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RF EXPOSURE PART 2 TEST REPORT

Applicant Name: Samsung Electronics Co., Ltd. 129, Samsung-ro, Maetan dong, Yeongtong-gu, Suwon-si Gyeonggi-do, 16677, Korea	**Date of Testing:** 02/18/2025 – 03/04/2025 **Test Site/Location:** Element, Columbia, MD, USA **Document Serial No.:** 1M2501020001-03.A3L (Rev1)

FCC ID:	**A3LSMG766U**
APPLICANT:	**SAMSUNG ELECTRONICS CO., LTD.**

DUT Type:	Portable Handset
Application Type:	Certification
FCC Rule Part(s):	CFR §2.1093
Model(s):	SM-S766U
Additional Model(s):	SM-S776U1
Device Serial Numbers:	Pre-Production Samples [3709M, 1967M, 2575M]

Note: This revised test report supersedes and replaces the previously issued test report on the same subject device for the same type of testing as indicated. Please discard or destroy the previously issued test report(s) and dispose of it accordingly.

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

RJ Ortanez
Executive Vice President

CERT #2041.01

T A B L E   O F   C O N T E N T S

1 DEVICE UNDER TEST

1.1 Device Overview

Band & Mode	Operating Modes	Tx Frequency
GSM/GPRS/EDGE 850	Voice/Data	824.20 - 848.80 MHz
GSM/GPRS/EDGE 1900	Voice/Data	1850.20 - 1909.80 MHz
UMTS 850	Voice/Data	826.40 - 846.60 MHz
UMTS 1750	Voice/Data	1712.4 - 1752.6 MHz
UMTS 1900	Voice/Data	1852.4 - 1907.6 MHz
LTE Band 71	Voice/Data	665.5 - 695.5 MHz
LTE Band 12	Voice/Data	699.7 - 715.3 MHz
LTE Band 13	Voice/Data	779.5 - 784.5 MHz
LTE Band 14	Voice/Data	790.5 - 795.5 MHz
LTE Band 26	Voice/Data	814.7 - 848.3 MHz
LTE Band 5	Voice/Data	824.7 - 848.3 MHz
LTE Band 66	Voice/Data	1710.7 - 1779.3 MHz
LTE Band 4	Voice/Data	1710.7 - 1754.3 MHz
LTE Band 25	Voice/Data	1850.7 - 1914.3 MHz
LTE Band 2	Voice/Data	1850.7 - 1909.3 MHz
LTE Band 30	Voice/Data	2307.5 - 2312.5 MHz
LTE Band 7	Voice/Data	2502.5 - 2567.5 MHz
LTE Band 41	Voice/Data	2498.5 - 2687.5 MHz
LTE Band 38	Voice/Data	2572.5 - 2617.5 MHz
LTE Band 48	Voice/Data	3552.5 - 3697.5 MHz
NR Band n71	Voice/Data	665.5 - 695.5 MHz
NR Band n14	Voice/Data	790.5 - 795.5 MHz
NR Band n5	Voice/Data	826.5 - 846.5 MHz
NR Band n70	Voice/Data	1697.5 - 1707.5 MHz
NR Band n66	Voice/Data	1712.5 - 1777.5 MHz
NR Band n25	Voice/Data	1852.5 - 1912.5 MHz
NR Band n2	Voice/Data	1852.5 - 1907.5 MHz
NR Band n30	Voice/Data	2307.5 - 2312.5 MHz
NR Band n41	Voice/Data	2501.01 - 2685 MHz
NR Band n48	Voice/Data	3555 - 3694.98 MHz
NR Band n78	Voice/Data	3455.01 - 3544.98 MHz; 3705 - 3795 MHz
NR Band n77	Voice/Data	3455.01 - 3544.98 MHz; 3705 - 3975 MHz
2.4 GHz WIFI	Voice/Data	2412 - 2462 MHz
5 GHz WIFI	Voice/Data	U-NII-1: 5180 - 5240 MHz U-NII-2A: 5260 - 5320 MHz U-NII-2C: 5500 - 5720 MHz U-NII-3: 5745 - 5825 MHz U-NII-4: 5845 - 5885 MHz
6 GHz WIFI	Voice/Data	U-NII-5: 5945 - 6415 MHz U-NII-6: 6435 - 6515 MHz U-NII-7: 6535 - 6875 MHz U-NII-8: 6895 - 7115 MHz
2.4 GHz Bluetooth	Data	2402 - 2480 MHz
NFC	Data	13.56 MHz

1.2 Time-Averaging Algorithm for RF Exposure Compliance

This device is enabled with Qualcomm Smart Transmit and Qualcomm® FastConnect features. These features perform their proprietary time averaging algorithms in real time to control and manage transmitting power and ensure the time-averaged RF exposure is in compliance with FCC requirements at all times. Section 2.1 and 2.2 has additional details regarding the implementation of these TAS algorithms.

This purpose of the Part 2 report is to demonstrate the DUT complies with FCC RF exposure requirement under Tx varying transmission scenarios, thereby validity of Qualcomm® Smart Transmit and FastConnect features implementation in this device. It serves to complement the Part 0 and Part 1 Test Reports to justify compliance per FCC.

1.2.1 Time-Averaging Algorithm for WWAN Smart Transmit RF Exposure Compliance

This device is enabled with Qualcomm® Smart Transmit feature. This feature performs time averaging algorithm in real time to control and manage transmitting power and ensure the time-averaged RF exposure is in compliance with FCC requirements all the time. DUT contains embedded file system (EFS) version 20 configured for the second generation (GEN2) for Sub6.

