



Part 2: Test Under Dynamic Transmission Condition

Test Report No. : 13760834H-C-R1

Applicant : Panasonic Corporation of North America

Type of EUT : Radio Module
(Tested inside of Panasonic Personal Computer FZ-G2)

Model number of EUT : WW21A

FCC ID : ACJ9TGW21A

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The information provided from the customer for this report is identified.

This test report is out of scope of any accreditation(s).

This report is a revised version of 13760834H-C. 13760834H-C is replaced with this report.

Date of test(s): September 9, 2021 to November 5, 2021

Representative test operator:

T. Nakagawa
Tomohisa Nakagawa
Engineer

Issued by:

Takayuki S.
Takayuki Shimada
Leader

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1 Introduction

This device uses Qualcomm® Smart Transmit feature. These modem(s) is enabled in Qualcomm® Smart Transmit Feature to control and manage transmitting power in real time and to ensure at all times the averaged RF exposure is in compliance with FCC requirements.

This purpose of the Part 2 report is to demonstrate the EUT complies with FCC RF exposure requirement under Tx varying transmission scenarios, thereby validity of Qualcomm® Smart Transmit feature for FCC equipment authorization of EUT.

The P_{limit} and *input.power.limit* used in this report is determined and listed in Part 0 report.

This description is an overview for STx and test results may not include both sub6 (SAR) and mmW (PD).

2 Customer information

Company Name	:	Panasonic Corporation of North America
Address	:	Two Riverfront Plaza, 9th Floor Newark, NEW JERSEY, 07102-5940, USA
Telephone Number	:	+1-201-348-7760
Facsimile Number	:	+1-201-348-7760
Contact Person	:	Ben Botros

The information provided from the customer is as follows;

- Applicant, Type of Equipment, Model No. FCC ID on the cover and other relevant pages
- Operating/Test Mode(s) (Mode(s)) on all the relevant pages
- SECTION 2: Customer information
- SECTION 3: Equipment under test (EUT) other than the Receipt Date

* The laboratory is exempted from liability of any test results affected from the above information in section 3.

3 Equipment under test (EUT)

3.1 Identification of EUT

Type	:	Radio Module
Model Number	:	WW21A
Serial number	:	0LTSA00730 *1) 0LTSA00731 *2) 0LTSA00732 *3)
Rating	:	DC 3.0 V to 3.6 V
Receipt Date	:	March 30, 2021
Condition	:	Production prototype (Not for Sale: This sample is equivalent to mass-produced items.)
Modification	:	No Modification by the test lab.

*1) Used for the test on 1 GHz to 2 GHz band

*2) Used for the test above 2.5 GHz (except Band 7)

*3) Used for the test below 1 GHz

<Information of Host device>

Type	:	Personal Computer FZ-G2(mk1) Intel Core i7 processor (1.1 GHz Max 4.9 GHz) 10.1 inch LCD (1920 x 1200)
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3.2 Product description

Model: WW21A (referred to as the EUT in this report) is a Radio Module.
EFS version 14.

Wireless technologies	Dup.	Band	Mode
WCDMA	FDD		2 UMTS Rel. 99 (Data) HSDPA (Rel. 5)
	FDD		4 HSUPA (Rel. 6), HSPA+ (Rel. 7), DC-HSDPA (Rel. 8)
	FDD		5
LTE	FDD		2 QPSK, 16QAM, 64AQM, 256QAM
	FDD		4
	FDD		5 Downlink MIMO Support: Yes(2x2, 4x4)
	FDD		7 Supported band : B2, B4, B7, B25, B38, B41, B42, B48, B66
	FDD		12
	FDD		13 Uplink MIMO Support: No
	FDD		14 Uplink transmission is limited to a single output stream.
	FDD		17
	FDD		25
	FDD		26
	FDD(RX only)		29
	TDD		38
	TDD		41
	TDD		42
	TDD(Rx only)		46
	TDD		48
	FDD		66
	FDD		71
LTE CA	Downlink		Uplink
	Maximum 7 carriers		*B42: not used in US (FCC) / B48: not used in Canada(ISED)
5G NR (FR1)	FDD	15 kHz	n2 Pi/2 BPSK (DFT-s-OFDM),
	FDD	15 kHz	n5 QPSK (CP-OFDM/DFT-s-OFDM),
	TDD	15 kHz	n41 16QAM (CP-OFDM/DFT-s-OFDM),
	FDD	15 kHz	n66 64QAM (CP-OFDM/DFT-s-OFDM),
	FDD	15 kHz	n71 256QAM (CP-OFDM/DFT-s-OFDM)
	TDD	30 kHz	n77 Downlink MIMO Support: Yes(2x2, 4x4)
	TDD	30 kHz	n78 Supported band : n2, n41, n66, n77, n78
	-	-	Uplink MIMO Support: No
	-	-	Uplink transmission is limited to a single output stream.
EN-DC(LTE-FR1 Sub6) (NSA mode only)	Supported combination		*n77, n78: not used in US (FCC)
	LTE Anchor Bands for NR band n2		LTE Band 5/12/13
	LTE Anchor Bands for NR band n5		LTE Band 2/7/66
	LTE Anchor Bands for NR band n41		LTE Band 2/25/26/66
	LTE Anchor Bands for NR band n66		LTE Band 5/12/13/14/71
	LTE Anchor Bands for NR band n71		LTE Band 2/7/66
	LTE Anchor Bands for NR band n77*		LTE Band 41
	LTE Anchor Bands for NR band n78*		LTE Band 2/5/7/12/38/66

Wireless module (Tested inside of Panasonic Tablet PC FZ-G2)			
Model : WL20B (FCC ID ACJ9TGWL20B / ISED certification Number 216H-CFWL20B)			
Wireless technologies	Dup.	Band	Mode
WLAN	TDD	2.4GHz	2412-2472 802.11b
			for US 802.11g
	TDD	5GHz	2412-2462 802.11n(20,40)
			for Canada 802.11ax(20,40)
			5180-5240 802.11a
			5260-5320 802.11n(20,40)
			5500-5720 802.11ac(20,40.80.160)
Bluetooth	TDD	2.4GHz	5745-5825 802.11ax(20,40.80.160)
			2402-2480 BR/EDR/LE

4 Location

UL Japan, Inc. Ise EMC Lab.
Shielded room for SAR testings
FCC Test Firm Registration Number: 884919 / ISED SAR Lab Company Number: 2973C
4383-326 Asama-cho, Ise-shi, Mie-ken 516-0021 JAPAN
Telephone: +81 596 24 8999
Facsimile: +81 596 24 8124

5 References

Federal Communications Commission. (October 23, 2015). *447498 D01 General RF Exposure Guidance v06*.
International Electrotechnical Commission. (2018). *IEC TR 63170:2018* .
SPEAG. (August 2018). *5G Module V1.2 Application Note: 5G Compliance Testing*.

6 Definitions, symbols, and abbreviations

6.1 Definitions

SAR_design_target : Target value to use STx and also this shall be less than regulatory SAR limit (i.e., 1gSAR limit for FCC) after accounting for all device design related uncertainties.

SAR_design_target_extremity : SAR_design_target for limbs

Tx_power_at_SAR_design_target : Transmit level that matches SAR_design_target

Δ min : housing material influence

PD_design_target : The design target for PD compliance. It should be less than regulatory power density limit to account for all device design related uncertainties

input.power.limit : For a PD characterized wireless device, the input power level at antenna port(s) for each beam corresponding to PD_design_target.

PD char : The table that contains input.power.limit fed to antenna port(s) for all supported beams.

N beams : The mmW device supports total N beams, where M out of N are single beams and the rest of (N-M) are beam pairs (where 2 single beams are excited at the same time).

power density (PD) or S_{av} : Energy per unit time and unit area crossing a surface of area A characterized by the normal unit vector $\hat{n}$ and averaging time.

$$S_{av} = \frac{1}{AT} \iint (\mathbf{E} \times \mathbf{H}) \cdot \hat{n} dA dT$$

Specific Absorption Rate (SAR): : The time derivative (rate) of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ), as shown in the following equation:

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dV} \right)$$

6.2 Symbols

Symbol	Quantity	Unit	Dimensions
E	Electric field	volt per meter	V / m
f	Frequency	hertz	Hz
H	Magnetic field	ampere per meter	A / m
λ	Wavelength	meter	m
S	Local power density	watt per square meter	W / m ²
PD or S _{av}	Spatial-average power density	watt per square meter	W / m ² (mW / cm ²)
SAR	Specific Absorption Rate	watt per kilo gram	W / kg

6.3 Abbreviations

DSI	: device state index
KDB	: knowledge data base from Federal communication committee (FCC)
BS or BSE	: base station or base station emulator
CW	: continuous wave
DUT	: device under test
NR	: new radio
PD	: power density
RF	: radio frequency
TER	: total exposure ratio
S_n	: surface number
S_{tot} or S_{total}	: total propagating power flux density into the phantom
S_n or S_{norm}	: surface normal propagating power flux density into the phantom or in normed vector space
Ant	: antenna
nG	: n generation (e.g. 3G, 4G and 5G)
☒	: applicable.
☐	: NOT applicable.

7 Qualcomm® Smart Transmit Operation Description

This description is just an overview for STx and test results may not include both sub6 (SAR) and mmW (PD).

7.1 Feature description

The regulatory RF exposure limit is defined based on time-averaged RF exposure. When running in a wireless device, Qualcomm® Smart Transmit algorithm enables *more elegant* power control mechanisms for RF exposure management. It ensures at all times the wireless device is in compliance with the regulatory limit of RF exposure time-averaged over a defined time window, denoted as T_{SAR} and T_{PD} for specific absorption rate (SAR for Tx frequency < 6 GHz) and power density (PD for Tx frequency > 6 GHz) time windows, respectively.

The Smart Transmit algorithm not only ensures the wireless device complies with RF exposure requirement, but also improves the user experience and network performance.

For a given wireless device, RF exposure is proportional to the Tx power.

- Once the SAR and PD of the wireless device is characterized at a Tx power level, RF exposure at a different power level for the characterized configurations can be scaled by the change in the corresponding power level.
- Therefore, for a characterized device, RF exposure compliance can be achieved through Tx power control and management.

The Smart Transmit algorithm embedded in Qualcomm® modems reliably controls the Tx power of the wireless device in real time to maintain the time-averaged Tx power, in turn, time-averaged RF exposure, below the predefined time-averaged power limit for each characterized technology and band.

- This predefined time-averaged power limit is denoted as P_{limit} corresponding to SAR design target (frequency < 6 GHz) and *input.power.limit* corresponding to PD design target (frequency > 6 GHz) in this report.

The wireless device with continuous Tx power at P_{limit} level or *input.power.limit* level complies with the regulatory RF exposure requirement.

In a simultaneous transmission scenario, the algorithm manages all active Tx and makes sure the total exposure ratio from each Tx does not exceed 1.

7.2 Basic concept of the algorithm

The Qualcomm® Smart Transmit algorithm controls and manages the instantaneous Tx power to maintain the time-averaged Tx power (in turn, time-averaged RF exposure) is in compliance with regulatory limits.

- If time-averaged Tx power approaches the P_{limit} , then the modem needs to limit instantaneous Tx power to ensure the time-averaged Tx power does not exceed the P_{limit} or *input.power.limit* in any T_{SAR} and T_{PD} time windows (i.e., the time-averaged RF exposure complies with the regulatory RF exposure limit in any T_{SAR} or T_{PD} time window).
- The wireless device can have high Tx powers at any instant and exceed the P_{limit} or *input.power.limit* level for a short duration before limiting the power to maintain the time-averaged Tx power under P_{limit} or *input.power.limit*.
- If the wireless device is at high Tx power for a long time, then the radio link needs to be dropped to be compliant with time-averaged Tx power requirement (see Figure 1).
- To avoid dropping the radio link, Smart Transmit algorithm starts the power limiting enforcement earlier in time to back off the Tx power to a reserve level (denoted as $P_{reserve}$), so the wireless device can maintain the radio link at a minimum reserve power level for as long as needed, and at the same time ensure the time-averaged Tx power over any defined time window is less than P_{limit} at all times

(see Figure 2). At all times, Smart Transmit meets the below equation:

$$\text{time.ave.Tx Power} = \frac{1}{T_{SAR}} \int_{t-T_{SAR}}^t \text{inst.TX power}(t) dt \leq P_{limit}$$

where, *time.avg.Tx power* is the Tx power averaged between $t-T_{SAR}$ and t time period; T_{SAR} is the time window defined by regulator for time-averaging RF exposure for Tx frequency less than 6GHz (sub6); *inst. Tx power (t)* is the instantaneous Tx power at t time instant; P_{limit} is the predefined time-averaged power limit. Similarly, Smart Transmit meets the below equation for mmW transmission:

$$\text{mmW_time.avg.Tx power} = \frac{1}{T_{PD}} \int_{t-T_{PD}}^t \text{mmW_Tx power}(t) dt \leq \text{input.power.limit}$$

where, *mmW_time.avg.Tx power* is the mmW Tx power averaged between $t-T_{PD}$ and t time period; T_{PD} is the time window defined by regulator for time-averaging RF exposure for mmW bands; *mmW_Tx power (t)* is the instantaneous mmW Tx power at t time instant; *input.power.limit* is the predefined time-averaged power limit for the beam under test.

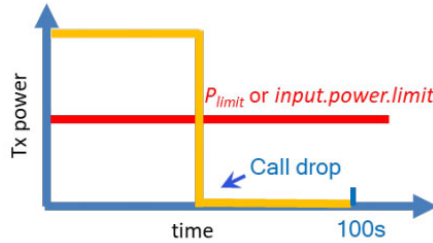
- In the case of simultaneous transmission, Smart Transmit manages all active Tx and makes sure the total exposure ratio is less than 1, i.e.,

$$\sum \frac{\frac{1}{T_{SAR}} \int_{t-T_{SAR}}^t SAR(t) dt}{\text{Regulatory SAR limit}} + \sum \frac{\frac{1}{T_{PD}} \int_{t-T_{PD}}^t 4cm^2 PD(t) dt}{\text{Regulatory PD limit}} \leq 1$$

or

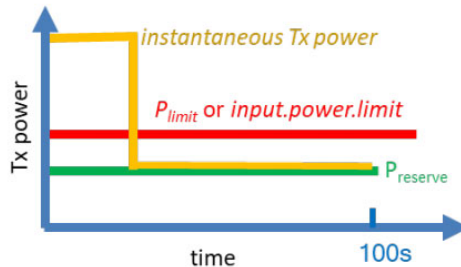
$$\sum \frac{\frac{1}{T_{SAR0}} \int_{t-T_{SAR0}}^t SAR0(t) dt}{\text{Regulatory SAR limit}} + \sum \frac{\frac{1}{T_{SAR1}} \int_{t-T_{SAR1}}^t SAR1(t) dt}{\text{Regulatory SAR limit}} \leq 1$$

where, SAR0 is primary transmitter and SAR1 is secondary transmitter.



(a)

Figure 1 High Tx power when needed and permitted



(b)

Figure 2 Tx power reduced to reserve power to support continuous transmission at a minimum power level ($P_{reserve}$)

7.3 Configurable parameters

The following input parameters are required for functionality of Qualcomm® Smart Transmit algorithm. These parameters cannot be accessed by the end user, because at the factory they are entered through the embedded file system (EFS) entries by the OEM

- Regulatory body

The regulatory body entry should be filled out with either “0” or “1” to correspond to the FCC or ICNIRP requirement, so that Smart Transmit algorithm can select the appropriate averaging time windows. For FCC, Smart Transmit uses 100 seconds averaging window for Tx frequencies $f < 3\text{GHz}$, 60 seconds for $3\text{GHz} < f < 6\text{GHz}$, and 4 seconds for $24\text{GHz} < f < 42\text{GHz}$. For countries adopting ICNIRP the time averaging window is 360 seconds

- Tx_power_at_SAR_design_target* (P_{limit} in dBm) for Tx frequency $< 6\text{GHz}$

The maximum time-averaged Tx power, in dBm, at which this radio configuration (i.e., band and technology) reaches the SAR_design_target. This SAR_design_target is pre-determined for the specific device and it shall be less than regulatory SAR limit after accounting for all design related tolerances. The time-averaged SAR is assessed against this SAR_design_target in real time to determine the compliance. The P_{limit} could vary with technology, band and DSI (device state index), therefore it has the unique value for each technology, band and DSI.

- Reserve_power_margin* (dB)

The margin, in dB, below the P_{limit} to reserve for future transmission with a minimum Tx power (*Preserve*):

$$Preserve \text{ (dBm)} = P_{limit} \text{ (dBm)} - Reserve_power_margin \text{ (dB)}$$

When the *Reserve_power_margin* is set to zero dB, Smart Transmit effectively limits the upper bound of wireless device Tx power to P_{limit} , in other words, the wireless device can be at continuous Tx power of P_{limit} , and in this case, Smart Transmit dynamic control feature is not utilized.

- input.power.limit* (dBm) for Tx frequency $\geq 6\text{GHz}$

The maximum time-averaged power at the input of antenna element port, in dBm, at which each antenna configuration (i.e., each beam) meets the *PD_design_target* that is less than the regulatory power density limit after accounting for all design related tolerances.

- Regulatory body configuration:*

Based on regulatory requirement for each countries/regions, FCC time window/limits and/or ICNIRP 1998 time window/limits can be selected and/or combined. Additionally, Time-Averaged Exposure mode or Peak Exposure mode can be selected based on MCC for Smart Transmit to operate. In Time-Averaged Exposure mode, as described in Section 7.2, the wireless device can instantaneously transmit at high transmit powers and exceed the P_{limit} for a short duration before limiting the power to maintain the time-averaged transmit power under the P_{limit} ; while in Peak Exposure mode, the maximum instantaneous transmit power is limited to P_{limit} . Depending on EFS version, regulatory body configuration is different. Please refer to corresponding user guide for details.

- force peak* for Tx transmitting frequency $< 6\text{GHz}$

The Smart Transmit feature applies time-averaging windows when the device detects an MCC that matches Time-Averaged Exposure MCCs list. For each of the MCCs under Time-Averaged Exposure MCCs list, the Smart Transmit feature can limit either maximum peak power or maximum time-average power to P_{limit} per tech/band/antenna/DSI. If force peak is set to ‘1’ for a given tech/band/antenna/DSI in the EFS, then the Smart Transmit feature limits the maximum Tx power to P_{limit} for the selected tech/band/antenna/DSI. In other words, with force peak set to ‘1’, under static condition (i.e., fixed tech/band/antenna/DSI) and in single active Tx scenario, Smart Transmit can guarantee Tx power level of P_{limit} at all times.

8 Tx Varying Transmission Test Cases and Test Proposal

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

8.1 transmission scenarios

1. During a time-varying Tx power transmission: To prove that the Smart Transmit feature accounts for Tx power variations in time accurately.
2. During a call disconnect and re-establish scenario: To prove that the Smart Transmit feature accounts for history of past Tx power transmissions accurately.
3. During technology/band handover: To prove that the Smart Transmit feature functions correctly during transitions in technology/band.
4. During DSI (Device State Index) change: To prove that the Smart Transmit feature functions correctly during transition from one device state (DSI) to another.
5. During antenna (or beam) switch: To prove that the Smart Transmit feature functions correctly during transitions in antenna (such as antenna diversity scenario) or beams (different antenna array configurations).
6. SAR vs. PD exposure switching during sub-6+mmW transmission: To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance during transitions in SAR dominant exposure, SAR+PD exposure, and PD dominant exposure scenarios.
7. During time window switch: To prove that the Smart Transmit feature correctly handles the transition from one time window to another specified by FCC, and maintains the normalized time-averaged RF exposure to be less than normalized FCC limit of 1.0 at all times.
8. SAR exposure switching between two active radios (radio1 and radio2): To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance when exposure varies among SAR_radio1 only, SAR_radio1 + SAR_radio2, and SAR_radio2 only scenarios. As described in Part 0 report, the RF exposure is proportional to the Tx power for a SAR- and PD-characterized wireless device. Thus, feature validation in Part 2 can be effectively performed through conducted (for $f < 6\text{GHz}$) and radiated (for $f \geq 6\text{GHz}$) power measurement.

