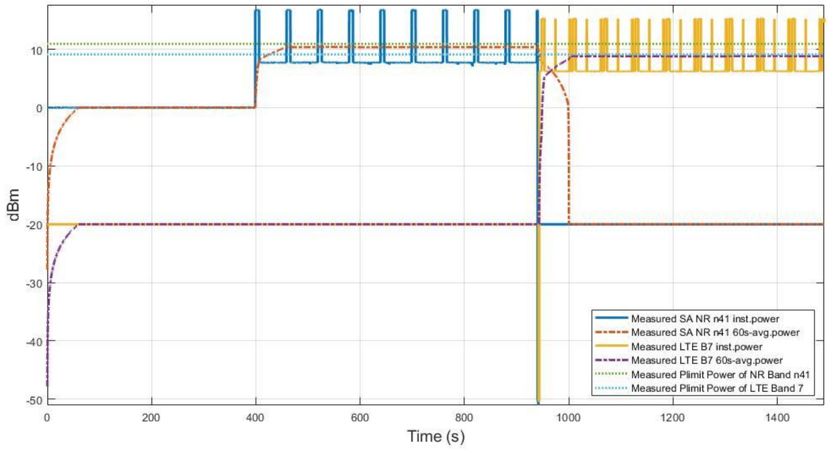

Figure 9.5-1 Conducted Tx power for SA IRAT re-selection for SA n41 and LTE B7 in TC09

In this test, measured 1g SAR would be 0.477 W/kg at 11.0dBm for NR n41 and 0.397 W/kg at 9.0dBm for LTE B7. Figure 9.5-1 shows the instantaneous and time-averaged conducted Tx power for both NR n41 and LTE B7 for the duration of the test. Around time stamp of ~900s, a RAT re-selection from NR n41 to LTE B7 was executed, resulting in reduction of time-averaged power of NR n41 and simultaneous increase in time-averaged power of LTE B7. Here, LTE can use back-off power just after re-selection. Since there is a correlation between NR n41 and B7, TAS algorithm needs to consider the SAR value used in NR n41 for B7. Figure 9.5-2 shows the time-averaged 1gSAR value for each of NR n41 and LTE B7, as well as the total SAR value. It can be confirmed that the total 1gSAR is always under the total FCC limit of 1.6W/Kg even in coupling case.

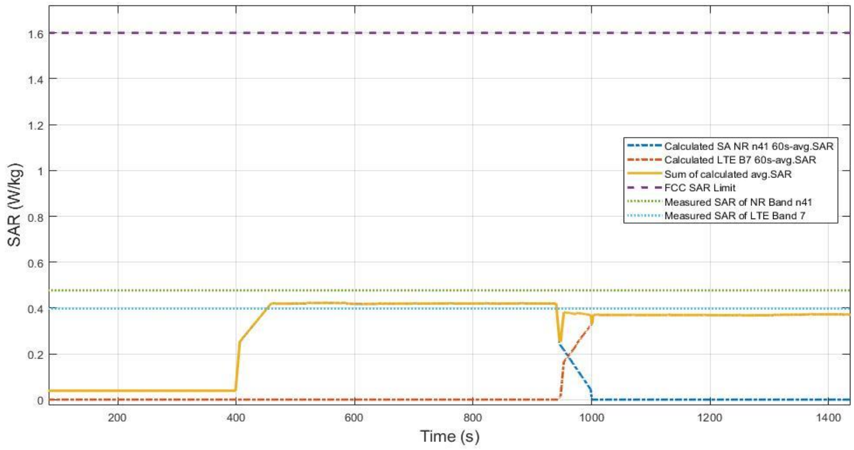

Figure 9.5-2 Total time-averaged SAR in TC09

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.423 W/kg
Device uncertainty	1 dB

9.6 SAR exposure switching test results

The test results in this Section are obtained following the procedure in Section5.3.5. The test cases correspond to TC#10 in Table 9-1.