The Smart Transmit algorithm maintains the time-averaged transmit power, in turn, time-averaged RF exposure of SAR_design_target, below the predefined time-averaged power limit (i.e., Plimit for sub-6 radio), for each characterized technology and band.

Smart Transmit allows the device to transmit at higher power instantaneously, as high as P_{max}, when needed, but enforces power limiting to maintain time-averaged transmit power to P_{limit} for frequencies < 6 GHz.

Note that the device uncertainty for this DUT is 1.0 dB for sub-6GHz.

The following input parameters are key parameters that are required for functionality of the Smart Transmit feature. 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.

- *Tx_power_at_SAR_design_target (Plimit in dBm) for Tx transmitting frequency < 6 GHz*

  The maximum time-average transmit 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 Plimit could vary with technology, band, antenna and DSI (device state index), therefore it has the unique value for each technology, band, antenna and DSI.

This purpose of the Part 2 report is to demonstrate the DUT complies with FCC RF exposure requirement under Tx varying transmission scenarios, thereby validity of Qualcomm® Smart Transmit feature implementation in this device. It serves to compliment the Part 0 and Part 1 Test Reports to justify compliance per FCC.

1.2.2 Time-Averaging Algorithm for WLAN FastConnect TAS RF Exposure Compliance

This device is enabled with Qualcomm® FastConnect features. These features perform their proprietary time averaging algorithms in real time to control and manage transmitting power and ensure the time-averaged RF exposure is in compliance with FCC requirements at all times. Section 2.1 and 2.2 has additional details regarding the implementation of these TAS algorithms.

Regulatory RF exposure limits are defined with respect to time-averaged RF exposure. Qualcomm FastConnect TAS algorithm performs transmit power control to ensures at all times the wireless device is in compliance with the configured limit of RF exposure averaged over a defined time window denoted as *TSAR* for SAR.

- A 30 second time-averaging window is used by FastConnect TAS for WLAN operation in 2.4GHz, 5GHz, and 6GHz WLAN bands.
- For ICNIRP 1998, the time-averaging window for radios operating <10GHz is 360 seconds. FastConnect TAS uses a 360s window for regions outside the U.S (e.g., ISED Canada).

The purpose of this report is to demonstrate the Qualcomm® FastConnect™ time averaged SAR (TAS) feature RF exposure compliance under dynamic transmission scenarios. This test report provides reference to test results and plots using parameters is determined from for static SAR test and configurate in FastConnect TAS BDF for validating the FastConnect TAS feature.

1.3 Bibliography

Report Type	Report Serial Number
Part 0 SAR Test Report	1M2501020001-02.A3L
Part 1 SAR Test Report	1M2501020001-01.A3L
RF Exposure Compliance Summary	1M2501020001-04.A3L

2 RF EXPOSURE LIMITS

2.1 Uncontrolled Environment

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

2.2 Controlled Environment

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

2.3 RF Exposure Limits for Frequencies Below 6 GHz

Table 2-1
SAR Human Exposure Specified in ANSI/IEEE C95.1-1992 and Health Canada Safety Code 6

HUMAN EXPOSURE LIMITS		
	UNCONTROLLED ENVIRONMENT *General Population* (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT *Occupational* (W/kg) or (mW/g)
Peak Spatial Average SAR Head	1.6	8.0
Whole Body SAR	0.08	0.4
Peak Spatial Average SAR Hands, Feet, Ankle, Wrists, etc.	4.0	20

1. The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.
2. The Spatial Average value of the SAR averaged over the whole body.
3. The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

2.4 RF Exposure Limits for Frequencies Above 6 GHz

Per §1.1310 (d)(3), the MPE limits are applied for frequencies above 6 GHz. Power Density is expressed in units of W/m^2 or mW/cm^2.

Peak Spatially Averaged Power Density was evaluated over a circular area of 4 cm^2 per interim FCC Guidance for near-field power density evaluations per October 2018 TCB Workshop notes.

Table 2-2
Human Exposure Limits Specified in FCC 47 CFR §1.1310

Human Exposure to Radiofrequency (RF) Radiation Limits		
Frequency Range [MHz]	**Power Density** [mW/cm^2]	**Averaging Time** [Minutes]
(A) Limits for Occupational / Controlled Environments		
1,500 – 100,000	5.0	6
(B) Limits for General Population / Uncontrolled Environments		
1,500 – 100,000	1.0	30

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

2.5 Time Averaging Windows for FCC Compliance

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

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

3 TIME VARYING TRANSMISSION TEST CASES

3.1 WWAN Smart Transmit Time-Varying Cases

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

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 a technology/band handover: To prove that the Smart Transmit feature functions correctly during transitions in technology/band.
4. During a 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 an antenna (or beam) switch: To prove that the Smart Transmit feature functions correctly during transitions in antenna (such as AsDiv scenario) or beams (different antenna array configurations) or beams (different antenna array configurations).
6. 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.
7. 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.
8. Exposure category switch: To prove that the Time-Averaged Specific Absorption Rate (TAS) feature functions correctly when the EUT exposure category changes.