Therefore, the compliance demonstration under dynamic transmission conditions and feature validation are done in conducted/radiated power measurement setup for transmission scenario 1 through 8.

To add confidence in the algorithm validation, the time-averaged SAR and PD measurements are also performed but only performed for transmission scenario 1 to avoid the complexity in SAR and PD measurement (such as, for scenario 3 requiring change in SAR probe calibration file to accommodate different bands and/or tissue simulating liquid).

The strategy for testing in Tx varying transmission condition is outlined as follows:

For conducted testing

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged power measurements
 - Measure conducted Tx power (for $f < 6\text{GHz}$) versus time, and radiated Tx power (EIRP for $f > 10\text{GHz}$) versus time.
 - Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
 - Perform running time-averaging over FCC defined time windows.
Max 100s SAR using Eq. 8-2
Instantaneous value using Eq. 8-1
- Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios (i.e., transmission scenarios 1, 2, 3, 4, 5, 6, 7, and 8) at all times.
 - Max Norm. Total RF Exposure Eq. 8-4
 - Instantaneous value using Eq. 8-3

Mathematical expression:

- For sub-6 transmission only:

$$1g_or_10gSAR(t) = \frac{conducted_Tx_power(t)}{conducted_Tx_power_P_{limit}} \times 1g_or_10gSAR_P_{limit}$$

Eq. 8-1

$$\frac{1}{T_{sar}} \int_{t-T_{sar}}^t 1g_or10gSAR(t)dt$$

Eq. 8-2

$$1g_or_10gSAR(t) / FCC\ SAR\ limit$$

Eq. 8-3

$$1g_or_10gSAR(t)_{normalized} = \frac{\frac{1}{T_{sar}} \int_{t-T_{sar}}^t 1g_or10gSAR(t)dt}{FCC\ SAR\ Limit}$$

Eq. 8-4

where, $conducted_Tx_power(t)$, $conducted_Tx_power_P_{limit}$, and $1g_or_10gSAR_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit} , and measured 1gSAR or 10gSAR values at P_{limit} corresponding to sub-6 transmission. P_{limit} is the parameters pre-defined in Part 0 and loaded via Embedded File System (EFS) onto the EUT. T_{SAR} is the FCC defined time window for sub-6 radio.

For radiated testing

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged SAR and PD measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
 - For sub-6 transmission only, measure instantaneous SAR versus time; for LTE+sub6 NR transmission, request low power (or all-down bits) on LTE so that measured SAR predominantly corresponds to sub6 NR.
 - For LTE + mmW transmission, measure instantaneous E-field versus time for mmW radio and instantaneous conducted power versus time for LTE radio.
 - Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
 - Perform time averaging over FCC defined time window
Max 100s SAR using Eq. 8-6
Instantaneous value using Eq. 8-5
 - Demonstrate that the total normalized time-averaged RF exposure is always less than 1 for transmission scenario 1.
Max Norm. Total RF Exposure Eq. 8-8
Instantaneous value Eq. 8-7

Mathematical expression:

- For sub-6 transmission only:

$$1g_or_10gSAR(t) = \frac{pointSAR(t)}{pointSAR_P_{limit}} \times 1g_or_10gSAR_P_{limit}$$

Eq. 8-5

$$\frac{1}{T_{sar}} \int_{t-T_{sar}}^t 1g_or10gSAR(t) dt$$

Eq. 8-6

$$1g_or_10gSAR(t) / ISED SAR limit$$

Eq. 8-7

$$1g_or_10gSAR(t)_{normalized} = \frac{\frac{1}{T_{sar}} \int_{t-T_{sar}}^t 1g_or10gSAR(t) dt}{FCC SAR Limit}$$

Eq. 8-8

where, $pointSAR(t)$, $pointSAR_P_{limit}$, and $1g_or_10gSAR_P_{limit}$ correspond to the measured instantaneous point SAR, measured point SAR at P_{limit} , and measured 1gSAR or 10gSAR values at P_{limit} corresponding to sub-6 transmission.

Note: cDASY6 measurement system by Schmid & Partner Engineering AG (SPEAG) of Zurich, Switzerland measures relative E-field, and provides ratio of $\frac{[pointE(t)]^2}{[pointE_input.power.limit]^2}$ versus time.

9 SAR Time Averaging Validation Test Procedures

This chapter provides the test plan and test procedure for validating Qualcomm® Smart Transmit algorithm for sub-6 transmission.

9.1 Test sequence determination for validation

Following the FCC recommendation, two test sequences having time-variation in Tx power are predefined for sub-6 ($f < 6$ GHz) validation:

Test sequence 1: requesting EUT to transmit at maximum power, measured $P_{\max}$ for 80s, then requesting for half of the maximum power, i.e., measured $P_{\max}/2$, for the rest of the time.

Test sequence 2: requesting EUT to transmit at time-varying Tx power levels. This sequence is generated relative to measured $P_{\max}$, measured P_{limit} and calculated P_{reserve} (= measured P_{limit} in dBm - *Reserve_power_margin* in dB) of EUT based on measured P_{limit} .

The details for generating these two test sequences is described and listed in Appendix A.

NOTE: For test sequence generation, “measured P_{limit} ” and “measured $P_{\max}$ ” are used instead of the “ P_{limit} ” specified in EFS entry and “ $P_{\max}$ ” specified for the device, because Smart Transmit algorithm operates against the actual power level of the “ P_{limit} ” that was calibrated for the EUT. The “measured P_{limit} ” accurately reflects what the algorithm is referencing to, therefore, it should be used during algorithm validation testing. The RF tune up and device-to-device variation are already considered in Part 0 report prior to determining P_{limit} .

9.2 Test configuration selection criteria for validating Smart Transmit feature

For validating Smart Transmit feature, this section provides a general guidance to select test cases. In practice, an adjustment can be made in test case selection. The justification/clarification may be provided.

Used the highest measured 1g_or_10g SAR at P_{limit} ($P_{\text{limit}} < P_{\max}$) shown in Part 1 report and for the selected tech/band/antenna/DSI out of all radio configurations and device positions

9.2.1 Test configuration selection for time-varying Tx power transmission

The Smart Transmit time averaging feature operation is independent of bands, modes, and channels for a given technology. Hence, validation of Smart Transmit in one band/mode/channel per technology is sufficient. Two bands per technology are proposed and selected for this testing to provide high confidence in this validation.

The criteria for the selection are based on the P_{limit} values determined in Part 0 report. Select two bands¹ in each supported technology that correspond to least² and highest³ P_{limit} values for validating Smart Transmit.

Note if possible, for this selection, delta ($P_{\max} - P_{\text{limit}}$) should be 1dB or higher.

9.2.2 Test configuration selection for change in call

The criteria to select a test configuration for call-drop measurement is:

¹ If one P_{limit} level applies to all the bands within a technology, then only one band needs to be tested. In this case, within the bands having the same P_{limit} , the radio configuration (e.g., # of RBs, channel#) and device position that correspond to the highest measured 1gSAR at P_{limit} shown in Part 1 report is selected.

² In case of multiple bands having the same least P_{limit} within the technology, then select the band having the highest measured 1gSAR at P_{limit} .

³ The band having a higher P_{limit} needs to be properly selected so that the power limiting enforced by Smart Transmit can be validated using the pre-defined test sequences. If the highest P_{limit} in a technology is too high ($> P_{\max}$) where the power limiting enforcement is not needed when testing with the pre-defined test sequences, then the next highest level is checked. This process is continued within the technology until the second band for validation testing is determined.

- Select technology/band with least P_{limit} among all supported technologies/bands and $P_{limit} < P_{max}$, then select one radio configuration within the selected band for this test.
- In case of multiple bands having same least P_{limit} , then select one band/radio configuration for this test.
- Test for change in call is not required if all $P_{limit} > P_{max}$

This test is performed with the EUT being requested to transmit at maximum power, the above band selection will result in Tx power enforcement (i.e., EUT forced to transmit at $P_{reserve}$) for longest duration in one FCC defined time window. The call change (call drop/reestablish) is performed during the Tx power enforcement duration (i.e., during the time when EUT is forced to transmit at $P_{reserve}$).

One test is sufficient as the algorithm operation is independent of technology and band.

9.2.3 Test configuration selection for change in technology/band

The selection criteria for this measurement is to have EUT switch from a technology/band with lowest (or highest) P_{limit} within the technology group to a technology/band with highest (or lowest) P_{limit} within the technology group, or vice versa. This test is performed with the EUT being requested to transmit at maximum power, the technology/band switch is performed during Tx power enforcement duration (i.e., during the time when EUT is forced to transmit at $P_{reserve}$).

- First select both technology/band configurations having $P_{limit} < P_{max}$. In case of multiple bands having the same P_{limit} , select one band/radio configuration for this test. If this cannot be found, then,
- Select at least one technology/band configuration having $P_{limit} < P_{max}$. If all $P_{limit} > P_{max}$, then, test for change in technology/band is not required.

This test is performed with the EUT being requested to transmit at maximum power, the technology/band switch is performed during Tx power enforcement (i.e., EUT forced to transmit at $P_{reserve}$).

One test is sufficient as the feature operation is independent of technology and band.

9.2.4 Test configuration selection for change in antenna

The criteria to select a test configuration for antenna switch (between primary and diversity antennas) measurement is:

- Whenever possible and supported by the EUT, first select antenna switch configuration within the same technology/band/DSI (i.e., same technology, band and DSI combination), and having different P_{limit} , and having both $P_{limit} < P_{max}$ where possible. Otherwise, select at least one antenna having $P_{limit} < P_{max}$.
- If the EUT does not support antenna switch within the same technology/band, but has multiple transmitting antennas to support different frequency bands, then antenna switch test should be performed in combination with technology and/or band switch.
- Test for change in antenna is not required if all $P_{limit} > P_{max}$

This test is performed with the EUT being requested to transmit in selected technology/band at maximum power out of antenna, the antenna switch is performed during Tx power enforcement (i.e., EUT forced to transmit at $P_{reserve}$).

One test is sufficient as the feature operation is independent of technology and band.

9.2.5 Test configuration selection for change in DSI

The criteria to select a test configuration for DSI change test is

- Select a technology/band having the $P_{limit} < P_{max}$ within any technology and DSI group, and for the same technology/band having a different P_{limit} ($P_{limit} < P_{max}$) and in any other DSI group. Both the selected DSIs should have $P_{limit} < P_{max}$ where possible. Otherwise, select at least one DSI having $P_{limit} < P_{max}$. Note that the selected DSI transition need to be supported by the device.
- Test for change in device state is not required if all $P_{limit} > P_{max}$.

This test is performed with the EUT being requested to transmit at maximum power in selected technology/band/antenna/device-state. The change in device state is performed during Tx power enforcement (i.e., EUT forced to transmit at P_{reserve}).

One test is sufficient as the feature operation is independent of technology, band, antenna and device state.

9.2.6 Test configuration selection for change in time window

FCC specifies different time window for time averaging based on operation frequency. The criteria to select a test configuration for validating Smart Transmit feature and demonstrating the compliance during the change in time window is

1. Select any technology/band that has operation frequency classified in one time window defined by FCC (such as 100s time window), and its corresponding P_{limit} is less than P_{max} if possible.
2. Select the 2nd technology/band that has operation frequency classified in a different time window defined by FCC (such as 60s time window), and its corresponding P_{limit} is less than P_{max} if possible.
3. It is preferred both P_{limit} values of two selected technology/bands are less than corresponding P_{max} , but if not possible or due to limitation of test setup, then at least one of technologies/bands has its P_{limit} less than P_{max} .
4. Else, if all $P_{\text{limit}} > P_{\text{max}}$, then,
 - a. first select both technologies/bands (one is in 100s time window, another is in 60s time window) having $(P_{\text{limit}} - P_{\text{max}}) < 2.2\text{dB}$; if it is not available, then
 - b. select at least one technology/band in 60s time window having $(P_{\text{limit}} - P_{\text{max}}) < 2.2\text{dB}$; if it is not available, then
 - c. Test for change in time window is not required.

This test is performed with the EUT being requested to transmit at maximum power in selected technology/band.

Test for one pair of time windows selected is sufficient as the feature operation is the same.

9.2.7 Test configuration selection for SAR exposure switching

If supported, the test configuration for SAR exposure switching should cover

1. SAR exposure switch when two active radios are in the same time window. The following radio configurations need to be covered if the device supports:
 - a. LTE + sub6 NR: LTE is protected as it is anchor in NR call. However, Sub6 NR can sustain the link if LTE is at low power
 - b. Interband ULCA: PCC is protected as it is primary in interband ULCA call. SCC will drop the link if SCC is requested to transmit continuously at or above P_{limit} regardless of PCC transmitting power level in devices with Smart Transmit EFS version 15 (or lower). SCC is expected to sustain the link when PCC is at low power in Smart Transmit EFS version 16 (or higher).

Note that Smart Transmit treats intraband ULCA as single Tx, so, this test is not needed for intraband ULCA. Note that in the case of MIMO, Smart Transmit combines the individual exposures of MIMO antennas, and operates as a single Tx. So, this test is not needed for Part 2. However, the combined exposure of MIMO should be assessed in Part 1.

2. SAR exposure switch when two active radios are in different time windows. Note that one test with two active radios in any two different time windows is sufficient as Smart Transmit operation is the same for RF exposure switch in any combination of two different time windows. For device supporting LTE + mmW NR, this test (i.e., Scenario 2) is covered in SAR vs PD exposure switch validation.

The Smart Transmit time averaging operation ensures total time-averaged RF exposure compliance independent of the source of SAR exposure (for example, LTE vs. Sub6 NR). Hence, validation of Smart Transmit in any one band combination for each simultaneous SAR transmission scenario (i.e., one band combination for LTE + Sub6

NR transmission, and one band combination for interband ULCA) is sufficient, where the SAR exposure varies among SAR_{radio1} only, $SAR_{radio1} + SAR_{radio2}$, and SAR_{radio2} only scenarios.

The criteria to select a test configuration for validating Smart Transmit feature during SAR exposure switching scenarios is

- Following the above two test requirements, select the required configuration(s) for the EUT supported simultaneous transmission scenario(s).
- Among all supported simultaneous transmission configurations, the selection order is
 - a. select one configuration where both P_{limit} of radio1 and radio2 is less than their corresponding P_{max} , preferably, with different P_{limits} . If this configuration is not available, then,
 - b. select one configuration that has P_{limit} less than its P_{max} for at least one radio. If this can not be found, then,
 - c. The test for SAR exposure switch when two active radios are in the same time window is not required. For SAR exposure switch when two active radios are in the different time windows, the selection order is:
 - i. Select both configurations that has P_{limit} of radio1 and radio2 greater than P_{max} but having $(P_{limit} - P_{max}) < 2.2\text{dB}$. If this can not be found, then,
 - ii. Select at least one configuration in 60s window that has $(P_{limit} - P_{max}) < 2.2\text{dB}$. If all $(P_{limit} - P_{max}) > 2.2\text{dB}$, then,
 - iii. Test for SAR exposure switch when two active radios are in the different time windows is not required.

Test for one band combination per each simultaneous transmission technology is sufficient as the feature operation is the same.

10 Validation criteria

The overall validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR and below 1 normalized value.

10.1.1 Conducted power measurement

The measured conducted Pmax and measured conducted Plimit should be in the range of:

nominal Pmax - device uncertainty $\leq$ measured Pmax $\leq$ min{nominal Pmax + device uncertainty, rated Pmax}
nominal Plimit - device uncertainty $\leq$ measured Plimit $\leq$ min{nominal Plimit + device uncertainty, rated Pmax}

10.1.2 Time-varying Tx power

The maximum of time-avg SAR $\leq$ (measured SAR@Plimit + device uncertainty).

10.1.3 Call drop Tx power

The combined maximum of time-avg SAR (max value of green curve) should be at the end of the 1st time window period and it should be equal to measured SAR@Plimit $\pm$ device(sub6) uncertainty.

10.1.4 Tech / band handover, DSI switch, Antenna switch, During time window switch, Switch in SAR exposure

The combined maximum of time-avg normalized SAR (max value of green curve) should occur at the end of the 1st time window period and it should be

between

{min[normalized measured SAR1@Plimit1, normalized measured SAR2@Plimit2] - device(sub6) uncert}

and

{max[normalized measured SAR1@Plimit1, normalized measured SAR2@Plimit2] + device(sub6) uncert}.

Sample calculation:

measured SAR1@Plimit1 = 0.7 W/kg

normalized measured SAR1@Plimit1 = 0.7 / 1.6 = 0.438

measured SAR2@Plimit2 = 0.6 W/kg

normalized measured SAR2@Plimit2 = 0.6 / 1.6 = 0.375

device(sub6) uncert = 1.0 dB

Lower criteria: min{0.438, 0.375} - 1.0 dB = 0.375 * 10^(-1.0/10) = 0.297

Higher criteria: max{0.438, 0.375} + 1.0 dB = 0.438 * 10^(+1.0/10) = 0.550

If combined maximum of time-avg normalized SAR is between 0.297 and 0.550, then validated.

Note: here, normalized measured SAR@Plimit = measured SAR@Plimit / RF exposure limit such as 1.6 W/kg.

Note: this report uses TXAGC uncertainty as conservative, that is +/- 1 dB

10.2 Test procedures for conducted power measurements

Perform conducted power measurement to validate Smart Transmit time averaging algorithm in the transmission scenarios described in Section 8

10.2.1 Time-varying Tx power transmission scenario

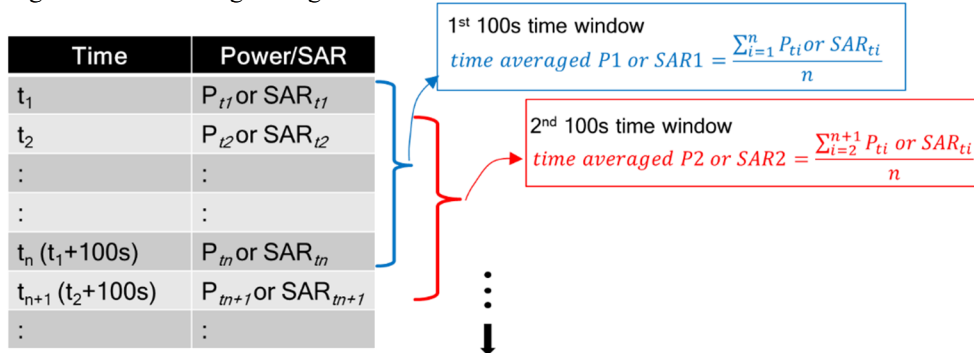
Test procedure

1. Measure P_{max} , measure P_{limit} and calculate $P_{reserve}$ (= measured P_{limit} in dBm – $Reserve_power_margin$ in dB) and follow Section 9.1 to generate the test sequences for all the technologies and bands selected in Section 9.2.1. Both test sequence 1 and test sequence 2 are created based on measured P_{max} and measured P_{limit} of the EUT. Test condition to measure P_{max} and P_{limit} is:
 - Measure P_{max} with Smart Transmit disabled and callbox set to request maximum power.
 - Measure P_{limit} with Smart Transmit enabled and $Reserve_power_margin$ set to 0 dB, callbox set to request maximum power.
2. Set $Reserve_power_margin$ to actual (intended) value (3dB for this EUT based on Part 1 report) and reset power on EUT to enable Smart Transmit, establish radio link in desired radio configuration, with callbox requesting the EUT to transmit at pre-defined test sequence1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. 8-1)) using measured P_{limit} from above Step 1. Perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus timeas illustrated in Figure 3.