9.6.1 TC10: NSA_FR1_Dominant_Power_Switching

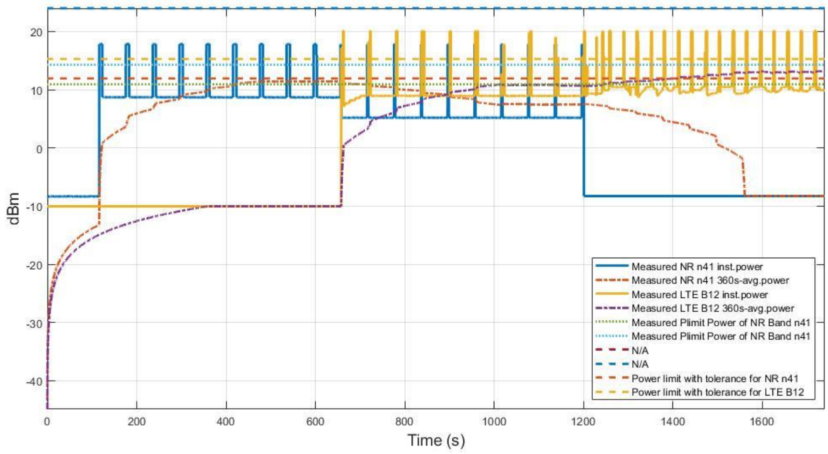

Figure 9.6-1 Time average SAR of LTE 12 and FR1 n41 in EN-DC case in TC10

In this test, measured 1g SAR would be 0.350 W/kg at 14.0dBm for LTE B12 and 0.477 W/kg at 11.0dBm for NR n41. Figure 9.6-1 shows the instantaneous and time-averaged Tx power for both LTE B12 and NR n41 versus time. When both LTE and FR1 operate in around 640s, Both LTE and NR Tx power is decreased but, averaged Tx power is increased by taking the SAR budget. After 540s, NR doesn't use transmitted power and LTE takes the all SAR budget.

As shown in Figure 9.6-2, total average SAR is less than 1W/Kg which is below the FCC limit of 1.6W/Kg.

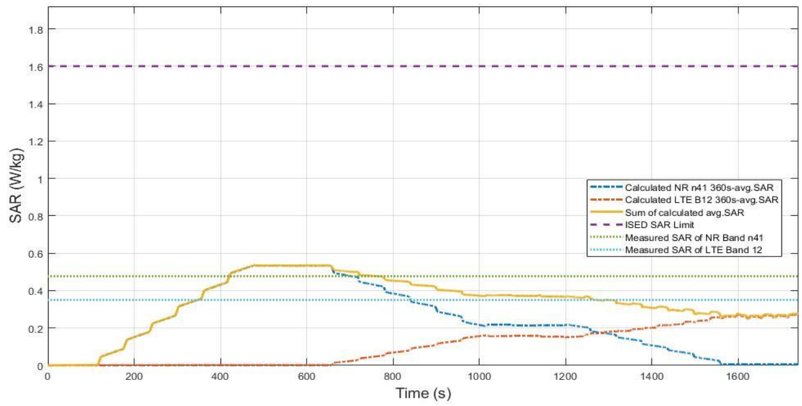

Figure 9.6-2 Total time-averaged SAR in TC10

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.536 W/kg
Device uncertainty	1 dB

9.7 Change in RSI value results

The test results in this Section are obtained following the procedure in Section5.3.4. The test cases correspond to TC#11 in Table 9-1.

9.7.1 TC11: SA_FR1_RF_SAR_Index_Change

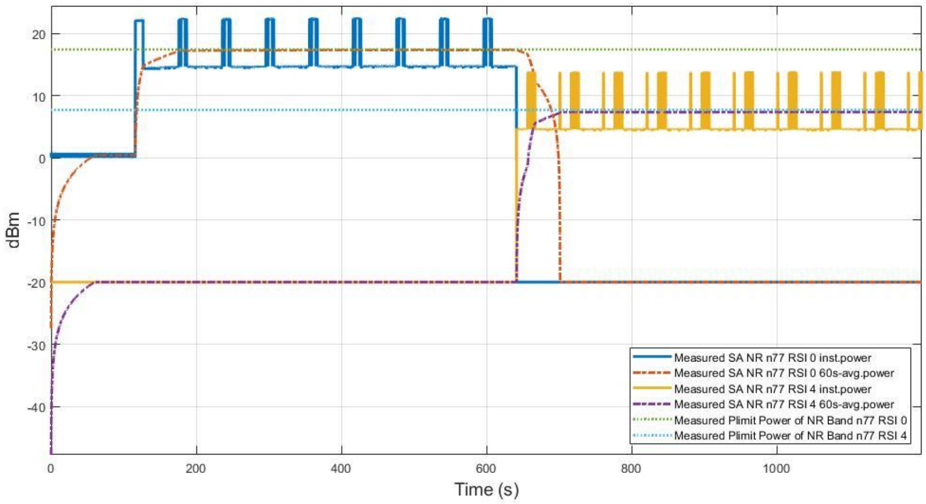

Figure 9.7-1 Conducted Tx power for SAR RSI change in test TC11 [NR Band n77]