NOTE: Technology in this test refers to WWAN, WLAN and/or Bluetooth

NOTE: For WWAN, theoretically, either sub6 radio or mmW radio can be selected for this system level compliance continuity test as Smart Transmit internal operation is identical. Thus, the test with either WWAN sub6 or mmW radio is sufficient. However, since FCC time average window for WWAN mmW NR is 4 seconds, to be more practical and feasible in actual measurement, sub6 WWAN radio is recommended to be selected for this test.

NOTE: BT allowed maximum power will be at one of the 3 levels populated in EFS depending on transmission scenarios, and BT's Pmax allocated by Smart Transmit is always ≤ Plimit. Therefore, for 10.b), either WWAN or WLAN can be selected as a terrestrial network for demonstrating the compliance continuity during bi-directional transitions between non-terrestrial networks and terrestrial network. Test with one pair of terrestrial and non-terrestrial radios is sufficiant as the continuity among all terrestrial technologies is covered and validated.

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 $f < 6$GHz) and radiated (for $f \geq 6$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 10.

To add confidence in the feature 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:

- 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* < 6GHz) versus time, and radiated Tx power (EIRP for f > 10GHz) 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.
    - 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.

Mathematical expression:

For < 6 GHz transmission only:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \le 1 \qquad (1b)$$

For sub-6+mmW transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (2a)$$

$$4cm^2PD(t) = \frac{radiated\_Tx\_power(t)}{radiated\_Tx\_power\_input.power.limit} * 4cm^2PD\_input.power.limit \qquad (2b)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2\ PD\ limit} \le 1 \qquad (2c)$$

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. Similarly, $radiated\_Tx\_power(t)$, $radiated\_Tx\_power\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit* (i.e., radiated power limit), and $4cm^2$PD value at *input.power.limit* corresponding to mmW transmission. Both P_{limit} and *input.power.limit* are 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; T_{PD} is the FCC defined time window for mmW radio.

- 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.
  - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for transmission scenario 1 at all times.

Mathematical expression:

- For sub-6 transmission only:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR(t)\_P_{limit} \qquad (3a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \qquad (3b)$$

- For sub-6 +*f* ≥ *6GHz* transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (4a)$$

$$4cm^2PD(t) = \frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2} * 4cm^2PD\_input.power.limit \qquad (4b)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ limit} \leq 1 \qquad (4c)$$

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. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous E-field, E-field at *input.power.limit*, and $4cm^2$PD value at *input.power.limit* corresponding to mmW 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.

3.2 WLAN FastConnect Time-Varying Cases

The following scenarios cover validation tests to prove FastConnect TAS accounts for the history of transmission power accuracy at all times including before, during, and after transition in each scenario.

Since RF exposure is proportional to the Tx power for a SAR wireless device, time-averaging algorithm validation can be effectively performed through conducted power measurements outlined below. In addition, since FastConnect TAS feature operates at the same averaged algorithm to all WLAN bands (2.4GHz, 5GHz, and 6GHz), test selection criteria described in Section 6.4 was used for time varying validation.

1. Time-Varying Test Sequence: This test proves the FastConnect TAS accounts for Tx power variations in time accurately. In addition, this test is performed to capture the maximum time-averaged results in at least two time-averaging windows duration.

2. Change in antenna (applicable when the software supports SISO diversity operation): This test is to prove that FastConnect functions correctly during transitions in Plim (at different antennas) within the same WLAN band and same Antenna Group. If device supports SISO and transmission diversity between an Antenna to another antenna, then this test is applicable. If WLAN MIMO CDD is implemented, then device is always under MIMO transmission, in this case, this test is NOT applicable.

3. Change in device state (DSI) (applicable when the device supports multiple DSI): This is to prove that FastConnect TAS performs power enforcements to maintain compliance during transitions in the device state.

4. Change in WLAN band: This is to prove that the FastConnect TAS functions correctly during transitions in radios and bands.

5. Simultaneous Transmission: This is to prove that the FastConnect TAS functions in transition from 1st standalone WLAN radio to simultaneous WLAN radios and back to 2nd standalone WLAN radio.

To add confidence in the feature validation, the time-averaged SAR measurements are also performed but only performed for transmission scenario 1 to avoid the complexity in SAR (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:

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR limits, through time-averaged power measurements:
    - Measure conducted power.
    - Convert it into RF exposure and divide by respective limits to get normalized exposure use equation as described in this section.
    - Perform time-averaging over predefined time windows.

- Demonstrate that the total normalized time-averaged RF exposure is <1 for all transmission scenarios.
- For frequency below 6GHz or if regulator requires SAR for WLAN 6GHz band.

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \qquad (1b)$$

- For frequency greater than 6GHz if regulator requires APD. (Applicable for ISED)

$$4cm^2\ PD(t) = \boxed{\frac{Conducted\_Tx\_power\ (t)}{Conducted\_Tx\_power\_Plim}} * 4cm^2\ PD\_\ Plim \qquad (1c)$$

$$\frac{\frac{1}{TSAR}\int_{t-TSAR}^{t} 4cm2\ PD(t)\ dt}{APD\ 4cm^2 PD\ limit} \leq 1 \qquad (1d)$$

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_\ Plim$ and $1g\_or\_10gSAR\_\ Plim$ correspond to the measured instantaneous conducted Tx power and conducted Tx power at *Plim* of DUT, and $1g\_or\_10gSAR$ values at *Plim* for the worst-case radio configuration within the tested band/Antenna/DSI. Similarly, 4cm2 PD_ $Plim$ correspond to the APD values at *Plim* for the worst-case radio configuration within the tested band (greater than 6GHz)/Antenna/DSI.