NOTE: In Eq. 8-1, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSARvalue by applying the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

NOTE: For an easier computation of the 100s running average, 0 dBm for 100s can be added at the beginning of the test sequences, so the 100s running average can be directly performed starting with the first 100-seconds data using software. This technique also applies to all tests performed in this Part 2 report for easier time- averaged computation using excel software.

Figure 3 100s running average illustration



3. Make one plot containing:
 - a. Instantaneous Tx power versus time measured in Step 2,
 - b. Requested transmit power used in Step 2 (test sequence),
 - c. Computed time-averaged power versus time determined in Step 2,
 - d. Time-averaged power limit (corresponding to FCC SAR limit of 1.6 W/kg for 1gSAR or 4.0W/kg for 10gSAR) given by

$$\text{time average power limit} = \text{meas. } P_{limit} + 10 \times \log\left(\frac{\text{FCC SAR limit}}{\text{meas. } SAR_P_{limit}}\right)$$

Eq. 10-1

where $\text{meas. } P_{limit}$ and $\text{meas. } SAR_P_{limit}$ correspond to measured power at P_{limit} and measured SAR at P_{limit} .

Time averaged mmW NR power limit

$$= \text{meas.EIRPinput.power.limit} + 10 \times \log\left(\frac{\text{FCC PD limit}}{\text{meas.PD_input.power.limit}}\right)$$

Eq. 10-2

where *meas.EIRPinput.power.limit* and *meas.PD_input.power.limit* correspond to measured EIRP at *input.power.limit* and measured power density at *input.power.limit*.

4. Make another plot containing:
 - a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
 - b. FCC 1gSARlimit of 1.6W/kg, FCC 10gSARlimit of 4.0W/kg or PD FCC limit of 10 W/m².
5. Repeat Steps 2 ~ 4 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 2 with test sequence 2.
6. Repeat Steps 2 ~ 5 for all the selected technologies and bands.

The validation criteria are, at all times, the time-averaged power versus time shown in Step 3 plot shall not exceed the time-averaged power limit (defined in Eq. 10-1), in turn, the time-averaged 1gSAR or 10gSAR versus time shown in Step 4 plot shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 8-2).

10.2.2 Change in call scenario

This test is to demonstrate that Smart Transmit algorithm accurately accounts for the past Txpowers during time-averaging when a new call is established.

The call disconnect and re-establishment needs to be performed during power limit enforcement,i.e., when the EUT transmits at P_{reserve} level, to demonstrate the continuity of RF exposure management and limiting in call change scenario. In other words, the RF exposure averaged overany FCC defined time window (including the time windows containing the call change) doesn't exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Test procedure

1. Measure P_{limit} for the technology/band selected in Section 9.2.2. Measure P_{limit} with Smart Transmit enabled and Reserve_power_margin set to 0 dB, callbox set to request maximumpower.
2. Set Reserve_power_margin to actual (intended) value and reset power on EUT to enable Smart Transmit.
3. Establish radio link with callbox in the selected technology/band.
4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for about ~60 seconds, and then drop the call for ~10 seconds. Afterwards, re-establish another call in the same radio configuration (i.e., same technology/band/channel) and continue callbox requesting EUT to transmit at maximum Tx power for the remaining time of at least another 100 seconds. Measure and record Tx power versus time. Once the measurement is done, extract instantaneous Tx power versus time, convert the measured conducted Tx power into 1gSAR or 10gSAR value using Eq. 8-1, and then perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus time.

NOTE: In Eq. 8-1, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

5. Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated using Eq. 10-1.

6. Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The validation criteria are, at all times, the time-averaged power versus time shall not exceed the time-averaged power limit (defined in Eq. 10-1), in turn, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 8-2).

10.2.3 Change in technology and band

This test is to demonstrate the correct power control by Smart Transmit during technology switches and/or band handovers.

Similar to the change in call test in Section 10.2.2, to validate the continuity of RF exposure limiting during the transition, the technology and band handover needs to be performed when

EUT transmits at $P_{reserve}$ level (i.e., during Tx power enforcement) to make sure that the EUT transmits from previous $P_{reserve}$ level to the new $P_{reserve}$ level (corresponding to new technology/band). Since the P_{limit} could vary with technology and band, Eq. 8-1 can be written as follows to convert the instantaneous Tx power in 1gSAR or 10gSAR exposure for the two given radios, respectively:

$$1g_or_10gSAR1(t) = \frac{conducted_Tx_power_1(t)}{conducted_Tx_power_P_{limit1}} \times 1g_or_10gSAR_P_{limit1}$$

Eq. 10-3

$$1g_or_10gSAR2(t) = \frac{conducted_Tx_power_2(t)}{conducted_Tx_power_P_{limit2}} \times 1g_or_10gSAR_P_{limit2}$$

Eq. 10-4

$$\frac{1}{T_{sar}} \left[\int_{t-T_{sar}}^{t1} 1g_or10gSAR1(t)dt + \int_{t1}^t 1g_or10gSAR2(t)dt \right]$$

FCC SAR Limit
Eq. 10-5

where, $conducted_Tx_power_1(t)$, $conducted_Tx_power_P_{limit_1}$, and $1g_or_10gSAR_P_{limit_1}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit} , and measured 1gSAR or 10gSAR value at P_{limit} of technology1/band1; $conducted_Tx_power_2(t)$, $conducted_Tx_power_P_{limit_2}(t)$, and $1g_or_10gSAR_P_{limit_2}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit} , and measured 1gSAR or 10gSAR value at P_{limit} of technology2/band2.

Test procedure

1. Measure P_{limit} for both the technologies and bands selected in Section 9.2.3. Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit
3. Establish radio link with callbox in first technology/band selected.
4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for about ~60 seconds, and then switch to second technology/band selected. Continue with callbox requesting EUT to transmit at maximum Tx power for the remaining time of at least another 100 seconds. Measure and record Tx power versus time for the full duration of the test.

5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value using Eq. 10-3 and Eq. 10-4 and corresponding measured P_{limit} values from Step 1 of this section. Perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus time.

NOTE: In Eq. 10-3 & Eq. 10-4, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

6. Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated using Eq. 10-1.
7. Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 10-5).

10.2.4 Change in antenna

This test is to demonstrate the correct power control by Smart Transmit during antenna switches from one antenna to another. The test procedure is identical to Section 9.2.4, by replacing technology/band switch operation with antenna switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

NOTE: If the EUT does not support antenna switch within the same technology/band, but has multiple antennas to support different frequency bands, then the antenna switch test is included as part of change in technology and band (Section 10.2.3) test.

10.2.5 Change in DSI

This test is to demonstrate the correct power control by Smart Transmit during DSI switches from one DSI to another. The test procedure is identical to Section 9.2.5, by replacing technology/band switch operation with DSI switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

10.2.6 Change in time window

This test is to demonstrate the correct power control by Smart Transmit during the change in averaging time window when a specific band handover occurs. FCC specifies time-averaging windows of 100s for Tx frequency < 3GHz, and 60s for Tx frequency between 3GHz and 6GHz. Since the P_{limit} could vary with technology and band, Eq. 8-1 can be written as follows to convert the instantaneous Tx power in 1gSAR or 10gSAR exposure for the two given radios, respectively:

$$1g_or_10gSAR1(t) = \frac{\text{conducted_Tx_power_1}(t)}{\text{conducted_Tx_power_P}_{limit1}} \times 1g_or_10gSAR_P_{limit1}$$

Eq. 10-6

$$1g_or_10gSAR2(t) = \frac{\text{conducted_Tx_power_2}(t)}{\text{conducted_Tx_power_P}_{limit2}} \times 1g_or_10gSAR_P_{limit2}$$

Eq. 10-7

$$\frac{\frac{1}{T1sar} \left[\int_{t-Tsar}^{t1} 1g_or10gSAR1(t) dt \right]}{FCC\ SAR\ Limit} + \frac{\frac{1}{T2sar} \left[\int_{t1}^t 1g_or10gSAR2(t) dt \right]}{FCC\ SAR\ Limit}$$

Eq. 10-8

where, $conducted_Tx_power_1(t)$, $conducted_Tx_power_P_{limit_1}$, and $Ig_or_10gSAR_P_{limit_1}$ correspond to the instantaneous Tx power, conducted Tx power at P_{limit} , and compliance Ig_or_10gSAR values of band1 at P_{limit_1} ; $conducted_Tx_power_2(t)$, $conducted_Tx_power_P_{limit_2}$, and $Ig_or_10gSAR_P_{limit_2}$ correspond to the instantaneous Tx power, conducted Tx power at P_{limit} , and compliance Ig_or_10gSAR values of band2 at P_{limit_2} . One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window ' T_{ISAR} ' to the second band with time-averaging window ' T_{2SAR} ' happens at time-instant ' t_1 '.

Test procedure:

1. Measure P_{limit} for both the technologies and bands selected in Section 9.2.6. Measure P_{limit} with Smart Transmit enabled and $Reserve_power_margin$ set to 0 dB, callbox set to request maximum power.
2. Set $Reserve_power_margin$ to actual (intended) value and enable Smart Transmit

Transition from 100s time window to 60s time window, and vice versa

3. Establish radio link with callbox in the technology/band having 100s time window selected in Section 9.2.6.
4. Request EUT's Tx power to be at 0 dBm for at least 100 seconds, followed by requesting EUT's Tx power to be at maximum power for about ~140 seconds, and then switch to second technology/band (having 60s time window) selected in Section 9.2.6. Continue with callbox requesting EUT's Tx power to be at maximum power for about ~60s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for at least another 100s. Measure and record Tx power versus time for the entire duration of the test.
5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. 10-6 and Eq. 10-7) using corresponding technology/band Step 1 result, and then perform 100s running average to determine time averaged 1gSAR or 10gSAR versus time. Note that in Eq. 10-6 & Eq. 10-7, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the worst-case 1gSAR or 10gSAR value tested in Part 1 for the selected technologies/bands at P_{limit} .
6. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 4.
7. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 5, (b) computed time-averaged 1gSAR versus time determined in Step 5, and (c) corresponding regulatory 1gSARlimit of 1.6W/kg or 10gSAR limit of 4.0W/kg.

Transition from 60s time window to 100s time window, and vice versa

8. Establish radio link with callbox in the technology/band having 60s time window selected in Section 9.2.6
9. Request EUT's Tx power to be at 0 dBm for at least 60 seconds, followed by requesting EUT's Tx power to be at maximum power for about ~80 seconds, and then switch to second technology/band (having 100s time window) selected in Section 9.2.6. Continue with callbox requesting EUT's Tx power to be at maximum power for about ~100s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for the remaining time for a total test time of 500 seconds. Measure and record Tx power versus time for the entire duration of the test.
10. Repeat above Step 5~7 to generate the plots

the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

10.2.7 SAR exposure switching

This test is to demonstrate that Smart Transmit feature is accurately accounts for switching in exposures among SAR from radio1 only, SAR from both radio1 and radio2, and SAR from radio2 only scenarios, and ensures total time-averaged RF exposure complies with the FCC limit. Here, radio1 represents primary radio (for example, LTE anchor in a NR non-standalone mode call) and radio2 represents secondary radio (for example, sub6 NR or mmW NR). The detailed test procedure for SAR exposure switching in the case of LTE+Sub6 NR non-standalone mode transmission scenario is provided in Appendix H of doc number 80-W2112-5 Rev. R from Qualcomm®.

Test procedure:

1. Measure conducted Tx power corresponding to Plimit for radio1 and radio2 in selected band. Test condition to measure conducted Plimit is:
 - a. Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 Plimit with Smart Transmit enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power.
 - b. Repeat above step to measure conducted Tx power corresponding to radio2 Plimit. If radio2 is dependent on radio1 (for example, non-standalone mode of Sub6 NR requiring radio1 LTE as anchor), then establish radio1 + radio2 call with callbox, and request all down bits for radio1 LTE. In this scenario, with callbox requesting maximum power from radio2 Sub6 NR, measured conducted Tx power corresponds to radio2 Plimit (as radio1 LTE is at all-down bits)
2. Set Reserve_power_margin to actual (intended) value, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one-time window. After one-time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one-time window and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one-time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR or 10gSAR value (see Eq. 10-3 and Eq. 10-4) using corresponding technology/band Plimit measured in Step 1, and then perform the running time average to determine time-averaged 1gSAR or 10gSAR versus time.
4. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.
5. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3.

the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

10.3 Test procedure for SAR measurements

To perform the validation through SAR measurement for transmission scenario 1 described in Section 2, the "path loss" between callbox antenna and EUT needs to be calibrated to ensure that the EUT Tx power reacts to the requested power from callbox in a radiated call. It should be noted that when signaling in closed loop mode, protocol-level power control is in play, resulting in EUT not solely following callbox TPC (transmit power control) commands. In other words, EUT response has many dependencies (RSSI, quality of signal, path loss variation, fading, etc.) other than just TPC commands. These dependencies have less impact in conducted setup (as it is a controlled environment and the path loss can be very well calibrated) but have significant impact on radiated testing in an uncontrolled environment, such as SAR test setup. Therefore, the deviation in EUT Tx power from callbox requested power is expected, however the time-averaged SAR should always not exceed FCC SAR requirement as Smart Transmit controls Tx power at EUT.

The following steps are for time averaging algorithm validation through SAR measurement:

1. “Path Loss” calibration: Place the EUT against the phantom in the worst-case position determined based on Section 9.2.1. For each band selected, prior to SAR measurement, perform “path loss” calibration between callbox antenna and EUT. Since the SAR test environment is not controlled and well calibrated for OTA (Over the Air) test, extreme care needs to be taken to avoid the influence from reflections. The test setup is described in Section 12.3 .
2. Time averaging algorithm validation:
 - a. For a given radio configuration (technology/band) selected in Section 9.2.1, enable Smart Transmit and set *Reserve_power_margin* to 0 dB, with callbox to request maximum power, perform area scan, conduct pointSAR measurement at peak location of the area scan. This point SAR value, *pointSAR_Plimit*, corresponds to point SAR at the measured *Plimit* (i.e., measured *Plimit* from the EUT in Step 1 of Section 10.2.1).
 - b. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit. Note, if *Reserve_power_margin* cannot be set wirelessly, care must be taken to re-position the EUT in the exact same position relative to the SAM or ELI phantom as in above Step 2.a. Establish radio link in desired radio configuration, with callbox requesting the EUT to transmit at power levels described by test sequence 1 generated in Step 1 of Section 10.2.1, conduct point SAR measurement versus time at peak location of the area scan determined in Step 2.a of this section. Once the measurement is done, extract instantaneous point SAR vs time data, *pointSAR(t)*, and convert it into instantaneous 1gSAR or 10gSAR vs. time using Eq. 8-5.
 - c. Perform 100s running average to determine time-averaged 1gSAR or 10gSAR versus time.
 - d. Make one plot containing: (a) time-averaged 1gSAR or 10gSAR versus time determined in Step 2.iii of this section, (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.
 - e. Repeat 2.b ~ 2.d for test sequence 2 generated in Step 1 of Section 10.2.1.
 - f. Repeat 2.a ~ 2.e for all the technologies and bands selected in Section 9.2.1.

The time-averaging validation criteria for SAR measurement is that, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 8-6).

11 Test Configurations

11.1 P_{max} P_{limit}

The P_{limit} values, corresponding to each DSI *SAR_design_target*, for technologies and bands supported by EUT are derived in Part 0 report and summarized in Table 11-1 P_{limit} for supported technologies and bands

Note all P_{limit} power levels entered in Table 11-1 P_{limit} for supported technologies and bands correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes (for e.g., GSM & LTE TDD).

DSI	State
0	Proximity sensor off or disable
1	Proximity sensor on

The P_{limit} used in this report are determined and listed in Part 0 report.

If $P_{max} < P_{limit}$ then
 P_{max} is used for test
Else P_{limit} is used for test

Considering uncertainty for TXAGC, upper limit is specified as $P_{limit} + 1$ dB, $P_{max} + 1$ dB.

Table 11-1 P_{limit} for supported technologies and bands

RAT	Band	DSI=0		DSI=1		P_{max} (Tune up limit) [dBm] +/-1dB
		SAR _{design_target} [W/kg]	P_{limit} [dBm]	SAR _{design_target} [W/kg]	P_{limit} [dBm]	
WCDMA	2	1.0	23.5	0.7	16.4	23.5
WCDMA	4	1.0	22.7	0.7	16.7	22.7
WCDMA	5	1.0	23.5	0.7	16.1	23.5
LTE	2	1.0	23.0	0.7	16.6	23.0
LTE	4	1.0	23.0	0.7	17.2	23.0
LTE	5	1.0	23.0	0.7	16.1	23.0
LTE	7	1.0	23.0	0.7	16.6	23.0
LTE	12	1.0	23.0	0.7	18.4	23.0
LTE	13	1.0	23.0	0.7	17.0	23.0
LTE	14	1.0	23.0	0.7	17.0	23.0
LTE	17	1.0	23.0	0.7	17.8	23.0
LTE	25	1.0	23.0	0.7	16.5	23.0
LTE	26	1.0	23.0	0.7	16.3	23.0
LTE	38	1.0	23.0	0.7	18.8	23.0
LTE	41	1.0	23.0	0.7	19.7	23.0
LTE	48	1.0	9.9	0.7	9.9	9.9
LTE	66	1.0	23.0	0.7	17.2	23.0
LTE	71	1.0	23.0	0.7	17.8	23.0
NR	n2	1.0	23.5	0.7	16.4	23.5
NR	n5	1.0	23.5	0.7	16.3	23.5
NR	n41	0.8	20.5	0.7	13.1	20.5
NR	n66	1.0	22.5	0.7	17.1	22.5
NR	n71	1.0	23.5	0.7	18.7	23.5

Powers are specified as burst average.

* Maximum tune up output power, P_{max} , is used to configure EUT during RF tune up procedure. The maximum allowed output power is equal to maximum tune up output power + 1dB device uncertainty.

Based on selection criteria described in Section 9.212, the selected technologies/bands and test configurations are highlighted in yellow in Table 11-1. The corresponding 1gSAR or 10gSAR values and relevant information extracted from Part 1 report are listed in Table 5-2.

Additionally, per Part 1 report, the *Reserve_power_margin* (dB) for this device is set to 3dB in EFS, and is used in Part 2 test.

For LTE B48

Uplink Downlink config (UDC)	Special sub frame (SSF)	Burst ave tune up DSI=1 [dBm]	Pmax burst ave [dBm]	Time ave DSI=1/0 [dBm]
0	0 to 7	9.9	9.9	7.5
1	0 to 7	11.3	11.3	7.5
2	0 to 7	14.2	14.2	7.5
3	0 to 7	12.8	12.8	7.5
4	0 to 7	14.4	14.4	7.5
5	0 to 7	17.3	17.3	7.5
6	0 to 7	10.4	10.4	7.5

LTE band 48 doesn't have a same burst tune up for UDC/SSF but has same time average tune up limit.

11.2 WWAN (sub-6) transmission configuration

Table 11-2 Radio configurations selected for part2 test.