In this test, measured 1g SAR would be 0.414W/kg at 18.0dBm (RSI 0) and 0.425 W/kg at 8.5 dBm (RSI 4). Figure 9.7-1 shows the instantaneous and time-averaged conducted Tx power for NR n77 for the duration of the test. Around time stamp of ~640s, the RSI value is changed from High RSI with Plimit of 18.0 dBm to Low RSI with Plimit of 8.5 dBm. It can be seen that Plimit value of high RSI is lower than that of low RSI, so in high RSI region, more Tx power is limited compared to low RSI region. Figure 9.7-2 shows the time-averaged 1gSAR value for each of low and high RSI value, as well as the total SAR value. We can see that the total 1gSAR is always under the total FCC limit of 1.6W/Kg.

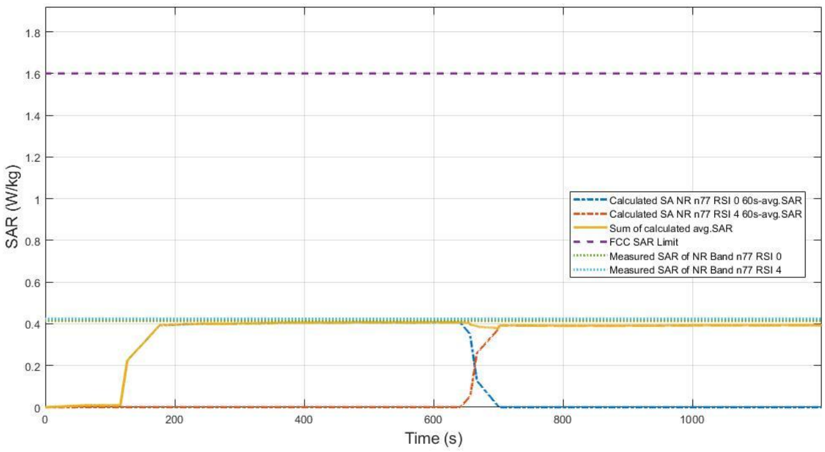

Figure 9.7-2 Total time-averaged SAR in TC11

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.409 W/kg
Device uncertainty	1 dB

9.8 NSA with FR1 antenna switching with spatial TAS

The test results in this section are obtained following the procedure in Section 5.3.6 The test cases correspond to TC#12 in Table 9-1

9.8.1 TC12: NSA_Ant_switching_Spatial_TAS

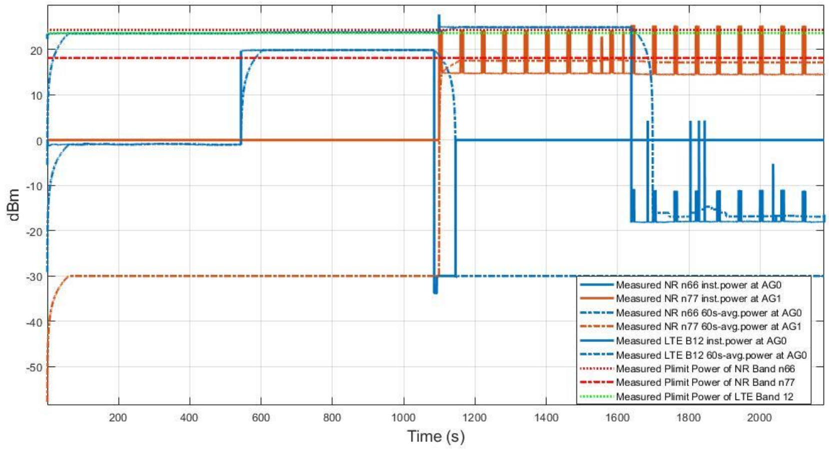

Figure 9.8-1 Conducted Transmitted power for LTE B12(AG0) and NR n66(AG0), n77(AG1) in Test TC12

In this test, measured 1g SAR would be 0.411 W/kg at 24.0dBm for LTE B12, 0.526W/kg at 24.0dBm and 0.419 W/kg at 18.0 dBm for NR n66 and n77. Figure 9.8-1 shows the instantaneous and time-averaged Tx power for both LTE B12 and NR Band n66 and NR n77 versus time. When both AG0 LTE and NR FR1 operate in around 1100s, averaged Tx power for NR is decreased and averaged Tx power of LTE is increased by taking the SAR budget. After 1100s, AG1 NR and AG0 LTE use the all SAR budget. After 1600s, AG1 NR takes all SAR budget. As shown in Figure 9.8-2, total average SAR is about 1W/Kg which is below the FCC limit of 1.6W/Kg.