The equations (1a) & (1b) are applicable if SAR is required by regulator to address RF exposure for the band greater than 6GHz.

NOTE: The ratio circled in red square is obtained from the measurement on the radio configuration is selected for validation test while the $1g_or_10gSAR$_Plim and 4cm2 PD_ $Plim$ must be from the SAR value in the worst-case radio configuration within the tested band/Antenna/DSI in static SAR report and scale to the $conducted\_Tx\_power\_\ Plim$ level is measured from DUT used in validation test.

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR limits, through time-averaged SAR measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
  - Choose worst case EUT orientation of SAR measurement per according to Static SAR test report and perform pointSAR measurement use cDASY6
  - Measure instantaneous SAR versus time and demonstrate total normalized time-averaged RF exposure is <1.0 at all times.
  - For frequency below 6GHz or if regulator requires SAR for WLAN 6GHz band.

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR(t)\_P_{limit} \qquad (3a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \qquad (3b)$$

- For frequency greater than 6GHz if regulator requires APD. (Applicable for ISED)

$$4cm^2\ PD(t) = \boxed{\frac{pointSAR\ (t)}{pointSAR\_Plim}} * 4cm^2\ PD\_\ Plim \qquad (2c)$$

$$\frac{\frac{1}{TSAR}\int_{t-TSAR}^{t} 4cm2\ PD(t)\,dt}{APD\ 4cm^2\ PD\ limit} \leq 1 \qquad (2d)$$

where, $pointSAR(t)$, $pointSAR\_Plim$, and $1g\_or\_10gSAR\_\ Plim$ correspond to the measured instantaneous point SAR and point SAR at *Plim* of DUT, and $1g\_or\_10gSAR$ values at *Plim* for the worst-case radio configuration within the tested band/Antenna/DSI. Similarly, 4cm2 PD_ $Plim$ is the APD values at *Plim* for the worst-case radio configuration within the tested band (greater than 6GHz)/Antenna/DSI.

The equations (2a) & (2b) are applicable if SAR is required by regulator to address RF exposure for the band greater than 6GHz.

NOTE: The ratio circled in red square is obtained from the measurement on the radio configuration is selected for validation test while the $1g\_or\_10gSAR\_\ Plim$ and 4cm2 PD_ $Plim$ must be from the SAR value in the worst-case radio configuration within the tested band/Antenna/DSI in static SAR report and scale to the $conducted\_Tx\_power\_\ Plim$ level is measured from DUT used in validation test.

3.3 Device Level Compliance Cases

At device level, corner cases exist that could result in temporal non-compliance during transitions between radios managed under different RF exposure control mechanisms (WWAN –WLAN –BT –Satellite). Temporal non-compliance cases were identified by industry experts for:

- Radios controlled by two independent TAS solutions.
- Switch between non-TAS radio and TAS radio.

NOTE: This evaluation was performed in the Proprietary Analysis for TAS + TAS report.

4 FCC MEASUREMENT PROCEDURES

This chapter provides the test plan and test procedure for validating Qualcomm WWAN Smart Transmit and Qualcomm WLAN FastConnect features for sub-6 transmission. The 100 seconds time window for WWAN technologies operating f < 3GHz is used as an example to detail the test procedures in this chapter. The same test plan and test procedures described in this chapter apply to 60 seconds time window for WWAN technologies operating f ≥ 3GHz and 30 second time-window for all WLAN technologies operating.

4.1 Test Sequence Determination for Validation

4.1.1 WWAN Test Sequence

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: request DUT's Tx power to be 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: request DUT's Tx power to vary with time. This sequence is generated relative to measured P_{max}, measured P_{limit} and calculated $P_{reserve}$ (= measured P_{limit} in dBm - *total_min_reserve* in dB) of DUT based on measured P_{limit}.

  The details for generating these two test sequences are described and listed in Appendix E.

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 the Smart Transmit feature operates against the actual power level of the "P_{limit}" that was calibrated for the DUT. The "measured P_{limit}" accurately reflects what the feature is referencing to, therefore, it should be used during feature validation testing. The RF tune up and device-to-device variation are already considered in Part 0 report prior to determining P_{limit}.

4.1.2 WLAN Test Sequence

Following the FCC recommendation, one test sequences having time-variation in Tx power are predefined for validation:

- Test sequence 1: request DUT's Tx power to be at maximum power, measured P_{max}†, for 30s, then requesting for half of the maximum power, i.e., measured $P_{max}/2$, for the rest of the time.

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

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

4.2 Test Configuration Selection Criteria for Validating WWAN Smart Transmit Feature

For validating the Smart Transmit feature, this section provides general guidance to select test cases.

4.2.1 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.

Note this test is designed for single radio transmission scenario. If UE supports sub6 NR in both non-standalone (NSA) and standalone (SA) modes, then validation in time-varying Tx power transmission scenario described in this section needs to be performed in SA mode. Otherwise, it needs to be performed in NSA mode with LTE anchor set to low power. The choice between SA and NSA mode needs to also take into account the selection criteria described below. In general, one mode out of the two modes (NSA or SA) is sufficient for this test.

The criteria for the selection are based on the P_{limit} values determined in Part 0 report. Select two bands* in each supported technology that correspond to least** and highest*** P_{limit} values that are less than P_{max} for validating Smart Transmit. Note:

1. P_{max} refers to maximum Tx power configured for this device in this technology/band (not rated P_{max}). This P_{max} definition applies throughout this Part 2 report.
2. If $P_{limit} > P_{max}$, the validation test with time-varying test sequences is not needed as no power enforcement will be required in this condition.