Scenario	Test method	RAT	TA mode	Ant#	DSI	Dup.	Band	Mode	Freq [MHz]	Rbnum	RBp	Pmax [dBm]	MPR [dB]	meas. Pmax [dBm]	Plim [dBm]	meas Plimi [dBm]	meas. SAR [W/kg]
Time-varying Tx power transmission	Cond. Power meas SAR meas.	WCDMA	FP	1	1	FDD	5	RMC	826.4	NA	NA	23.5	0	23.2	16.1	15.8	0.671
Time-varying Tx power transmission	Cond. Power meas SAR meas.	WCDMA	FP	1	1	FDD	4	RMC	1732.6	NA	NA	22.7	0	23.2	16.7	16.5	0.551
Time-varying Tx power transmission	Cond. Power meas SAR meas.	LTE	FP	1	1	FDD	5	QPSK	836.5	50	0	23.0	1	21.7	16.1	15.9	0.671
Time-varying Tx power transmission	Cond. Power meas SAR meas.	LTE	TAE	1	1	TDD	41	QPSK	2549.5	50	50	23.0	1	22.0	19.7	20.0	0.940
Time-varying Tx power transmission	Cond. Power meas SAR meas.	NR	TAE	2	1	TDD	n41	BPSK	2593.0	135	69	20.5	0	20.5	13.1	13.2	1.020
Time-varying Tx power transmission	Cond. Power meas SAR meas.	NR	TAE	1	1	TDD	n71	BPSK	680.5	50	28	23.5	0	22.5	18.7	17.9	0.859
Change in call	Cond. Power meas	NR	TAE	2	1	TDD	n41	BPSK	2593.0	135	69	20.5	0	20.5	13.1	13.2	1.020
Change in technology and band	Cond. Power meas	LTE	TAE	1	1	TDD	41	QPSK	2549.5	50	50	23.0	1	22.0	19.7	20.0	0.940
Change in DSI	Cond. Power meas	WCDMA	FP	1	1	FDD	5	RMC	826.4	NA	NA	23.5	0	24.0	16.1	16.6	0.671
Change in time window	Cond. Power meas	LTE	TAE	1	1	FDD	66	QPSK	1770.0	50	24	23.0	0	22.8	17.2	17.0	0.754
SAR exposure switching (ENDC)	Cond. Power meas	LTE	TAE	1	1	FDD	66	QPSK	1720.0	1	99	23.0	0	22.8	23.0	22.8	0.888
		LTE	TAE	1	1	FDD	5	QPSK	836.5	50	0	23.0	1	21.7	16.1	15.9	0.671
		LTE	FP	1	1	TDD	48	QPSK	3560.0	50	50	9.9	0	10.2	9.9	10.2	0.525
		LTE	TAE	1	1	FDD	2	QPSK	1860.0	100	0	23.0	1	21.3	16.6	16.0	0.692
		NR	TAE	1	1	FDD	n5	BPSK	836.5	1	1	23.5	0	22.9	16.3	16.2	0.732

Notes

1. TA: Time average mode
2. FP : force peak mode
3. TAE: time averaging exposure mode
4. TDD mode is corrected to burst mode
5. Time varying test for LTE, selected next lowest band because lowest Plimit is band 48 but it doesn't satisfy with selection criterion as per 9.2.1.
6. Change in antenna test is omitted because this device has two antennas, but second antenna is treated second active radiator that is only supported new radio(n41) and tested as ENDC mode.
7. SAR exposure switching test is only conducted with ENDC mode because device doesn't support inter ULCA also intra band is treated as single radiator.
8. SAR exposure switching test is only conducted with same time window because ENDC doesn't support in different time windows.
9. SAR vs. PD exposure switching during sub-6+mmW transmission is omitted because this test report covers only sub6.
10. Based on the selection criteria described in Section 9.2, test configuration is SAR worst case.

12 Conducted Power Test Results for Sub-6 Smart Transmit Algorithm Validation

12.1 Measurement setup for conducted power measurement.

The Rohde & Schwarz CMW500 callbox is used in this test. The test setup picture and schematic are shown in below for measurements with a single antenna of EUT, and for measurements involving antenna switch. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the EUT using a directional coupler. For antenna & technology switch measurement, two ports (RF1 COM and RF3 COM) of the callbox used for signaling two different technologies are connected to a combiner, which is in turn connected to a directional coupler. The other end of the directional coupler is connected to a splitter to connect to two RF ports of the EUT corresponding to the two antennas of interest. In both the setups, power meter is used to tap the directional coupler for measuring the conducted output power of the EUT. For time averaging validation test, call drop test, and DSI switch test, only RF1 COM port of the callbox is used to communicate with the EUT. For technology/band switch measurement, both RF1 COM and RF3 COM port of callbox are used to switch from one technology communicating on RF1 COM port to another technology communicating on RF3 COM port. Note that for this EUT, antenna switch test is included within technology/band switch test as the selected technology/band combinations for the technology/band switch test are on two different antennas. All the path losses from RF port of EUT to the callbox RF COM port and to the power meter are calibrated and manually entered as offsets in the callbox and the power meter, respectively.

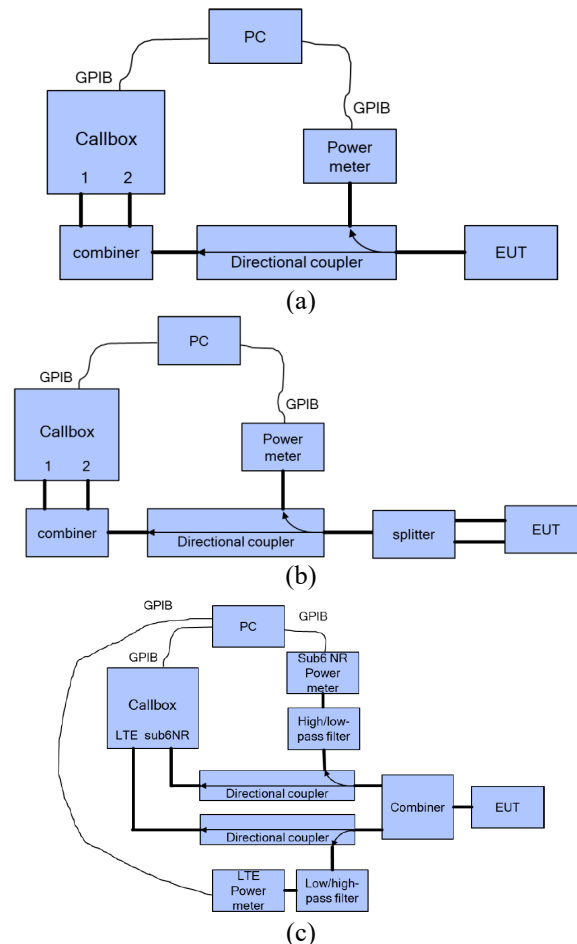


Figure 4 Example conducted power measurement setup

Both the callbox and power meter are connected to the PC using GPIB cables. Two test scripts are custom made for automation, and the test duration set in the test scripts is 500 seconds.

For time-varying transmit power measurement, the PC runs the 1st test script to send GPIB commands to control the callbox's requested power versus time, while at the same time to record the conducted power measured at EUT RF port using the power meter. The commands sent to the callbox to request power are:

1. 0dBm for 100 seconds
2. test sequence 1 or test sequence 2, for 360 seconds
3. stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

Power meter readings are periodically recorded every 100ms. A running average of this measured Tx power over 100 seconds is performed in the post-data processing to determine the 100s-time averaged power.

For call drop, technology/band/antenna switch, and DSI switch tests, after the call is established, the callbox is set to request the EUT to transmit at 0dBm for 100 seconds while simultaneously starting the 2nd test script runs at the same time to start recording the Tx power measured at EUT RF port using the power meter. After the initial 100 seconds since starting the Tx power recording, the callbox is set to request maximum power from the EUT for the rest of the test.

Note that the technology/band/antenna switch or DSI switch is manually performed when the Tx power of EUT is at $P_{reserve}$ level. See Section 9.2.2 for detailed test procedure of technology/band/antenna switch test and DSI switch test.

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

The measured P_{limit} for all the selected radio configurations given in result are listed in next. P_{max} was also measured for radio configurations selected for testing time-varying Tx power transmission scenarios in order to generate test sequences following the test procedures.

Table 11-2 Radio configurations selected for part2 test.

Within the TXAGC uncertainty, +/- 1dB

Validated

12.3 Measurement setup for SAR measurement.

The measurement setup is similar to normal SAR measurements wirelessly connected with the callbox. The difference in SAR measurement setup for time averaging algorithm validation is that the callbox is signaling in close loop power control mode (instead of requesting maximum power in open loop control mode) and callbox is connected to the PC using GPIB so that the test script executed on PC can send GPIB commands to control the callbox's requested power over time (test sequence). The same test script used in conducted setup for time-varying transmit power measurements is also used here for running the test sequences during SAR measurements, and the recorded values from the disconnected power meter by the test script were discarded. As mentioned, for EUT to follow TPC command sent from the callbox wirelessly, the "path loss" between callbox antenna and the EUT needs to be calibrated. Since the SAR chamber is in uncontrolled environment, precautions must be taken to minimize the environmental influences on "path loss". The EUT is placed in worst-case position against phantom.

Time-averaged SAR measurements are conducted using ES3DV3 probe at peak location of area scan over 500 seconds. The distance between ES3DV3 probe tip to flat section of the SAM Twin phantom surface is 3 mm, and the distance between ES3DV3 probe sensor to probe tip is 2 mm. cDASY6 records pointSAR values periodically every 0.1 seconds, where

Probe integration times depend on the communication signal being tested. Integration times used by SPEAG for their probe calibrations can be downloaded from here (integration time is listed on the bottom of the first page for each tech):

<https://www.speag.com/assets/downloads/services/cs/UIDSummary171205.pdf>

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the individual pointSAR data from cDASY6 are extracted into excel spreadsheet and the number of points in 100s interval is determined by $\text{total_points} \times (100\text{s} / \text{pointSAR_total_scan_time_duration})$. Running average is performed over these number of points in excel spreadsheet to obtain 100s-averaged pointSAR.

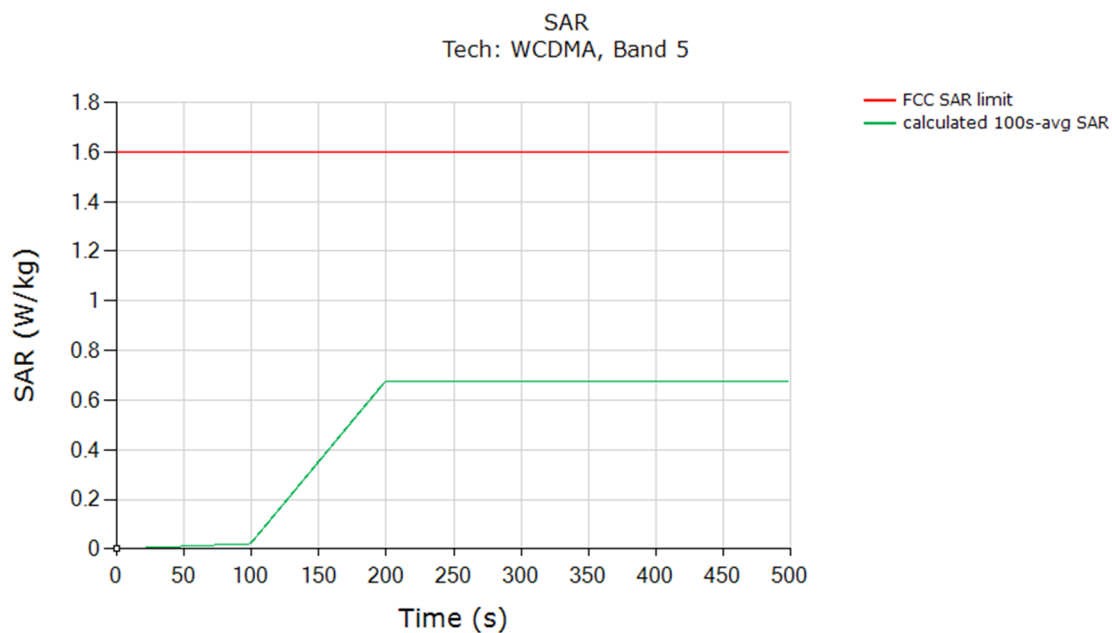
1. With *Reserve_power_margin* set to 0 dB, area scan is performed at *Plimit*, and time-averaged pointSAR measurements are conducted to determine the pointSAR at *Plimit*, denoted as *pointSARPlimit*.
2. With *Reserve_power_margin* to actual (intended) value (see Table 3-1), two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR values by using equation listed below:

12.4 Time-varying Tx power measurement results

12.4.1 WCDMA band 5

Test result for test sequence 1 (Conducted RF exposure):

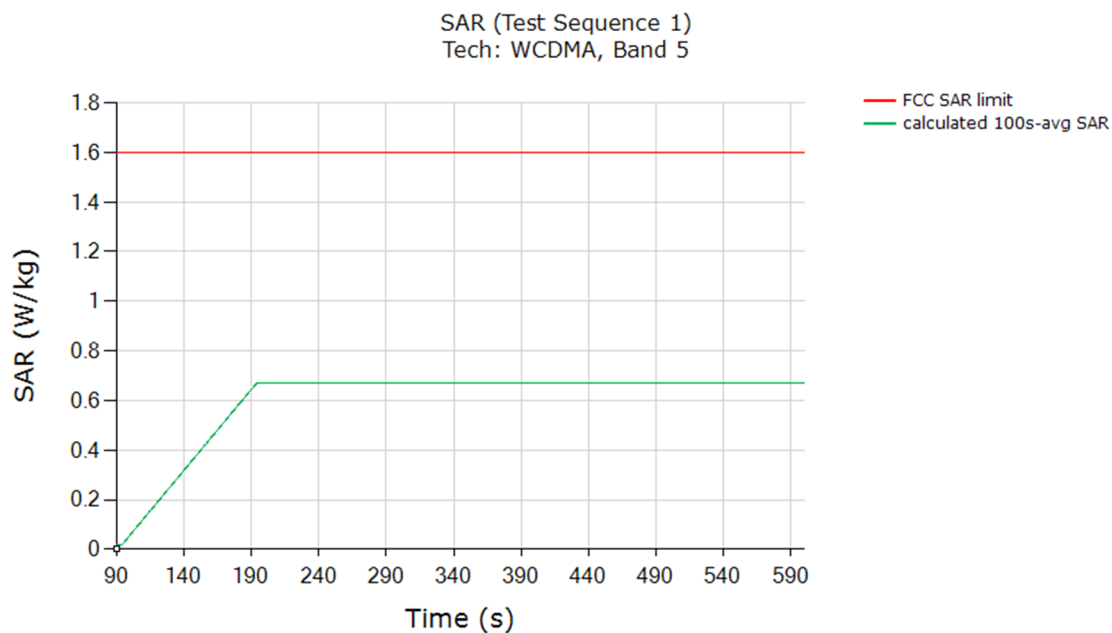


Max 100s SAR = 0.675

Max 100s SAR / Meas.SAR @ Plimit = 0.026 dB

Validated

Test result for test sequence 1 (SAR):

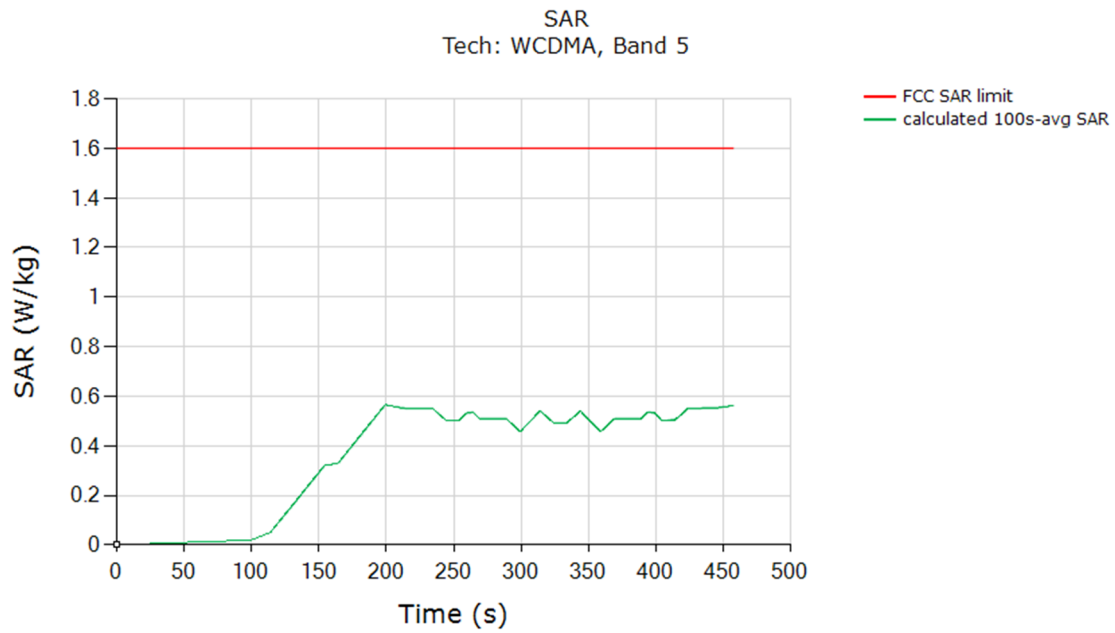


Max 100s SAR = 0.669 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.016 dB

Validated

Test result for test sequence 2 (Conducted RF exposure):

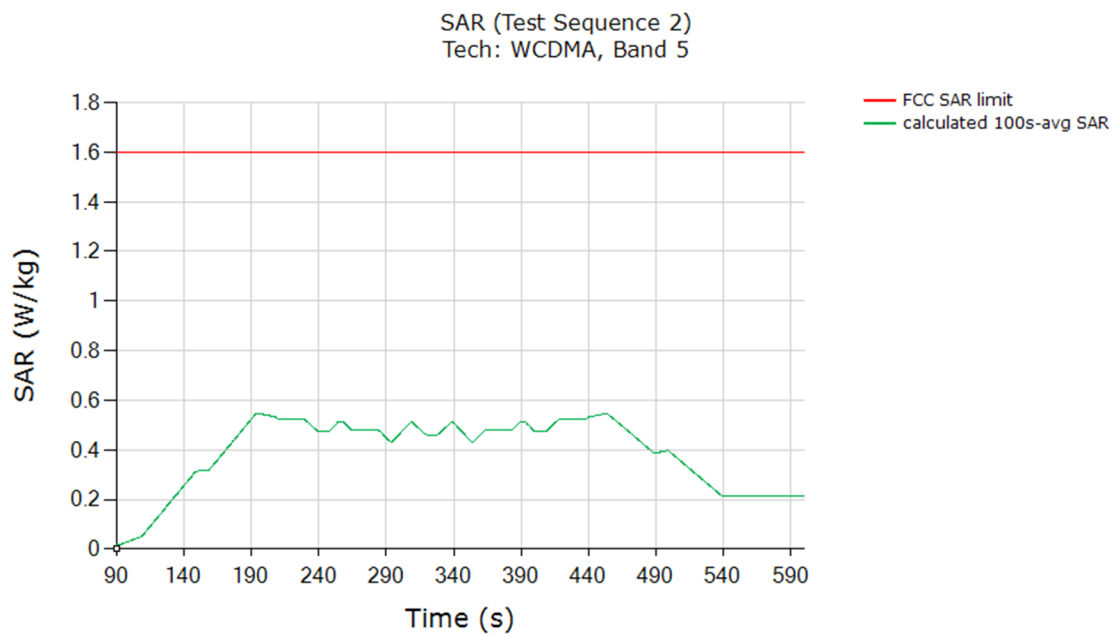


Max 100s SAR = 0.564

Max 100s SAR / Meas.SAR @ Plimit = -0.753 dB

Validated

Test result for test sequence 2 (SAR):