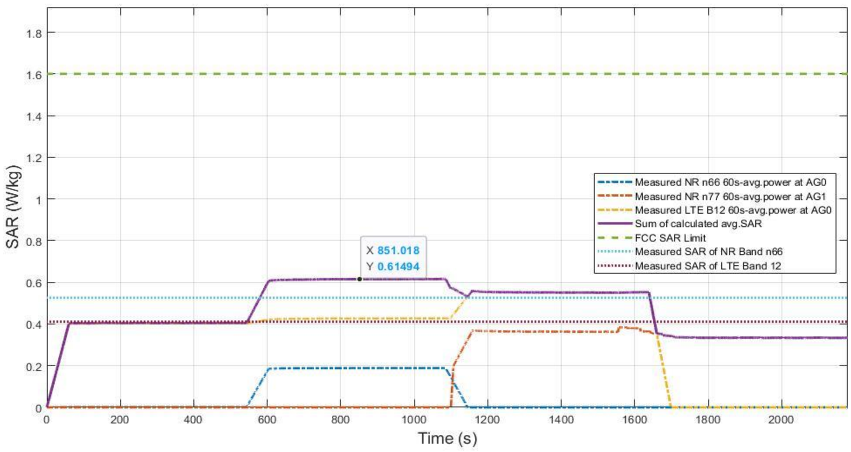

Figure 9.8-2 Total time-averaged SAR in TC12

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (Purple curve)	0.615 W/kg
Device uncertainty	1 dB

9.9 Intra Band ULCA

The test results in this Section are obtained following the procedure in Section5.3.7.1 The test cases correspond to TC#13 in Table 9-1.

9.9.1 TC13: LTE_Intra Band ULCA

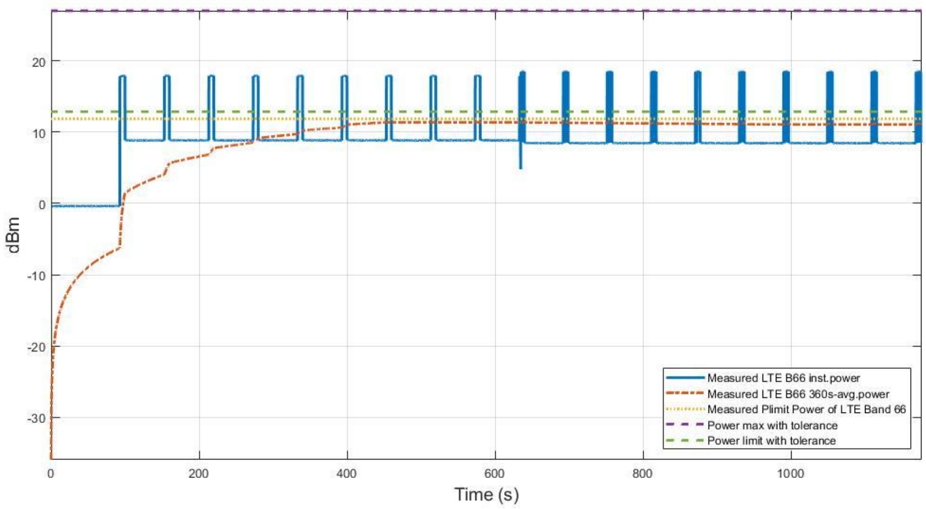

Figure 9.9-1 Conducted Tx power in LTE intra-band ULCA in test TC 13

In this test, measured 1g SAR would be 0.333 W/kg at 24.0dBm for LTE B66. Figure 9.9-1shows the conducted Tx power plot with calculated time-averaged power based on the measured instantaneous Tx power with 1gSAR FCCLimit value. After 100s seconds from the start a single CC is transmitted. Next after 100s from a single CC transmission, an intra-band CA is configured (CA_66C) where a new CC is added and the transmission is continued for another 600s. As shown in Figure 9.9-1, the total power of the two CC is kept almost the same as in the single CC transmission. Average power assures the compliance of the average power of the transmitted signal which is around 11.8 dBm and consequently the average SAR in Figure 9.9-2is around 1W/kg which is below the FCC limit of 1.6W/kg..