* 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.

** 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}.

*** 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 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.

4.2.2 Change in Call

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

- Select a technology/band with least P_{limit} among all supported technologies/bands, and select the radio configuration (e.g., # of RBs, channel#) in this technology/band that corresponds to the highest *measured* 1gSAR at P_{limit} listed in Part 1 report.

- In case of multiple bands having same least P_{limit}, then select the band having the highest *measured* 1gSAR at P_{limit} in Part 1 report.

This test is performed with the DUT's Tx power requested to be at maximum power, the above band selection will result in Tx power enforcement (i.e., DUT forced to have Tx power 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 DUT is forced to have Tx power at $P_{reserve}$). One test is sufficient as the feature operation is independent of technology and band.

4.2.3 Change in Technology/Band

The selection criteria for this measurement is, for a given antenna, to have DUT switch from a technology/band with lowest P_{limit} within the technology group (in case of multiple bands having the same P_{limit}, then select the band with highest *measured* 1gSAR at P_{limit}) to a technology/band with highest P_{limit} within the technology group, in case of multiple bands having the same P_{limit}, then select the band with lowest *measured* 1gSAR at P_{limit} in Part 1 report, or vice versa.

This test is performed with the DUT's Tx power requested to be at maximum power, the technology/band switch is performed during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

4.2.4 Change in Antenna

The criteria to select a test configuration for antenna switch measurement is:

- Whenever possible and supported by the DUT, first select antenna switch configuration within the same technology/band (i.e., same technology and band combination).
- Then, select any technology/band that supports multiple Tx antennas, and has the highest difference in P_{limit} among all supported antennas.
- In case of multiple bands having same difference in P_{limit} among supported antennas, then select the band having the highest *measured* 1gSAR at P_{limit} in Part 1 report.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and antenna change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

4.2.5 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} in any other DSI group. Note that the selected DSI transition need to be supported by the device.

NOTE: The antennas corresponding to the selected DSIs should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW, and selected DSIs should be under the same exposure category (i.e., both selected DSIs are either under head exposure category or under non-head exposure category) if EUT is enabled with Smart Transmit version 18 or higher.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and DSI change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

4.2.6 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:

- Select any technology/band that has operation frequency classified in one time window defined by FCC (such as 100-seconds time window), and its corresponding P_{limit} is less than P_{max} if possible.
- Select the 2nd technology/band that has operation frequency classified in a different time window defined by FCC (such as 60-seconds time window), and its corresponding P_{limit} is less than P_{max} if possible.
- Note it is preferred both P_{limit} values of two selected technology/band less than corresponding P_{max}, but if not possible, at least one of technologies/bands has its P_{limit} less than P_{max}.

This test is performed with the EUT's Tx power requested to be at maximum power in selected technology/band. Test for one pair of time windows selected is sufficient as the feature operation is the same.

4.2.7 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
2. SAR exposure switch when two active radios are in different time windows. 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.

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

- Select any two < 6GHz technologies/bands that the EUT supports simultaneous transmission (for example, LTE+Sub6 NR).
- Among all supported simultaneous transmission configurations, the selection order is
  1. 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,
  2. select one configuration that has P_{limit} less than its P_{max} for at least one radio. If this cannot be found, then,

3. select one configuration that has P_{limit} of radio1 and radio2 greater than P_{max} but with least ($P_{limit} – P_{max}$) delta.

Test for one simultaneous transmission scenario is sufficient as the feature operation is the same.

4.3 Test Procedures for WWAN Smart Transmit Conducted Power Measurement

This section provides general conducted power measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 3. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

4.3.1 Time-Varying Tx Power Transmission Scenario

This test is performed with the two pre-defined test sequences described in Section 4.1 for all the technologies and bands selected in Section 4.2.1. The purpose of the test is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged SAR (corresponding time-averaged Tx power) does not exceed the FCC limit at all times (see Eq. (1a) and (1b)).

Test procedure:

1. Measure P_{max}, measure P_{limit} and calculate $P_{reserve}$ (measured P_{limit} in dBm – *total_min_reserve* in dB) and follow Section 4.1 to generate the test sequences for all the technologies and bands selected in Section 4.2.1. Both test sequence 1 and test sequence 2 are created based on measured P_{max} and measured P_{limit} of the DUT. Test condition to measure P_{max} and P_{limit} is:
    a. Measure P_{max} with Smart Transmit disabled and callbox set to request maximum power.
    b. Measure P_{limit} with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode, establish radio link in desired radio configuration, with callbox requesting the DUT's Tx power to be at pre-defined test sequence 1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. (1a)) using measured P_{limit} from above Step 1. Perform running time average to determine time-averaged power and 1gSAR or 10gSAR versus time as illustrated in Figure 4-1 where using 100-seconds time window as an example.

   Note: In Eq.(1a), 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.