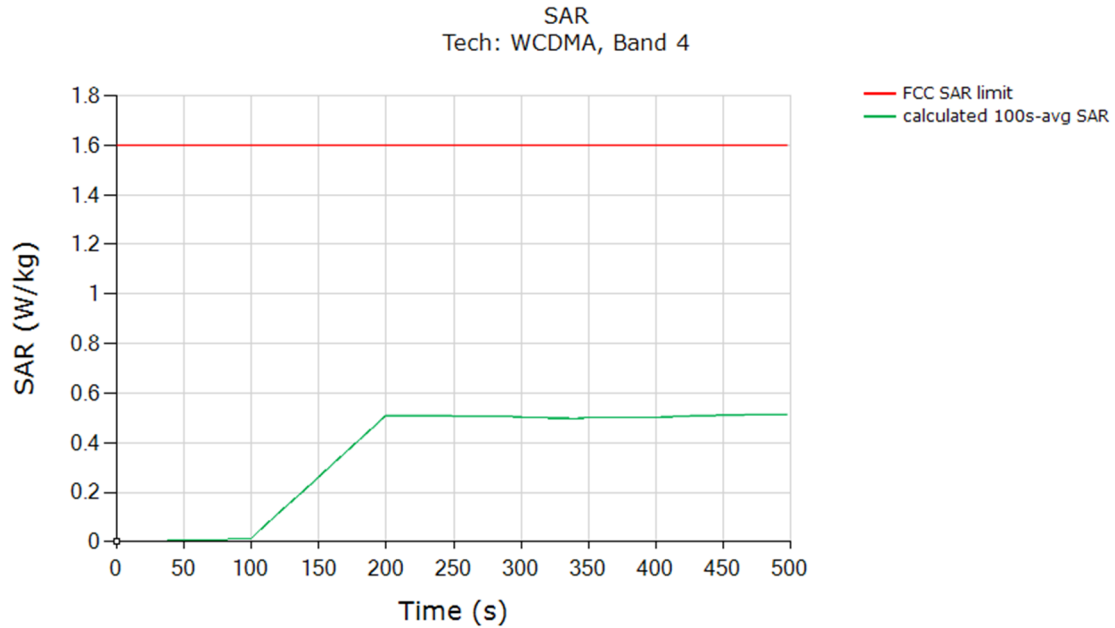
Max 100s SAR = 0.547 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.890 dB

Validated

12.4.2 WCDMA band 4

Test result for test sequence 1 (Conducted RF exposure):

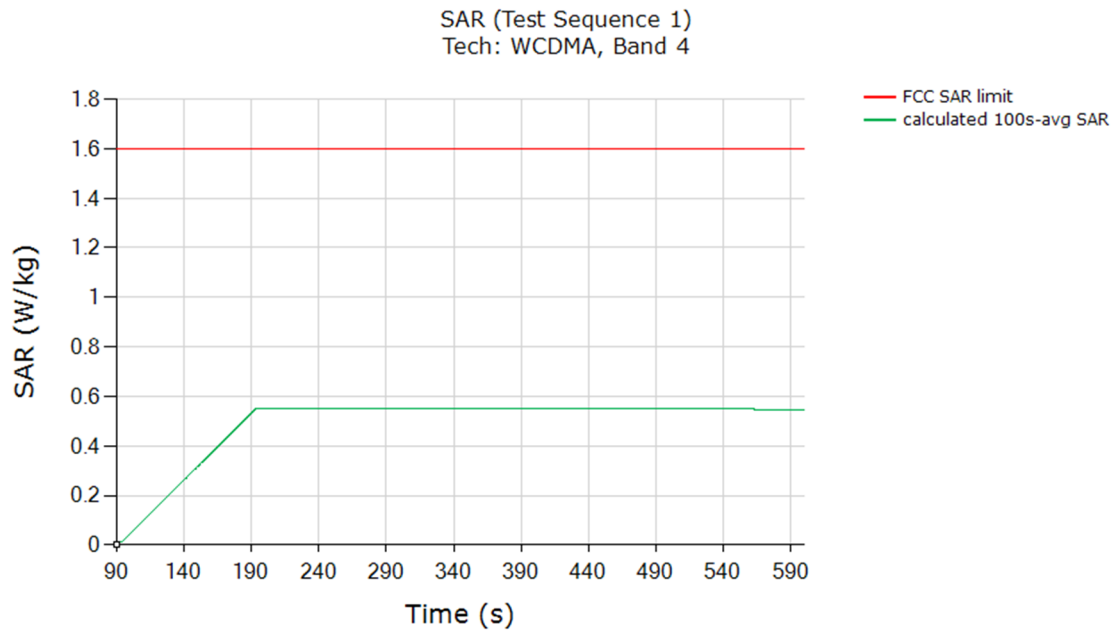


Max 100s SAR = 0.512 W/kg

Max 100s SAR / Meas.SAR @ Plimit = -0.321 dB

Validated

Test result for test sequence 1 (SAR):

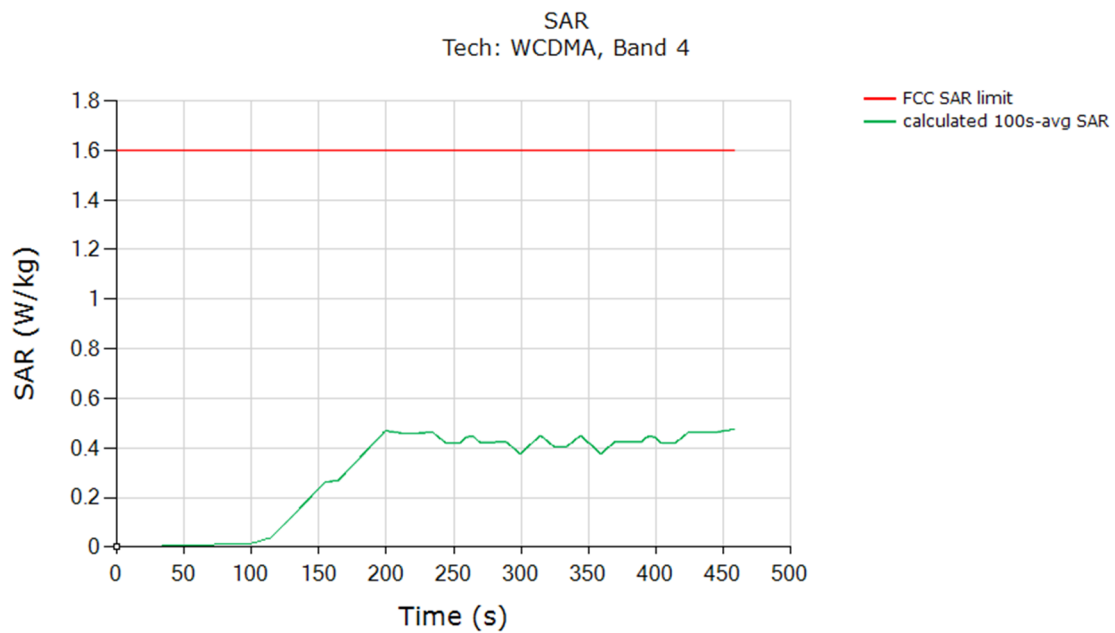


Max 100s SAR = 0.549 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.020 dB

Validated

Test result for test sequence 2 (Conducted RF exposure):

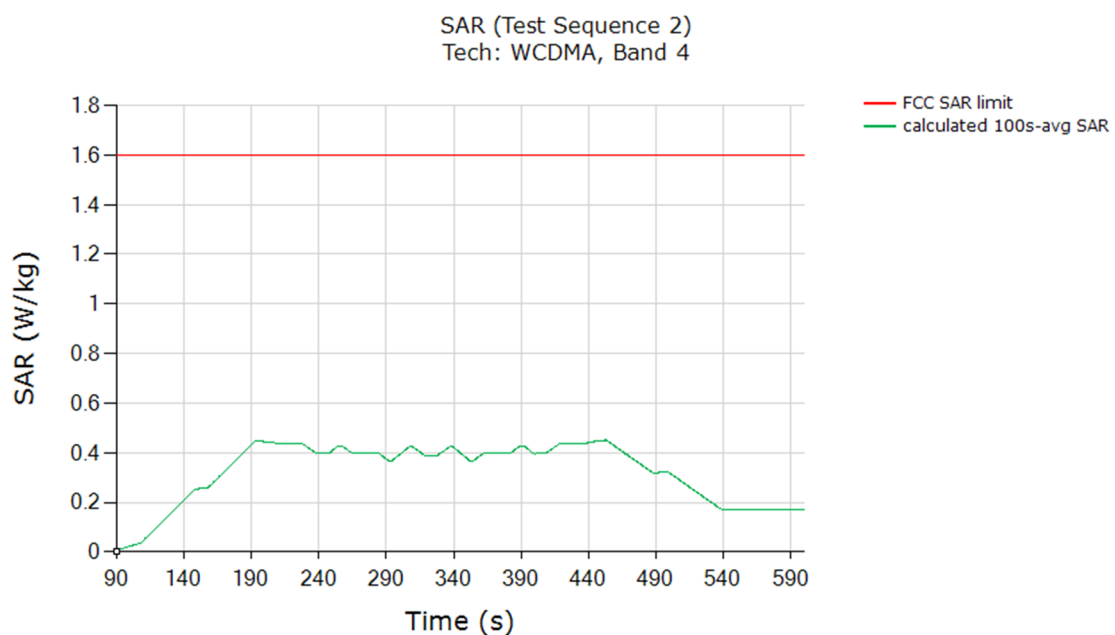


Max 100s SAR = 0.475 W/kg

Max 100s SAR / Meas.SAR @ Plimit = -0.645 dB

Validated

Test result for test sequence 2 (SAR):



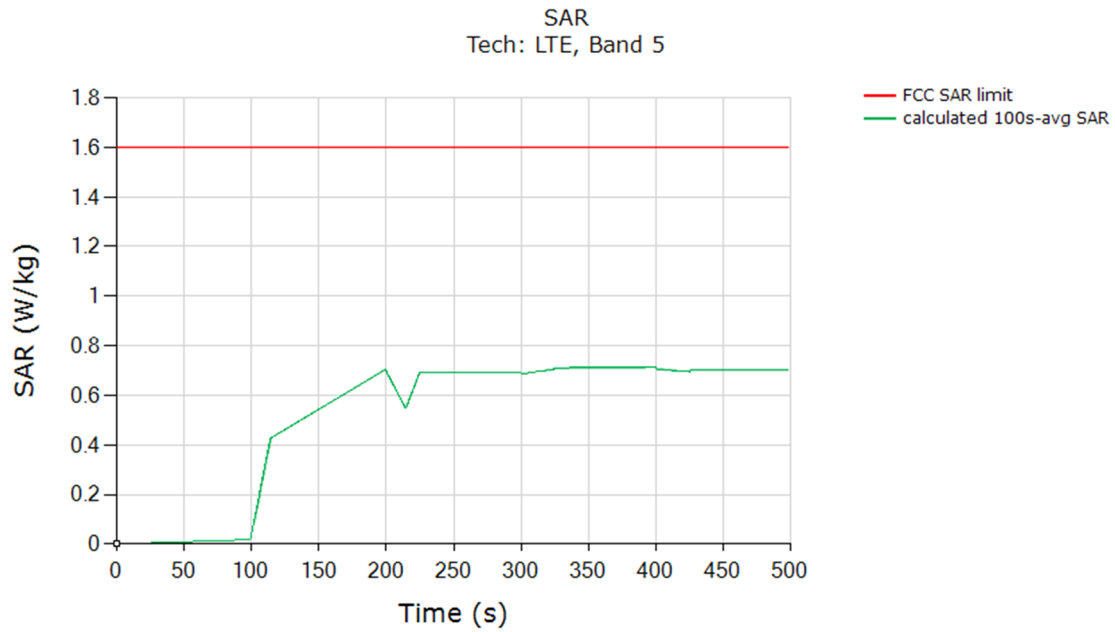
Max 100s SAR = 0.450 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.878 dB

Validated

12.4.3 LTE band 5

Test result for test sequence 1 (Conducted RF exposure):

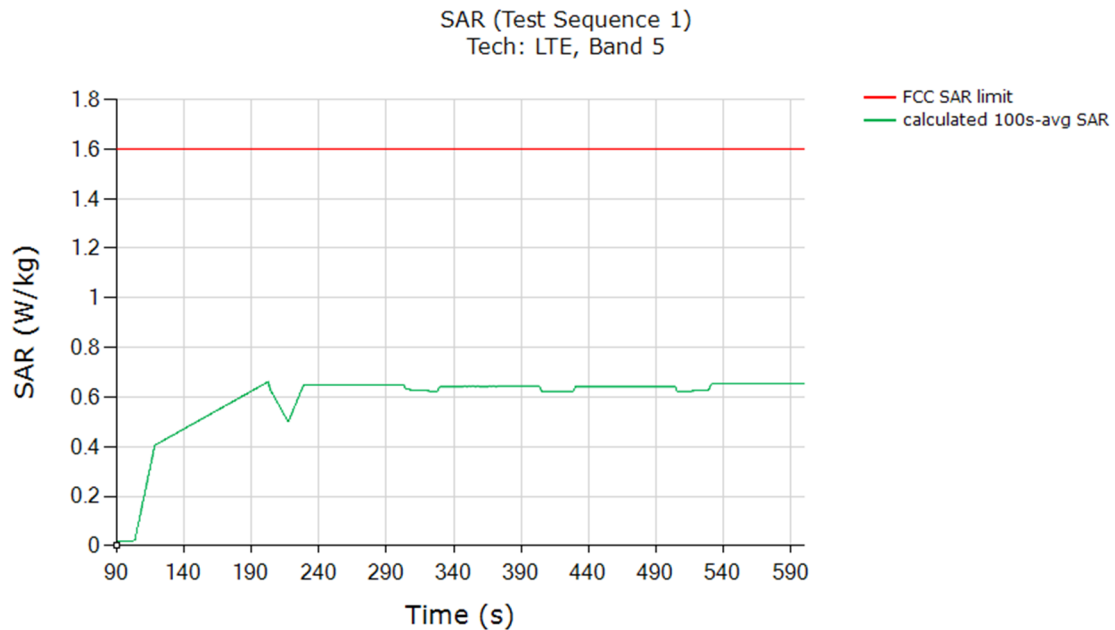


Max 100s SAR = 0.711 W/kg

Max 100s SAR / Meas.SAR @ Plimit = 0.253 dB

Validated

Test result for test sequence 1 (SAR):

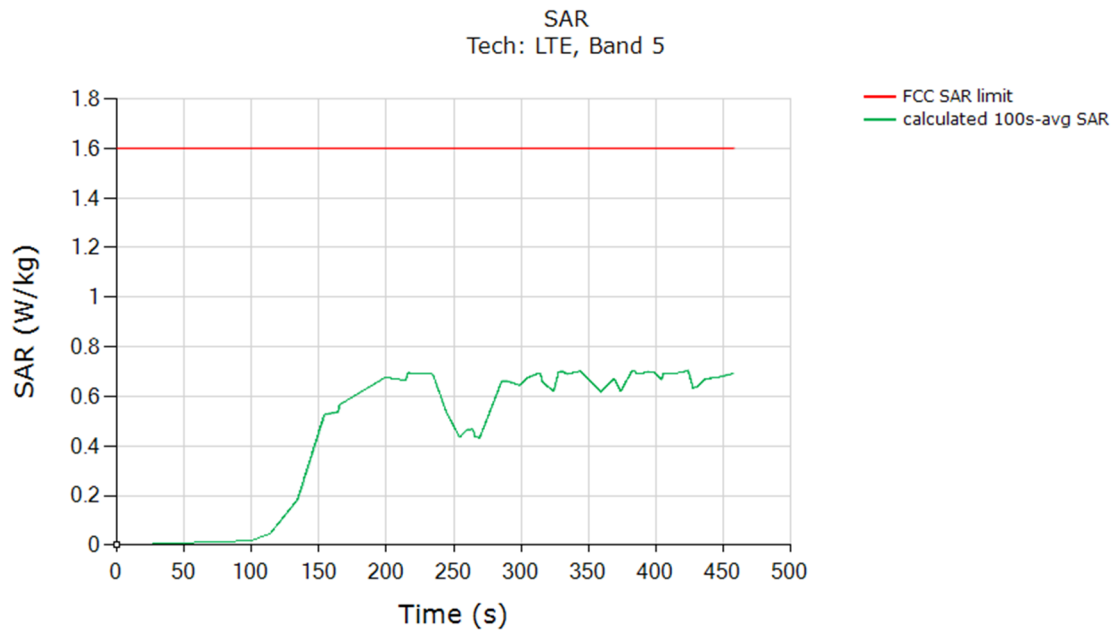


Max 100s SAR = 0.660 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.074 dB

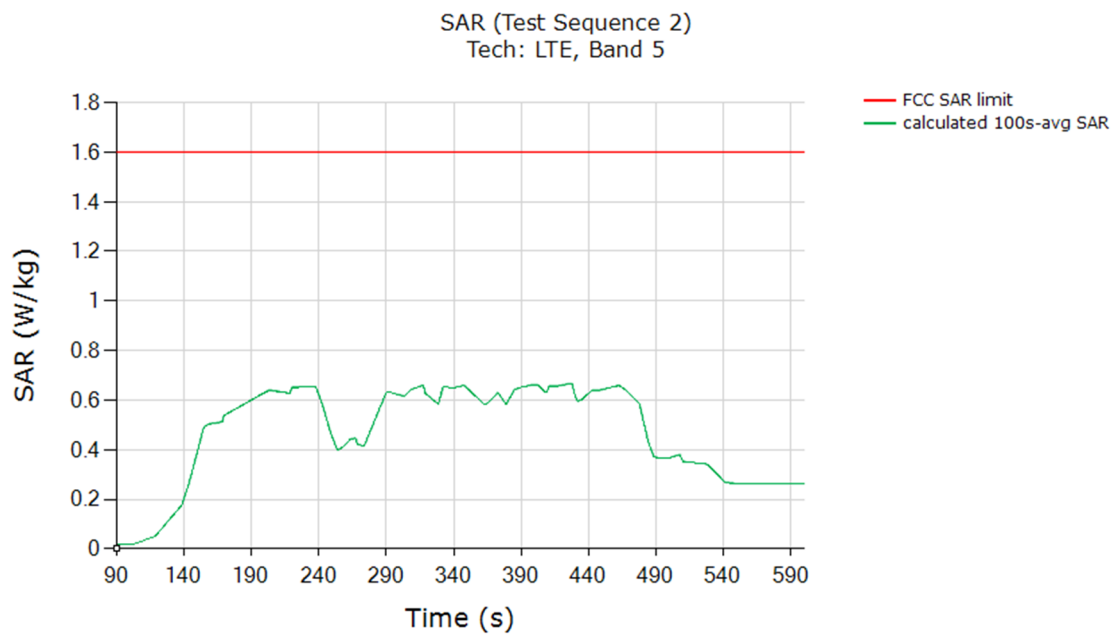
Validated

Test result for test sequence 2 (Conducted RF exposure):