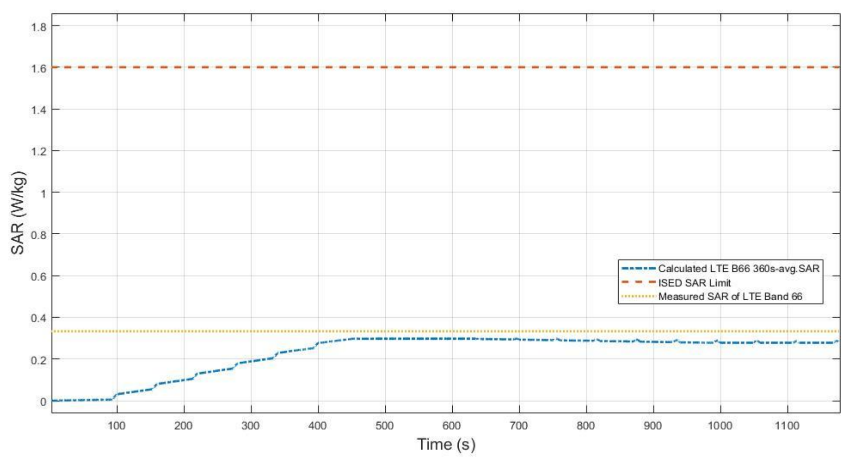

Figure 9.9-2 Total time-averaged SAR in TC13

FCC 1gSAR limit	1.6 W/kg
Max 60s-time average 1gSAR (blue curve)	0.298 W/kg
Device uncertainty	1 dB

10. Equipment List

Manufacturer	Type / Model	S/N	Calib. Date	Calib.Interval	Calib.Due
Agilent	11636B/Power Divider	58698	01/13/2025	Annual	01/13/2026
LOTUS COMMUNICATION SYSTEMS	Low Pass Filter	184401	02/04/2025	Annual	02/04/2026
LOTUS COMMUNICATION SYSTEMS	Low Pass Filter	184401	02/04/2025	Annual	02/04/2026
Narda	Directional Coupler / 4216-10	2090710	06/25/2024	Annual	06/25/2025
Narda	Directional Coupler / 4216-10	01652	06/25/2024	Annual	06/25/2025
HP	Power Divider/11636B	50659	05/21/2024	Annual	05/21/2025
RFCOREA	2Way Spliter	473841	12/09/2024	Annual	12/09/2025
Anritsu	Radio Communication Analyzer / MT8821C	6262044720	11/27/2024	Annual	11/27/2025
Anritsu	Radio Communication Test Station / MT8000A	6262036812	11/27/2024	Annual	11/27/2025
ROHDE & SCHWARZ	Power Sensor / NRP8S	104617	06/25/2024	Annual	06/25/2025
ROHDE & SCHWARZ	Power Sensor / NRP8S	109996	11/12/2024	Annual	11/22/2025

11. Conclusion

Samsung Time-Averaging SAR (TAS) feature employed in Samsung Tablet (FCC ID: A3LSMX528U) has been validated through conducted power measurement as well as SAR measurement. As demonstrated in this report, TAS feature limit the transmit power effectively and shows that SAR value does not exceed 1.6 W/kg for all the transmission scenarios.

12. References

The following documents contain reference in this technical document.

[1] [OEM][Samsung+S.LSI_S5400]+Time+average+SAR+algorithm+(FCC)_v1.1
[2] [OEM] [Samsung S.LSI_S5300] Time-averaged SAR algorithm (FCC)_v.3.3

Appendix A. Test Sequence

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

1. Measured maximum power (P_{max})
2. Measured Tx power (P_{limit}) to satisfy SAR Compliance
3. Setup time to make SAR Remaining be full
4. Do test according to test sequence

1.2 Test Sequence A waveform:

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

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

1.3 Test Sequence B waveform:

Based on the parameters above, the Test Type B is generated with pre-defined power levels, which
is described in Table 1.3.1

Table 1.3.1 Table of test sequence B

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

Appendix B. Test Setup Photo

Please refer to test setup photo file no as follows

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