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

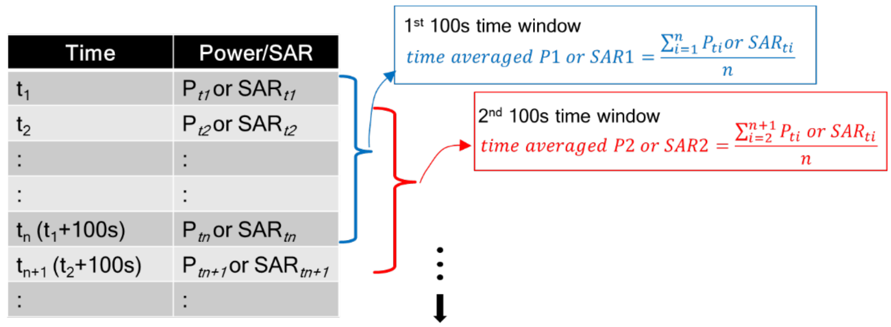


Figure 4-1
Running Average Illustration

3. Make one plot containing:
    a. Instantaneous Tx power versus time measured in Step 2,
    b. Requested Tx power used in Step 2 (test sequence 1),
    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

$$Time\ averaged\ power\ limit = meas.P_{limit} + 10 \times \log(\frac{FCC\ SAR\ limit}{meas.SAR\_Plimit}) \qquad \text{(5a)}$$

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

4. Make another plot containing:
    a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
    b. FCC $1gSAR_{limit}$ of 1.6W/kg or FCC $10gSAR_{limit}$ of 4.0W/kg.
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.
7. 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. (5a)), 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. (1b)).

4.3.2 Change in Call Scenario

This test is to demonstrate that Smart Transmit feature accurately accounts for the past Tx powers 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 DUT's Tx power is 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 over any 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 4.2.2. Measure P_{limit} with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode.
3. Establish radio link with callbox in the selected technology/band.
4. Request DUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting DUT's Tx power to be at maximum 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 DUT's Tx power to be at maximum power for the remaining time of at least another full duration of the specified time window. 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. (1a), and then perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   NOTE: In Eq.(1a), 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.(5a).
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.(5a)), 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. (1b)).

4.3.3 Change In Technology/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 4.3.2, to validate the continuity of RF exposure limiting during the transition, the technology and band handover needs to be performed when DUT's Tx power is at $P_{reserve}$ level (i.e., during Tx power enforcement) to make sure that the DUT's Tx power 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. (1a) can be written as follows to convert the instantaneous Tx power in 1gSAR or 10gSAR exposure for the two given radios, respectively:

$$1g\_or\_10gSAR_1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_P_{limit\_1}} * 1g\_or\_10gSAR\_P_{limit\_1} \quad (6a)$$

$$1g\_or\_10gSAR_2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_P_{limit\_2}} * 1g\_or\_10gSAR\_P_{limit\_2} \quad (6b)$$

$$\frac{1}{T_{SAR}}\left[\int_{t-T_{SAR}}^{t_1} \frac{1g\_or\_10gSAR_1(t)}{FCC\ SAR\ limit}dt + \int_{t-T_{SAR}}^{t} \frac{1g\_or\_10gSAR_2(t)}{FCC\ SAR\ limit}dt\right] \leq 1 \quad (6c)$$

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. Transition from technology1/band1 to the technology2/band2 happens at time-instant 't_1'.

Test procedure:

1. Measure P_{limit} for both the technologies and bands selected in Section 4.2.3. Measure P_{limit} with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode. Establish radio link with callbox in first technology/band selected. Establish radio link with callbox in first technology/band selected.
3. Request DUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting DUT's Tx power to be at maximum power for about ~60 seconds, and then switch to second technology/band selected. Continue with callbox requesting DUT's Tx power to be at maximum power for the remaining time of at least another full duration of the specified time window. Measure and record Tx power versus time for the full duration of the test.
4. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value using Eq. (6a) and (6b) and corresponding measured P_{limit} values from Step 1 of this section. Perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   NOTE: In Eq.(6a) & (6b), 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.(5a).
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 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. (6c)).

4.3.4 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 4.3.3, 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 DUT 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 4.3.3) test.

4.3.5 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 4.3.3, 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.

4.3.6 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.

To validate the continuity of RF exposure limiting during the transition, the band handover test needs to be performed when EUT handovers from operation band less than 3GHz to greater than 3GHz and vice versa. The equations (3a) and (3b) in Section 2 can be written as follows for transmission scenario having change in time window,

$$1gSAR_1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_P_{limit\_1}} * 1g\_or\ 10g\_SAR\_P_{limit\_1} \qquad (7a)$$

$$1gSAR_2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_P_{limit\_2}} * 1g\_or\ 10g\_SAR\_P_{limit\_2} \qquad (7b)$$

$$\frac{1}{T1_{SAR}}\left[\int_{t-T1_{SAR}}^{t_1} \frac{1g\_or\ 10g\_SAR_1(t)}{FCC\ SAR\ limit}dt\right] + \frac{1}{T2_{SAR}}\left[\int_{t-T2_{SAR}}^{t} \frac{1g_{or}10g\_SAR_2(t)}{FCC\ SAR\ limit}dt\right] \le 1 \qquad (7c)$$

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_*P_{limit_1}*(t)*, and *1g_ or 10g_SAR_*P_{limit_1} correspond to the instantaneous Tx power, conducted Tx power at P_{limit}, and compliance *1g_ or 10g_SAR* values at P_{limit_1} of band1 with time-averaging window '$T1_{SAR}$'; *conducted_Tx_power_2(t)*, *conducted_Tx_power_*P_{limit_2}*(t)*, and *1g_ or 10g_SAR_*P_{limit_2} correspond to the instantaneous Tx power, conducted Tx power at P_{limit}, and compliance *1g_ or 10g_SAR* values at P_{limit_2} of band2 with time-averaging window '$T2_{SAR}$'. One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window '$T1_{SAR}$' to the second band with time-averaging window '$T2_{SAR}$' happens at time-instant 't_1'.