Max 100s SAR = 0.703 W/kg
Max 100s SAR / Meas.SAR @ Plimit = 0.203 dB
Validated

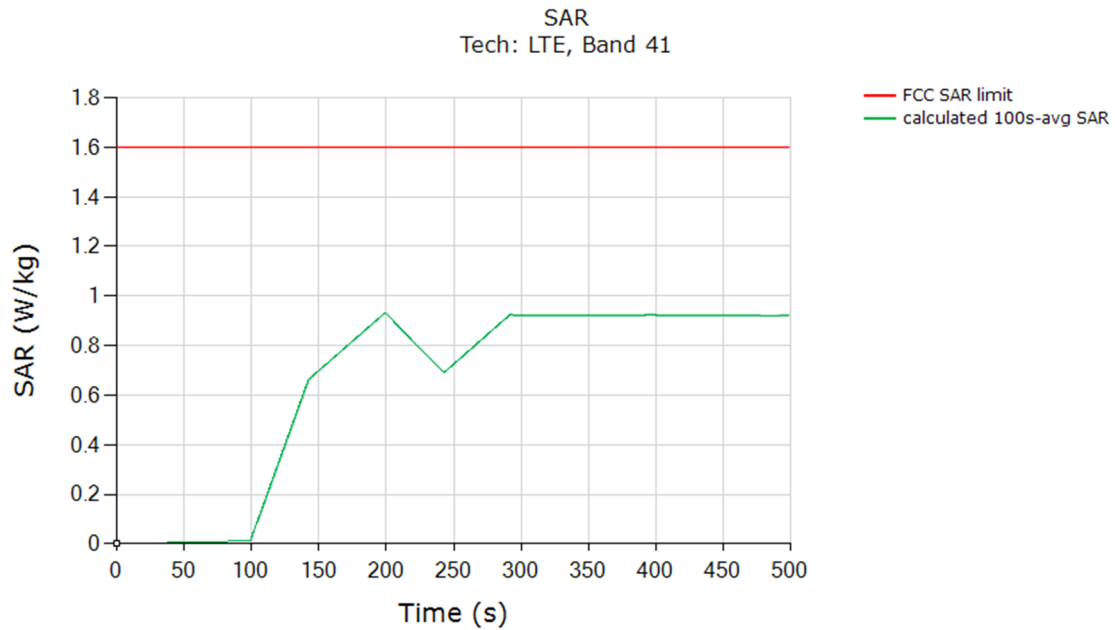
Test result for test sequence 2 (SAR):



Max 100s SAR = 0.667 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.026 dB
Validated

12.4.4 LTE band 41

Test result for test sequence 1 (Conducted RF exposure):

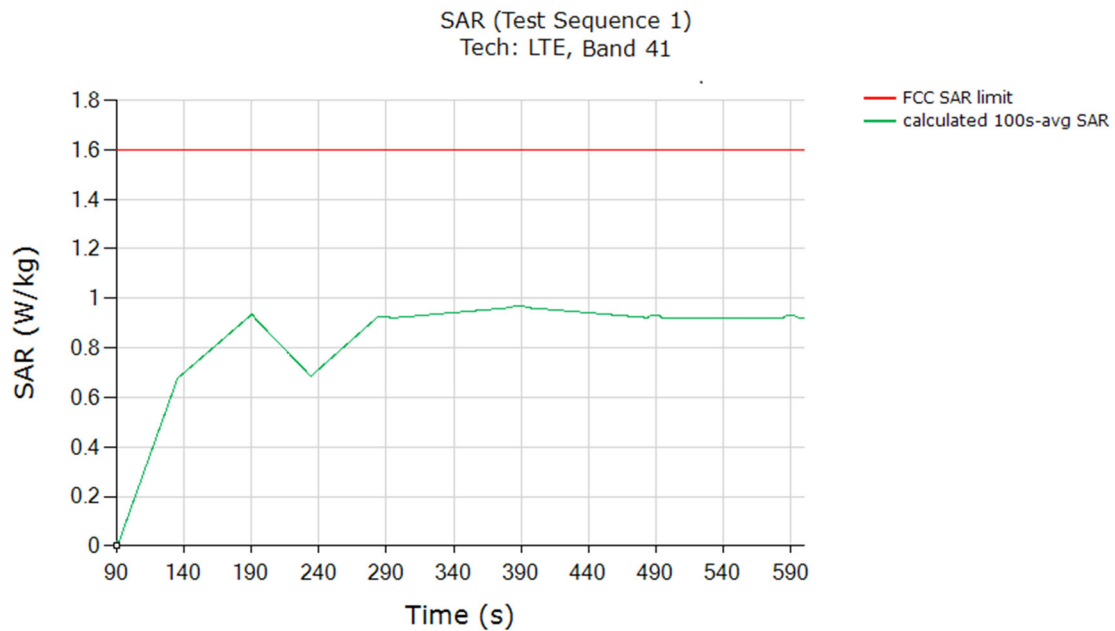


Max 100s SAR = 0.932 W/kg

Max 100s SAR / Meas.SAR @ Plimit = -0.039 dB

Validated

Test result for test sequence 1 (SAR):

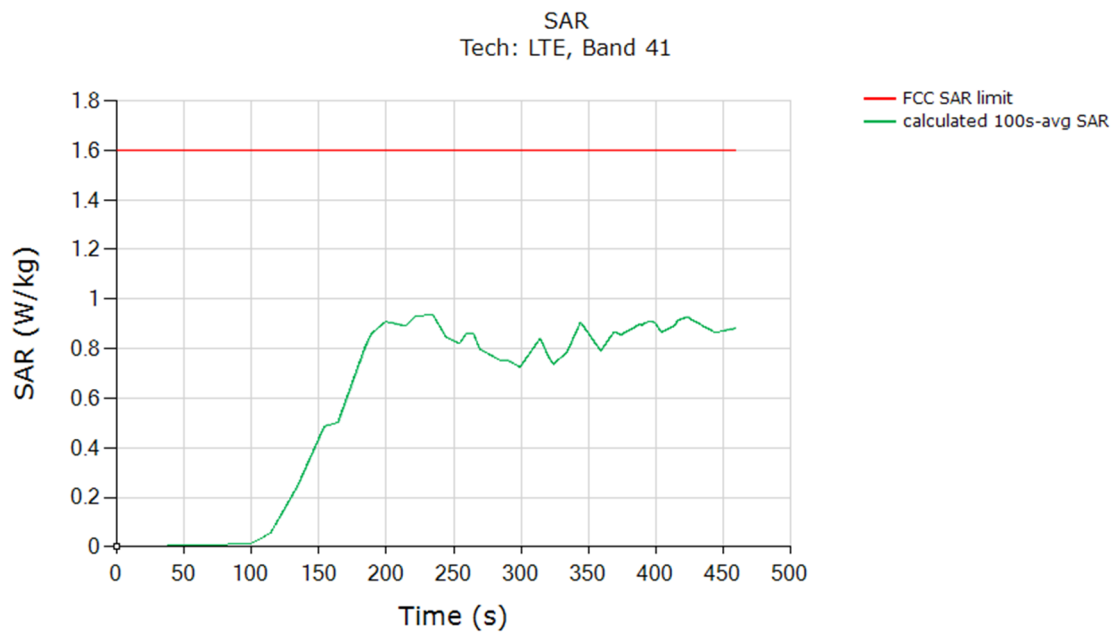


Max 100s SAR = 0.971 W/kg

Max 100s SAR / Meas. SAR @ Plimit = 0.140 dB

Validated

Test result for test sequence 2 (Conducted RF exposure):

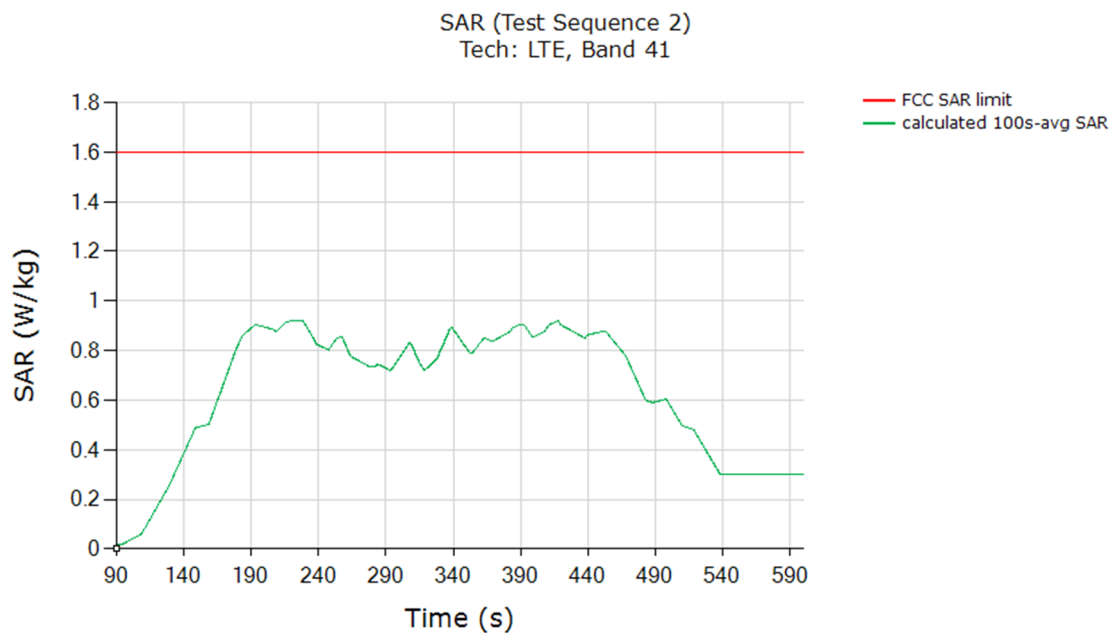


Max 100s SAR = 0.937

Max 100s SAR / Meas.SAR @ Plimit = -0.013 dB

Validated

Test result for test sequence 2 (SAR):



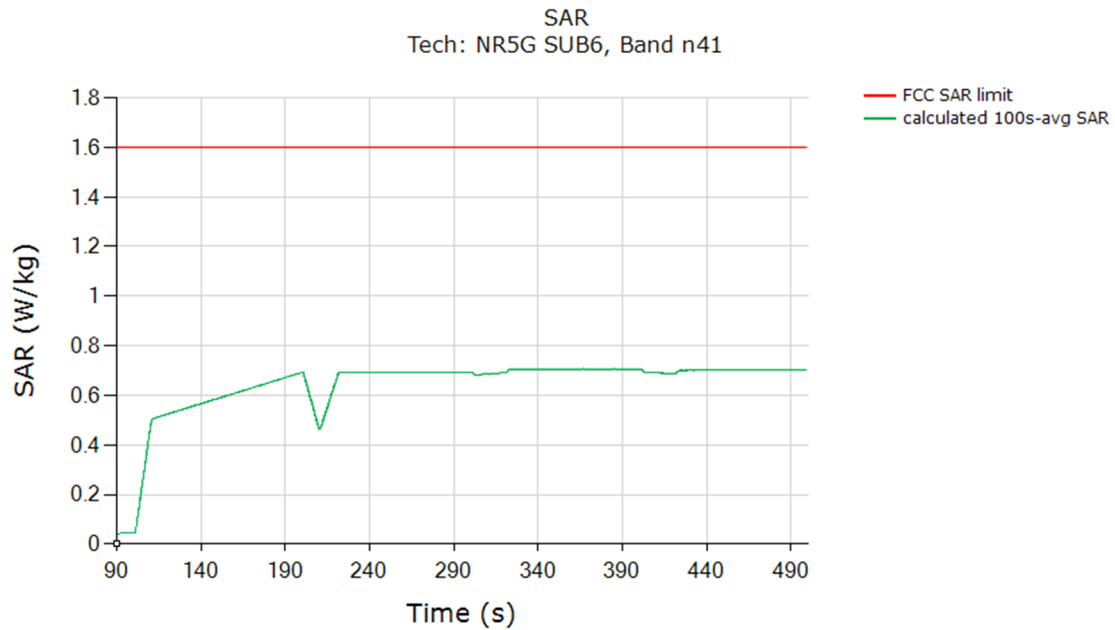
Max 100s SAR = 0.921 W/kg

Max 100s SAR / Meas. SAR @ Plimit = -0.089 dB

Validated

12.4.5 NR n41

Test result for test sequence 1 (Conducted RF exposure):

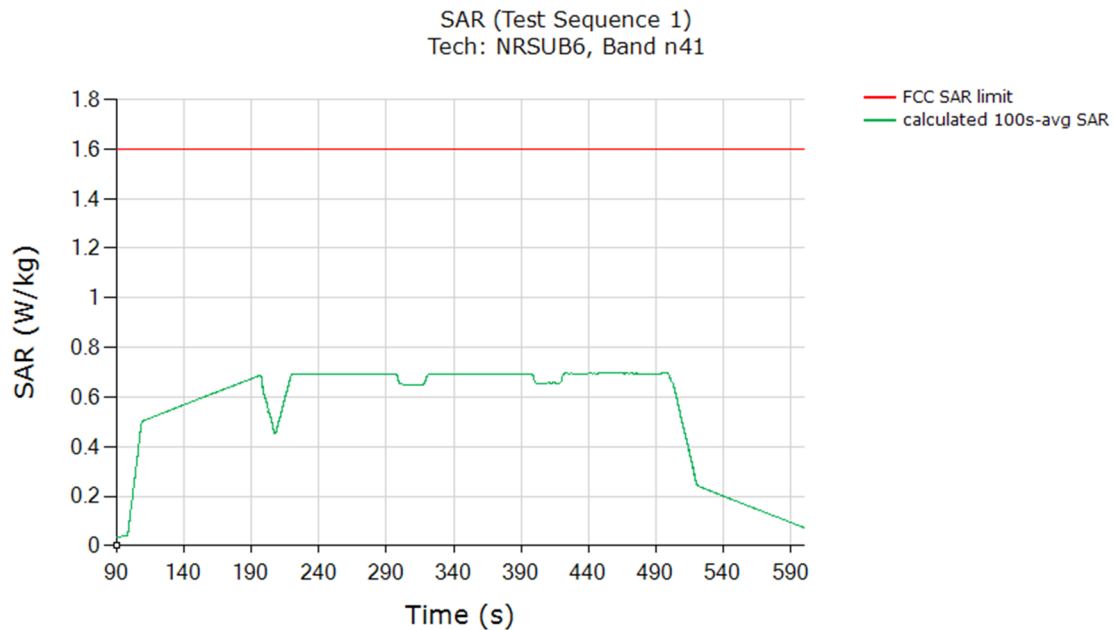


Max 100s SAR = 0.705 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.353 dB

Validated

Test result for test sequence 1 (SAR):

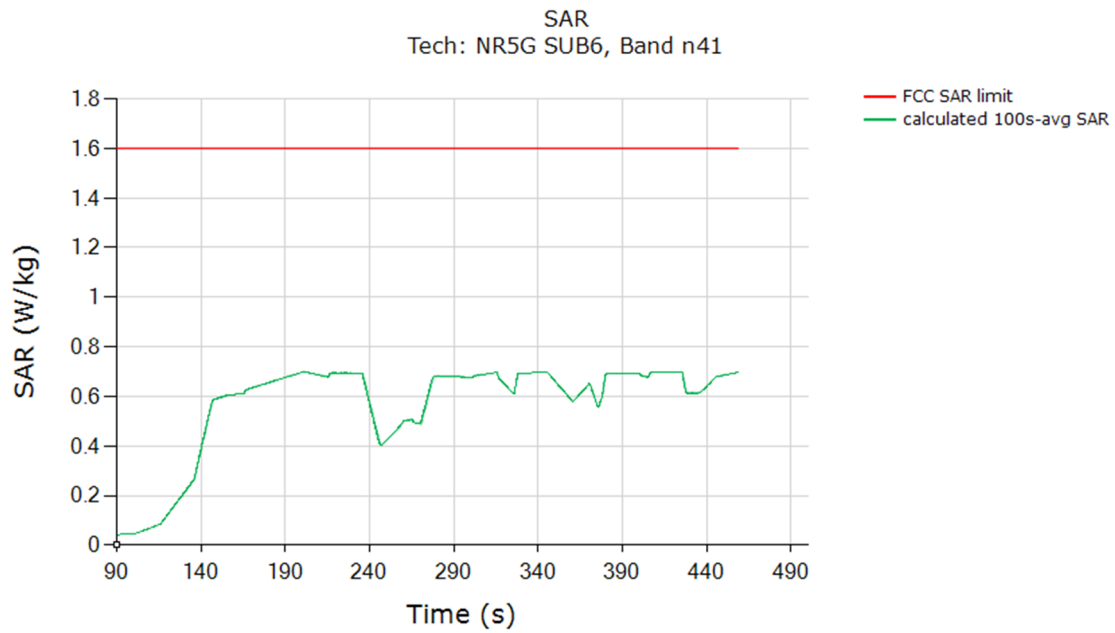


Max 100s SAR = 0.695 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.419 dB

Validated

Test result for test sequence 2 (Conducted RF exposure):

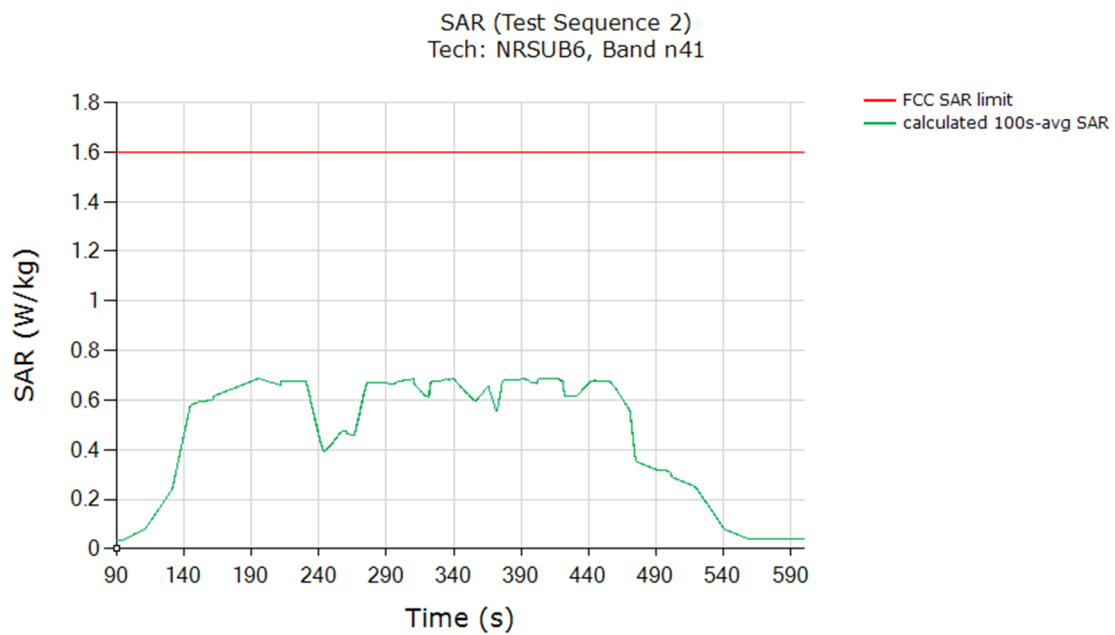


Max 100s SAR = 0.698 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.395 dB

Validated

Test result for test sequence 2 (SAR):