Test procedure:

1. Measure P_{limit} for both the technologies and bands selected in Section 4.2.6. Measure P_{limit} with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode.

   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 4.2.6.

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 4.2.6. 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. (7a) and (7b)) 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.(7a) & (7b), 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 $1gSAR_{limit}$ 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 4.2.6.
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 4.2.6. 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 validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

4.3.7 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 F.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for radio1 and radio2 in selected band. Test condition to measure conducted P_{limit} is:

- □ Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 P_{limit} with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
- □ Repeat above step to measure conducted Tx power corresponding to radio2 P_{limit}. 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 P_{limit} (as radio1 LTE is at all-down bits)

2. Set DUT to the intended Smart Transmit exposure mode, 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. (6a) and (6b)) using corresponding technology/band P_{limit} 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, and (c) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

NOTE: If *multi_Tx_factor* is set to > 1.0 with EFS version 19 (or higher), then in single Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radio managed by Smart Transmit. In simultaneous Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * *multi_Tx_factor* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radios managed by Smart Transmit. These simultaneous transmission scenarios are listed below:

- 2-or-more radio scenarios within WWAN like EN-DC, LTE ULCA, etc.
- 2-or-more-radio across technologies such as WWAN+WLAN, WWAN+BT, WLAN+BT and WWAN+WLAN+BT transmission scenarios (if WLAN/BT radios are also managed by Smart Transmit).

4.4 Test Procedure for WWAN Smart Transmit Time-Varying SAR Measurement

This section provides general time-varying SAR measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 3. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

To perform the validation through SAR measurement for transmission scenario 1 described in Section 3, the "path loss" between callbox antenna and DUT needs to be calibrated to ensure that the DUT 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 DUT not solely following callbox TPC (Tx power control) commands. In other words, DUT 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 DUT Tx power from callbox requested power is expected, however the time-averaged SAR should not exceed FCC SAR requirement at all times as Smart Transmit controls Tx power at DUT.

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

1. "Path Loss" calibration: Place the DUT against the phantom in the worst-case position determined based on Section 4.2.1. For each band selected, prior to SAR measurement, perform "path loss" calibration between callbox antenna and DUT. 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 6.2.
2. Time averaging feature validation:
    i For a given radio configuration (technology/band) selected in Section 4.2.1, enable Smart Transmit peak exposure mode, with callbox to request maximum power, perform area scan, conduct pointSAR measurement at peak location of the area scan. This point SAR value, *pointSAR_*P_{limit}, corresponds to point SAR at the measured P_{limit} (i.e., measured P_{limit} from the DUT in Step 1 of Section 4.3.1).

    ii Set DUT to the intended Smart Transmit exposure mode. Note, if *Total_min_reserve* cannot be set wirelessly, care must be taken to re-position the DUT in the exact same position relative to the SAM phantom as in above Step 2.i. Establish radio link in desired radio configuration, with callbox requesting the DUT's Tx power at power levels described by test sequence 1 generated in Step 1 of Section 4.3.1, conduct point SAR measurement versus time at peak location of the area scan determined in Step 2.i 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. (3a), re-written below:

    $$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit}$$

    where, *pointSAR_*P_{limit} is the value determined in Step 2.i, and *pointSAR(t)* is the instantaneous point SAR measured in Step 2.ii, $1g\_or\_10gSAR\_P_{limit}$ is the measured 1gSAR or 10gSAR value listed in Part 1 report.

    iii Perform 100s running average to determine time-averaged 1gSAR or 10gSAR versus time.

    iv 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.

    v Repeat 2.ii ~ 2.iv for test sequence 2 generated in Step 1 of Section 4.3.1.

vi Repeat 2.i ~ 2.v for all the technologies and bands selected in Section 4.2.1.

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. (3b)).

4.5 Test Configuration Selection Criteria for Validating WLAN FastConnect Feature

The conducted power measurement method is used for all validation test scenarios. These tests demonstrate the power enforcement by FastConnect TAS where ***Plim*** could vary before and after transition.

4.5.1 Time-Varying Test Sequence

Select one representative test channel from all the available radio configurations (band/ant(s)/DSI) that has Pmax > Plim + device uncertainty.

- If Pmax < Plim + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plim dBm) value.
- If Pmax > Plim + device uncertainty for more than one radio configuration. Then, order of preference is given by:
  - If multiple radio configurations (band/ant(s)/DSI) meet this criteria, then SISO is preferred over MIMO due to simplified test setup.
  - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plim dBm) dB delta.
- Test to be performed at two bands for Time-Varying Test sequence test. If only one band within a configuration has Pmax > Plim and Plim > Pmax in all other configurations, then only one band needs to be tested.
- Test is not required if Plim > Pmax for all radio configurations.

NOTE: The same selection criteria are applicable for both conducted & radiated tests.

4.5.2 Change in Antenna

This test scenario does not apply if SISO mode diversity is not supported. (e.g., CDD is enabled and always use MIMO). The criteria to select test configuration for Change in Antenna measurement is:

- The antennas selected for this test should be in the same antenna group.
- Whenever possible and supported by the EUT, first select antenna switch configuration within the same band/DSI (i.e., same band and DSI combination), and having different Plim, and having both Pmax > Plim + device uncertainty where possible. Otherwise, select at least one antenna having Pmax > Plim + device uncertainty.
  - If multiple radio configurations (band/DSI) meet Pmax > Plim + device uncertainty, then select the configuration that has largest (Pmax dBm – Plim dBm) dB delta.