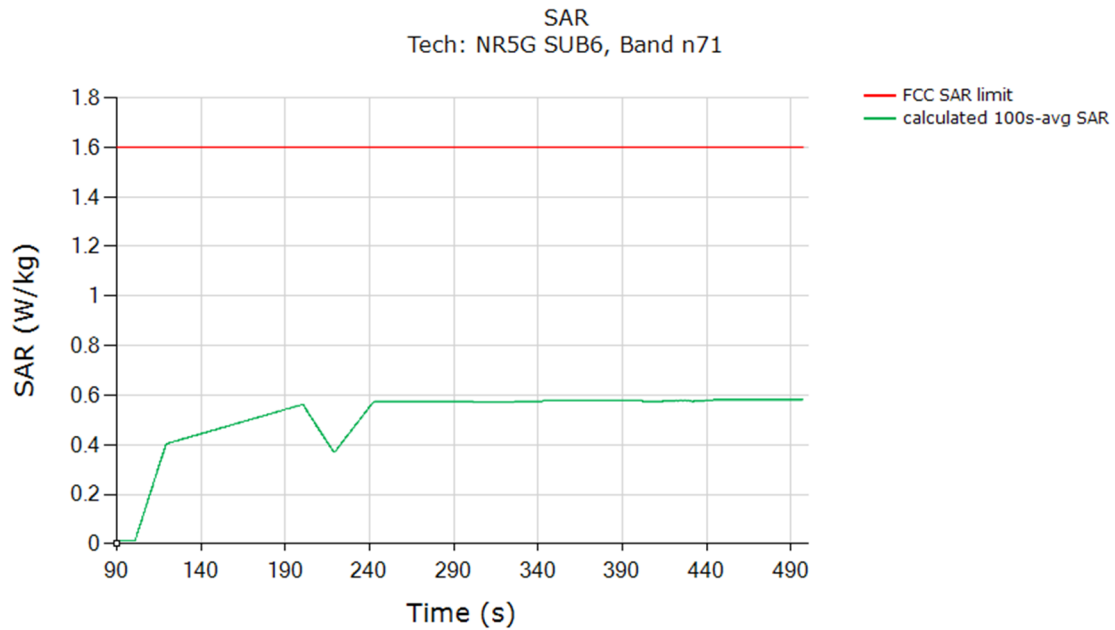
Max 100s SAR = 0.687 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.470 dB

Validated

12.4.6 NR n71

Test result for test sequence 1 (Conducted RF exposure):

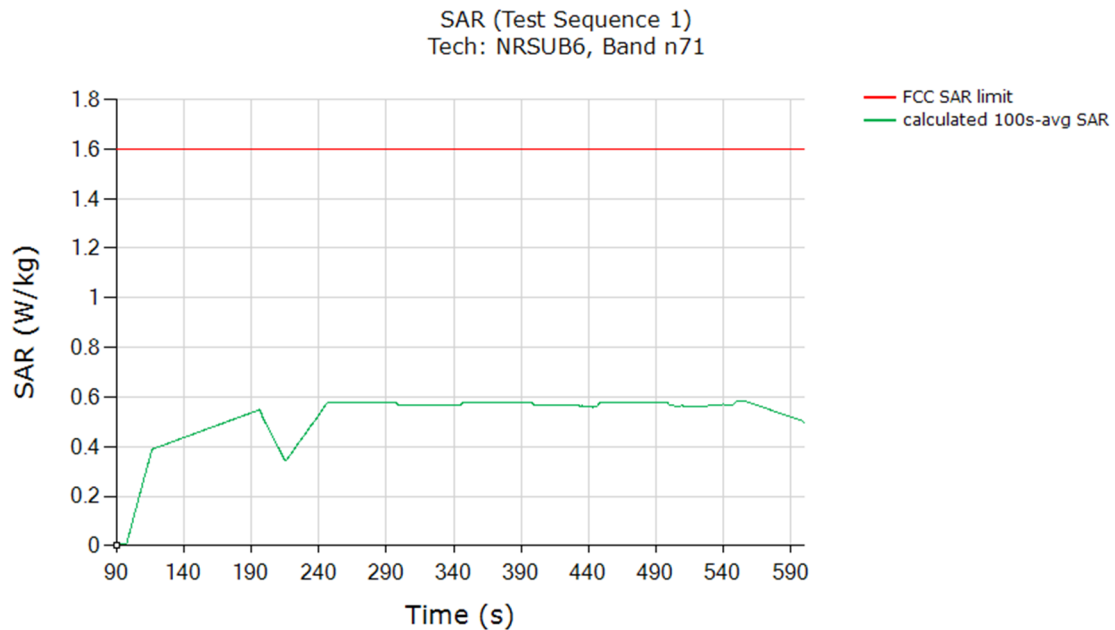


Max 100s SAR = 0.581 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.450 dB

Validated

Test result for test sequence 1 (SAR):

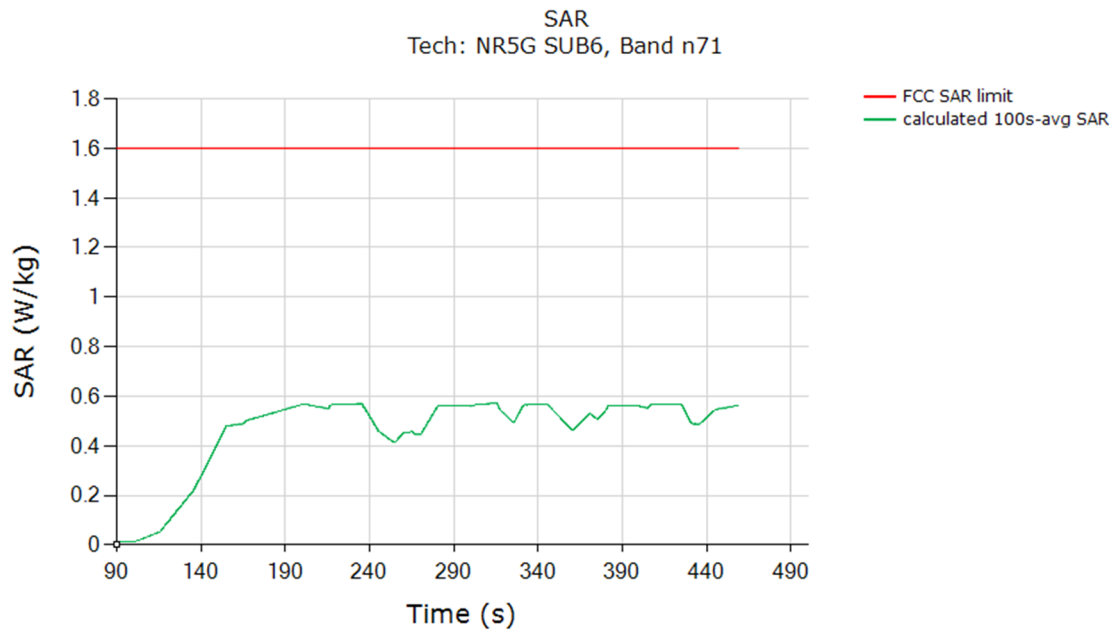


Max 100s SAR = 0.582 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.444 dB

Validated

Test result for test sequence 2 (Conducted RF exposure):

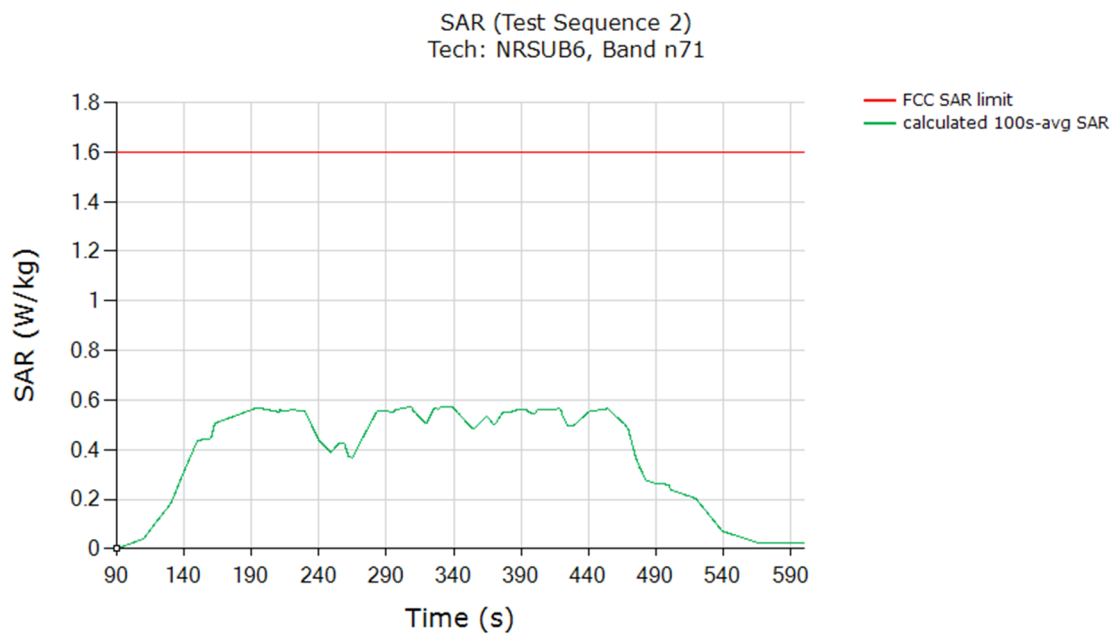


Max 100s SAR = 0.572 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.518 dB

Validated

Test result for test sequence 2 (SAR):



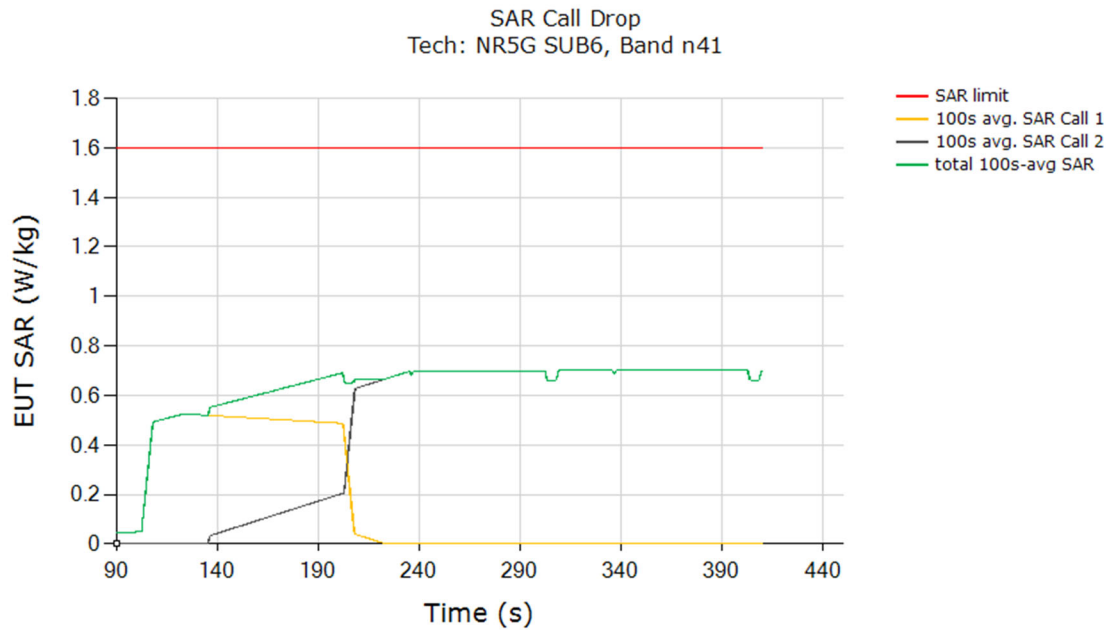
Max 100s SAR = 0.573 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.511 dB

Validated

12.5 Change in Call Test Results

12.5.1 NR band n41



Call Drop Time = 123.900 seconds

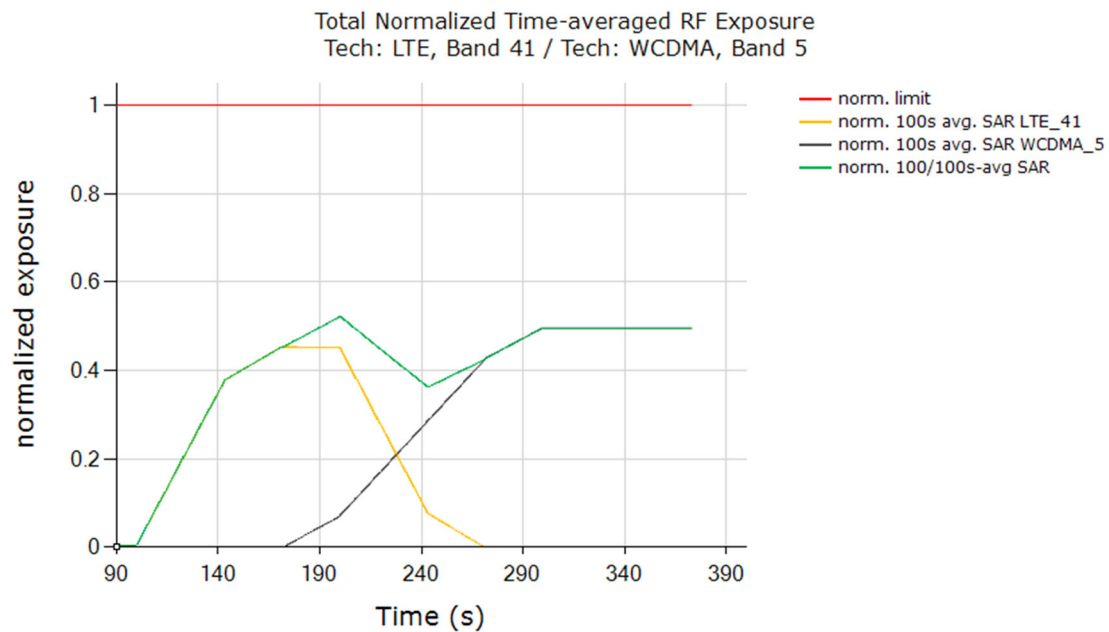
Max 100s SAR = 0.702 W/kg

Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.373 dB

Validated

12.6 Change in technology/band test results

12.6.1 LTE band 41 to WCDMA band 5



Switch time = 171.900 seconds

Max norm. 100s SAR for Tech/Band/Ant/DSI 1 = 0.453

Max norm. 100s SAR for Tech/Band/Ant/DSI 2 = 0.495

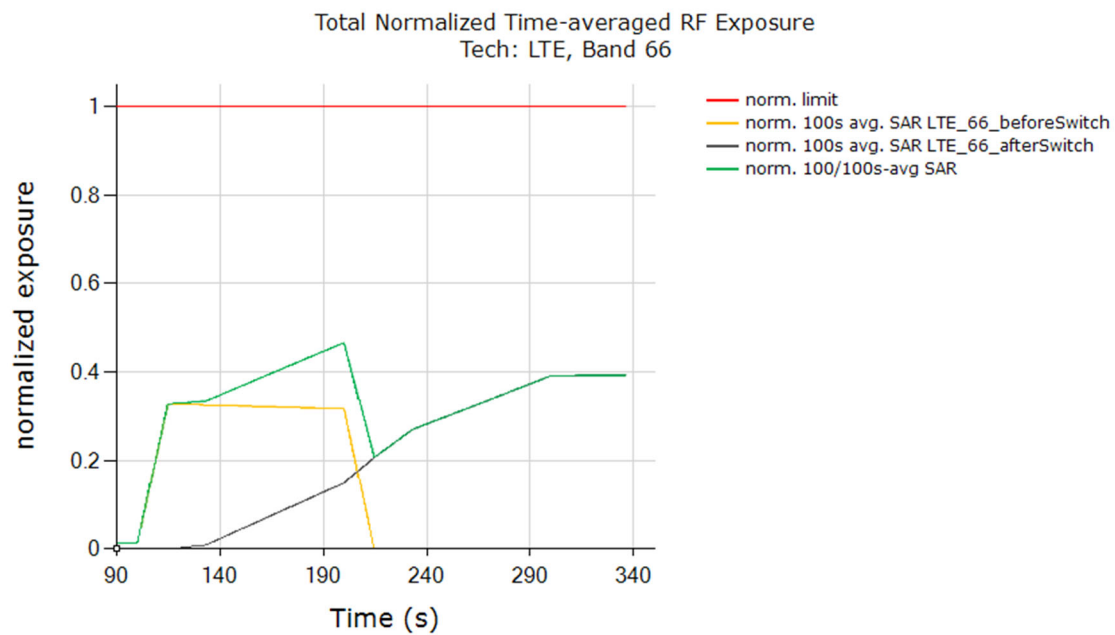
Maximum norm. Total time-avg. SAR = 0.523

Band	meas.SAR [W/kg]	norm SAR	Criteria
41	0.940	0.588	Lower limit = $0.420 - 1 \text{ dB} = 0.334$
5	0.671	0.420	Higher limit = $0.588 + 1 \text{ dB} = 0.740$

Validated

12.7 Change in DSI test results

12.7.1 LTE band 66 DSI1 to DSI0



Switch time = 115.600 seconds

Max Norm. 100s SAR for DSI 1 = 0.328

Max Norm. 100s SAR for DSI 0 = 0.474

Maximum Norm. Total time-avg. SAR = 0.497

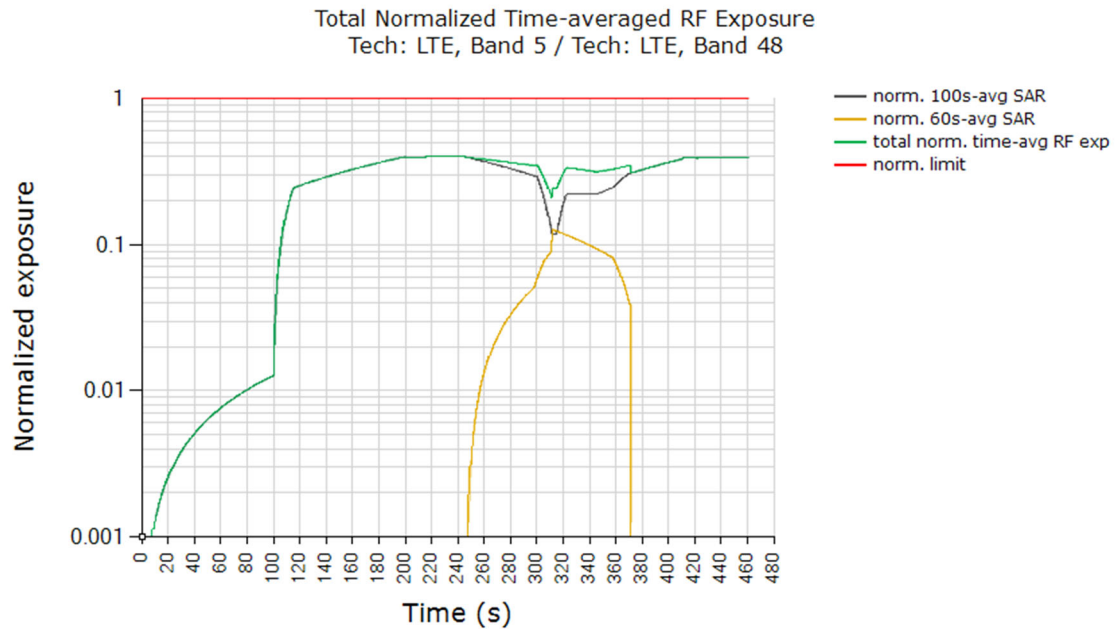
DSI	meas.SAR [W/kg]	norm SAR	Criteria
1	0.754	0.471	Lower limit = 0.471 - 1dB = 0.374
0	0.888	0.555	Higher limit = 0.555 + 1dB = 0.698

Validated

12.8 Change in Time Window

This test was conducted with callbox requesting maximum power, and with time-window from 100s window to 60s window vice versa. Following procedure detailed in Section 10.2.6, and using the measurement setup shown in Figure 4 (a), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level.

12.8.1 100 sec to 60 sec to 100 sec



Switch time 1 = 246.100 seconds

Switch time 2 = 311.900 seconds

Max Norm. 100s SAR = 0.398

Max Norm. 100s SAR = 0.398

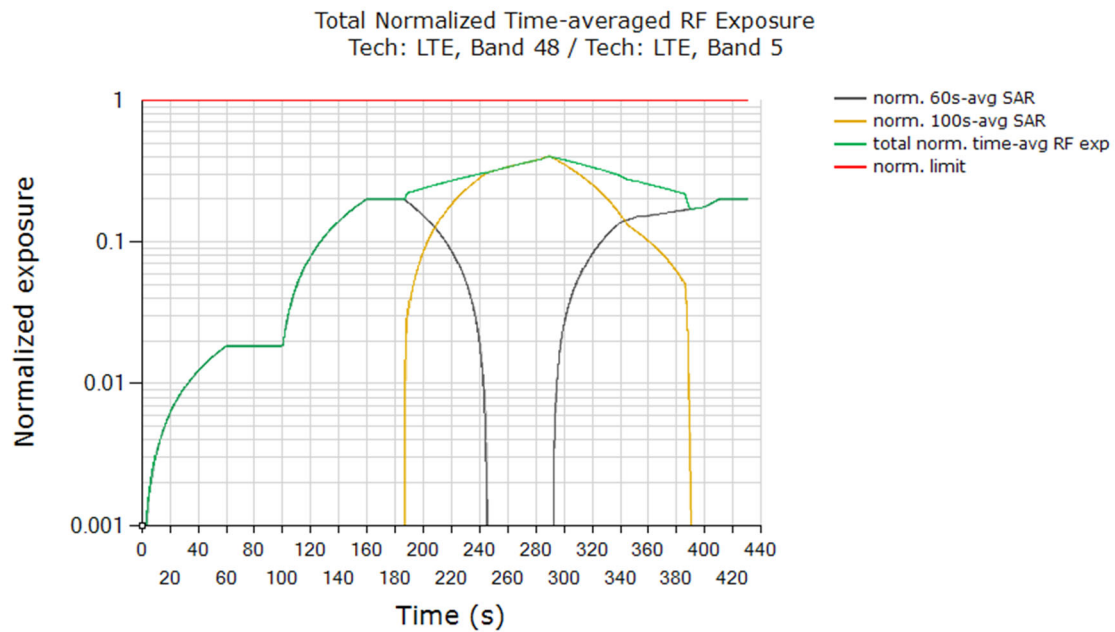
Max Norm. 60s SAR = 0.127

Max Norm. Total time-avg. SAR = 0.398

Band	meas.SAR [W/kg]	norm SAR	Criteria
5	0.671	0.420	Lower limit = $0.329 - 1 \text{ dB} = 0.261$
48	0.525	0.329	Higher limit = $0.420 + 1 \text{ dB} = 0.527$

Validated

12.8.2 60 sec to 100 sec to 60 sec



Switch time 1 = 186.700 seconds

Switch time 2 = 292.000 seconds

Max Norm. 60s SAR = 0.201

Max Norm. 60s SAR = 0.201

Max Norm. 100s SAR = 0.401

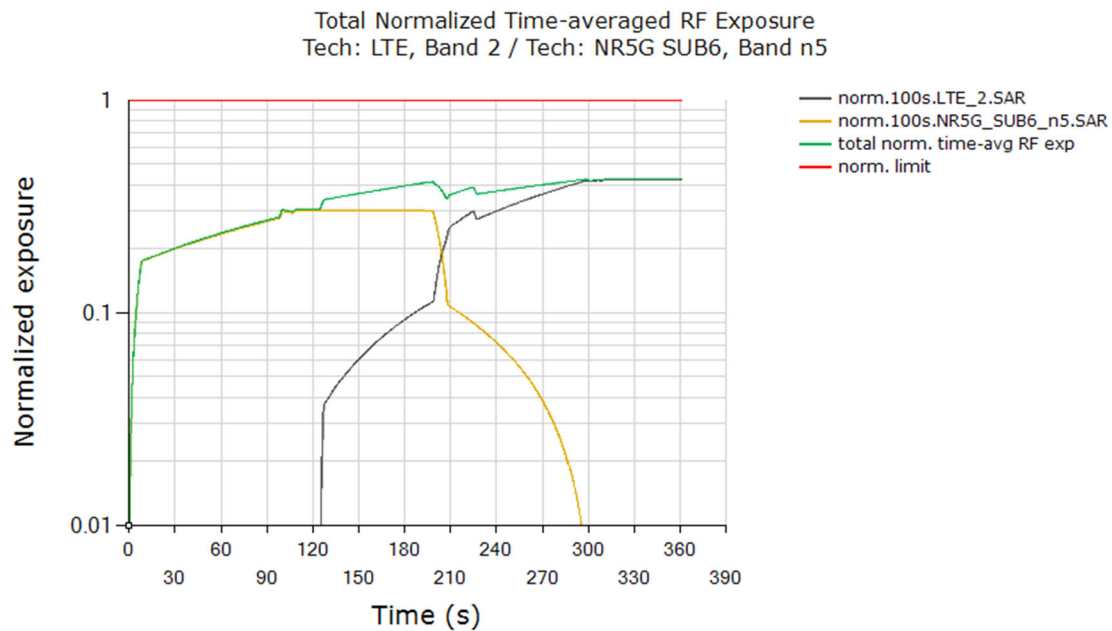
Max Norm. Total time-avg. SAR = 0.401

Band	meas.SAR [W/kg]	norm SAR	Criteria
5	0.671	0.420	Lower limit = $0.329 - 1 \text{ dB} = 0.261$
48	0.525	0.329	Higher limit = $0.420 + 1 \text{ dB} = 0.527$

Validated

12.9 Switch in SAR exposure test results

12.9.1 ENDC LTE band 2 / NR band n5



Max Norm. 100s SAR for LTE = 0.423

Max Norm. 100s SAR for Sub6NR = 0.304

Max Norm. 100s SAR for LTE / Meas. SAR @ Plimit for LTE = -0.097 dB

Max Norm. 100s SAR for Sub6NR / Meas. SAR @ Plimit for sub6NR / reserve factor for sub6NR = -0.528 dB

Max Norm. Total time-avg. SAR = 0.425

Band	meas.SAR [W/kg]	norm SAR	Criteria
2	0.692	0.433	Lower limit = $0.433 + 1 \text{ dB} = 0.344$
n5	0.732	0.458	Higher limit = $0.458 + 1 \text{ dB} = 0.575$

Validated

13 Test instrument

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
MMBBL600-6000	Body Simulating Liquid	Schmid & Partner Engineering AG	MBBL600-6000	SL AAM U16 BC	-	-
MOS-37	Digital thermometer	LKM electronic	DTM3000	-	2021/07/08	12
MNA-03	Vector Reflectometer	COPPER MOUNTAIN TECHNOLOGIES	PLANAR R140	0030913	2021/04/19	12
MDPK-03	Dielectric assessment kit	Schmid&Partner Engineering AG	DAKS-3.5	0008	2021/04/14	12
MAT-78	Attenuator	Telegrartner	J01156A0011	42294119	-	-
MHDC-21	Dual Directional Coupler	Keysight Technologies Inc	778D	MY52180243	-	-
MHDC-12	Dual Directional Coupler	Hewlett Packard	772D	2839A0016	-	-
MPSE-24	Power sensor	Anritsu Corporation	MA24106A	1026164	2021/08/17	12
MPSE-25	Power sensor	Anritsu Corporation	MA24106A	1031504	2021/08/17	12
MSG-10	Signal Generator	Keysight Technologies Inc	N5181A	MY47421098	2020/11/17	12
MRFA-24	Pre Amplifier	R&K	R&K CGA020M602-2633R	B30550	2021/06/16	12
MPSE-20	Power sensor	Keysight Technologies Inc	N8482H	MY53050001	2021/06/08	12
MPM-11	Dual Power Meter	Keysight Technologies Inc	E4419B	MY45102060	2021/08/10	12
MDA-19	Dipole Antenna	Schmid&Partner Engineering AG	D2600V2	1030	2019/03/14	36
MDA-23	Dipole Antenna	Schmid & Partner Engineering AG	D3500V2	1052	2019/12/11	24
SSDA-20	Dipole Antenna	Schmid&Partner Engineering AG	D750V3	1058	2021/05/18	12
COTS-MPSE-02	Software for MA24106A	Anritsu Corporation	Anritsu PowerXpert	-	-	-
COTS-MSAR-04	Dielectric assessment software	Schmid&Partner Engineering AG	DAK	-	-	-
COTS-MSAR-05	Dasy6	Schmid & Partner Engineering AG	DASY6	-	-	-
MPB-08	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3917	2021/05/20	12
MDAE-02	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	1369	2021/05/11	12
MOS-33	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	-	2021/07/08	12
MRBT-03	SAR robot	Schmid&Partner Engineering AG	TX60 Lspeag	F13/5PP1D1/A/01	2021/04/20	12
MPF-03	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1203	2021/05/28	12
MPB-07	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3825	2021/07/21	12
MPB-08	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3917	2021/05/21	12
MDAE-01	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	509	2021/07/13	12
MOS-31	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	3101	2021/07/08	12
MRBT-04	SAR robot	Schmid&Partner Engineering AG	TX60 Lspeag	F13/5PP1A1/A/01	2021/04/20	12
MPF-04	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1207	2021/05/28	12
MURC-10	Wideband Radio Communication Tester	Rohde & Schwarz	CMW500	165750	2021/06/15	12
MURC-05	Wideband Radio Communication Tester	Rohde & Schwarz	CMW500	127576	-	-
MURC-13	UXM 5G Wireless Test Platform	Keysight Technologies Inc	E7515B	MY59321679	2021/03/29	12
MPSE-28	RF Device, Active, Power Meter	Rohde & Schwarz	NRP8S	110600	2021/06/15	12
MPSE-29	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101418	2021/06/15	12
MPSE-30	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101419	2021/06/15	12

*Hyphens for Last Calibration Date and Cal Int (month) are instruments that Calibration is not required (e.g. software), or instruments checked in advance before use.

The expiration date of the calibration is the end of the expired month.

As for some calibrations performed after the tested dates, those test equipment have been controlled by means of an unbroken chains of calibrations.

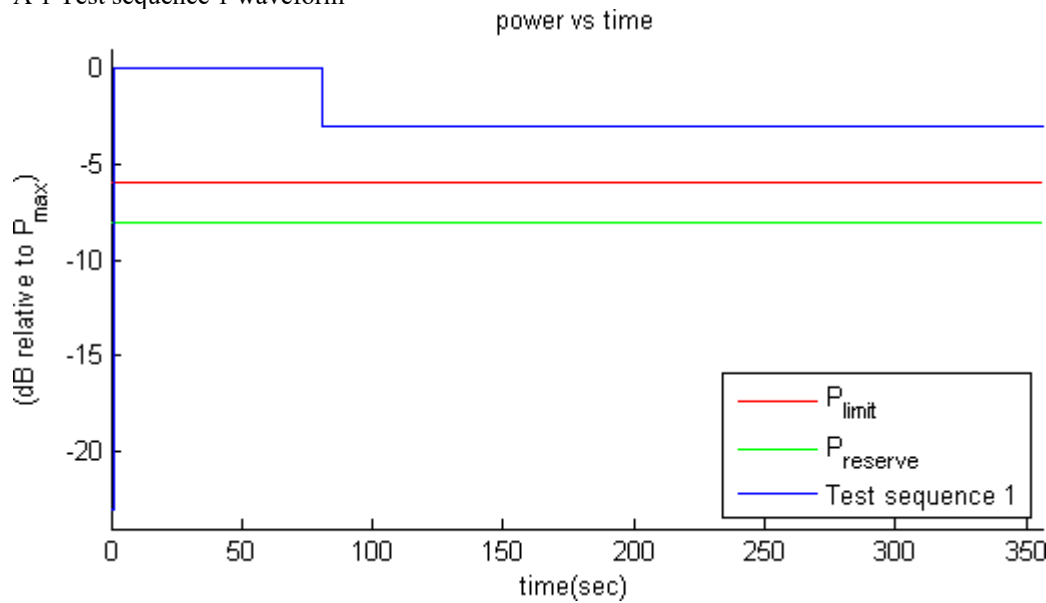
The expiration*1) This test equipment was used for the tests before the expiration date of the calibration.

All equipment is calibrated with valid calibrations. Each measurement data is traceable to the national or international standards.

APPENDIX A TEST SEQUENCES

1. Test sequence is generated based on below parameters of the EUT:
 - a. Measured maximum power (P_{max})
 - b. Measured Tx_power_at_SAR_design_target (P_{limit})
 - c. Reserve_power_margin (dB)
 - i. $P_{reserve}(\text{dBm}) = \text{measured } P_{limit}(\text{dBm}) - \text{Reserve_power_margin (dB)}$
 - d. SAR_time_window (100s for FCC)
2. Test Sequence 1 Waveform: Based on the parameters above, the Test Sequence 1 is generated with one transition between high and low Tx powers. Here, high power = P_{max} ; low power = $P_{max}/2$, and the transition occurs after 80 seconds at high power P_{max} . This 80s duration makes sure that EUT is enforced to limit power first before the transition from high (P_{max}) to low ($P_{max}/2$) occurs. If 80s is not long enough for power limiting enforcement (transition) to take place, then the high power duration needs to be increased accordingly. The Test sequence 1 waveform is shown below:

A 1 Test sequence 1 waveform

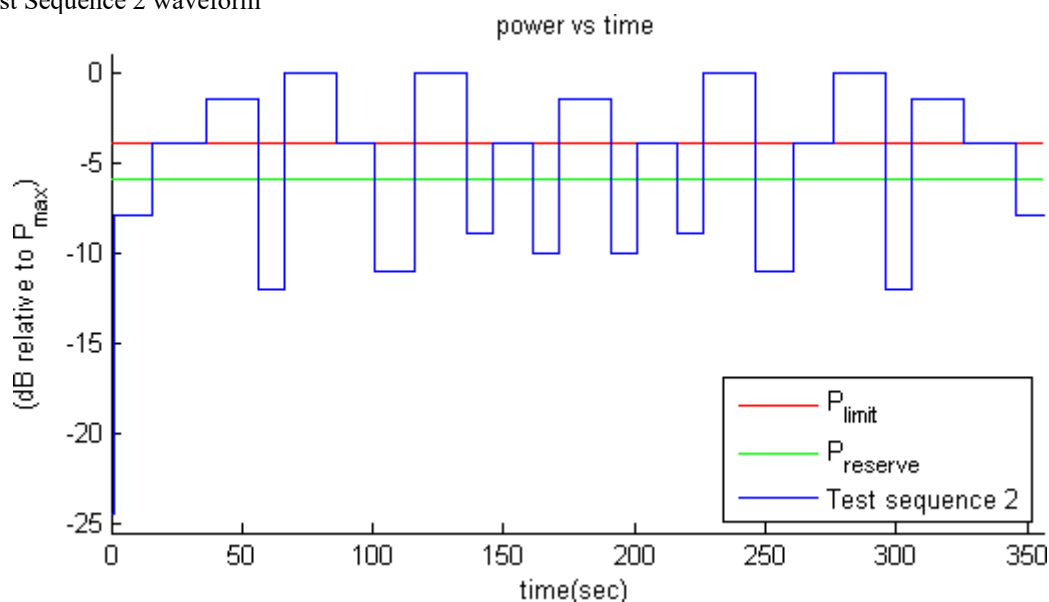


3. Test Sequence 2 Waveform: Based on the parameters in A-1, the Test Sequence 2 is generated as described in Table 10-1, which contains two 170 second-long sequences (yellow and green highlighted rows) that are mirrored around the center row of 20s, resulting in a total duration of 360 seconds:

A 2 Test Sequence 2

Time duration (seconds)	dB relative to P_{limit} or $P_{reserve}$
15	$P_{reserve} - 2$
20	P_{limit}
20	$(P_{limit} + P_{max})/2$ averaged in mW and rounded to nearest 0.1 dB step
10	$P_{reserve} - 6$
20	P_{max}
15	P_{limit}
15	$P_{reserve} - 5$
20	P_{max}
10	$P_{reserve} - 3$
15	P_{limit}
10	$P_{reserve} - 4$
20	$(P_{limit} + P_{max})/2$ averaged in mW and rounded to nearest 0.1 dB step
10	$P_{reserve} - 4$
15	P_{limit}
10	$P_{reserve} - 3$
20	P_{max}
15	$P_{reserve} - 5$
15	P_{limit}
20	P_{max}
10	$P_{reserve} - 6$
20	$(P_{limit} + P_{max})/2$ averaged in mW and rounded to nearest 0.1 dB step
20	P_{limit}
15	$P_{reserve} - 2$

A 3 Test Sequence 2 waveform



APPENDIX B UNCERTAINTY OF MEASUREMENT

Power measurement

The following uncertainties have been calculated to provide a confidence level of 95 % using a coverage factor $k=2$.

300 MHz to 6000 MHz 0.85 dB

20 GHz to 40 GHz 1.24 dB

SAR testing

Error Description	Uncert. value	Prob. Dist.	Div.	(ci) 1g	(ci) 10g	Std. Unc. (1g)	Std.Unc. (10g)
Measurement System Errors							
Probe Calibration	± 14.00 %	N	2	1	1	±7.0%	±7.00%
Probe Calibration Drift	± 1.7 %	R	√3	1	1	±1.0%	±1.0%
Probe Linearity	± 4.7 %	R	√3	1	1	±2.7%	±2.7%
Broadband Signal	± 2.6 %	R	√3	1	1	±1.5%	±1.5%
Probe Isotropy	± 7.6 %	R	√3	1	1	±4.4%	±4.4%
Data Acquisition	± 0.3 %	N	1	1	1	±0.3%	±0.3%
RF Ambient	± 1.8 %	N	1	1	1	±1.8%	±1.8%
Probe Positioning	± 0.2 %	N	1	0.33	0.33	±0.1%	±0.1%
Data Processing	± 2.3 %	N	1	1	1	±2.3%	±2.3%
Phantom and Device Errors							
Conductivity (meas.)DAK	± 10.0 %	N	1	0.78	0.71	±7.8%	±7.1%
Conductivity (temp.)BB	± 3.4 %	R	√3	0.78	0.71	±1.5%	±1.4%
Phantom Permittivity	± 14.0 %	R	√3	0.25	0.25	±2.0%	±2.0%
Distance DUT - TSL	± 2.0 %	N	1	2	2	±4.0%	±4.0%
Device Positioning (+/- 0.5mm)	± 1.0 %	N	1	1	1	±1.0%	±1.0%
Device Holder	± 3.6 %	N	1	1	1	±3.6%	±3.6%
DUT Modulationm	± 2.4 %	R	√3	1	1	±1.4%	±1.4%
Time-average SAR	± 2.6 %	R	√3	1	1	±1.5%	±1.5%
DUT drift	± 2.5 %	N	1	1	1	±2.5%	±2.5%
Val Antenna Unc.val	± 0.0 %	N	1	1	1	±0.0%	±0.0%
Unc. Input Powerval	± 0.0 %	N	1	1	1	±0.0%	±0.0%
Correction to the SAR results							
Deviation to Target	± 1.9 %	N	1	1	0.84	±1.9%	±1.6%
SAR scalingp	± 0.0 %	R	√3	1	1	±0.0%	±0.0%
Combined Std. Uncertainty						±14.1%	±13.7%
Expanded STD Uncertainty ($\kappa=2$)						±28.2%	±27.4%

APPENDIX C REVISION HISTORY

Original Test Report No.: 13760834H-C

Revision	Test report No.	Date	Revision details
- (Original)	13760834H-C	November 25, 2021	-
1	13760834H-C-R1	December 16, 2021	Section 11.1 Corrected value of P_{limit} for DSI=0 in Table 11-1
			Section 11.1 Added note at bottom of Table 11-1: "Powers are specified as burst average."

End of Report