- If Pmax < Plim + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plim dBm) value.

- If the EUT does not support antenna switch within the same band but has multiple transmitting antennas to support different frequency bands, then antenna switch test should be performed in combination with Change in WLAN band test scenario.
- Test for Change in Antenna is not required if all Plim > Pmax for all radio configurations.

4.5.3 Change in Device State Index (DSI)

This test scenario does not apply if multiple DSIs are not supported in the device. The criteria to select test configuration for Change in DSI measurement is:

- Select a band/antenna having the Pmax > Plim + device uncertainty within any DSI, and for the same band/antenna(s) having a different Plim in any other DSI. Both the selected DSIs should have Pmax > Plim + device uncertainty where possible. Otherwise, select at least one DSI having Pmax > Plim + device uncertainty.
- If Pmax < Plim + device uncertainty for all band/antenna(s), then select radio configuration with largest (Pmax dBm – Plim dBm) value.
- If Pmax > Plim + device uncertainty for more than one radio configuration, then order of preference is given by:
  - If multiple radio configurations (band/ant(s)/DSI) meet these criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
  - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plim dBm) dB delta.

Test for Change in DSI is not required if all Plim > Pmax for all radio configurations.

4.5.4 Change in WLAN Band

The criteria to select test configuration for Change in WLAN band measurement is:

- First select both bands in a DSI having Pmax > Plim + device uncertainty where possible. Otherwise, select at least one band having Pmax > Plim + device uncertainty.
- If Pmax < Plim + device uncertainty for all radio configurations, then select radio configuration with largest (Pmax dBm – Plim dBm) value.
- If Pmax > Plim + device uncertainty for more than one radio configuration. Then, order of preference is given by:
  - If multiple radio configurations (band/ant(s)/DSI) meet this criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
  - After determining SISO vs. MIMO configuration, then select the configuration that has largest (Pmax dBm – Plim dBm) dB delta.
- The antennas corresponding to the selected bands should be in the same antenna group.

- Test for Change in WLAN band is not required if all Plim > Pmax for all radio configurations.

4.5.5 Simultaneous Transmission

This test scenario does not apply if simultaneous transmission within WLAN bands is not supported in the device. The criteria to select test configuration for Simultaneous Transmission measurement is:

- The bands must be selected from supported Simultaneous Transmission configuration. (e.g., WLAN DBS and/or HBS)
- First select both bands in a DSI having $P_{max} > P_{lim}$ + device uncertainty where possible. Otherwise, select at least one band having $P_{max} > P_{lim}$ + device uncertainty.
- If $P_{max} < P_{lim}$ + device uncertainty for all radio configurations, then select radio configuration with largest (P_{max} dBm – P_{lim} dBm) value.
- If $P_{max} > P_{lim}$ + device uncertainty for more than one radio configuration. Then, order of preference is given by:
    - If multiple radio configurations (band/ant(s)/DSI) meet this criteria and if device support SISO. Then SISO is preferred over MIMO due to simplified test setup.
    - After determining SISO vs. MIMO configuration, then select the configuration that has largest (P_{max} dBm – P_{lim} dBm) dB delta.
- The antennas corresponding to the selected bands should be in the same antenna group.
- Even if a device has $P_{lim} > P_{max}$ for all radio configurations, then "Simultaneous Transmission" test scenario should still be performed for validation of FastConnect TAS device.

4.6 Test Procedures For WLAN FastConnect Conducted Power Measurement

1. Measure Plim for modes at validation antenna ports, bands and/or DSIs with FastConnect TAS Peak Exposure Mode enabled with callbox to establish the chosen mode for test. Denote this measured power value as Conducted_Tx_power_Plim.

NOTE: The measurement of Peak Exposure Mode should be performed with 70% or higher WLAN duty cycle (for example, using iPerf to generate UL traffic).

2. Set EUT to the intended FastConnect TAS mode.

3. Establish radio link with the callbox in the selected band.

NOTE: For the purpose of collecting repeatable time averaged power data, it is recommended to include a section of 30s at the beginning of every test with the device WLAN connection disconnected or turned off or transmitting at a very low duty cycle.

4. Request EUT to transmit in following Transition sequence:

a. Time-Varying Test Sequence – Request EUT to transmit maximum power for at least 30s with 100% duty cycle and 50% duty cycle for 60s to determine time-averaged 1gSAR versus time.

Time duration (seconds)	Duty Cycle (%)
30	100%
60	50%

b. Change in antenna – EUT operates at Antenna 1 (e.g., Main antenna port) and requests to transmit at maximum power for at least 60s. Then switch to operation on Antenna 2 (e.g., Aux antenna port), followed by at least 120s of observation.

c. Change in device state (DSI) – EUT operates at DSI 1 and requests to transmit at maximum power for at least 60s. Then switch to operation on DSI 2, followed by at least 120s of observation (observation period includes transition time).

d. Change in WLAN band – EUT operates at Band 1 and requests to transmit at maximum power for at least 60s. Then it switches to Band 2 using the same antenna port and observes another 120s (observation period includes transition time).

e. Simultaneous Transmissions: First establish WLAN connection with the callbox in radio2 configuration and request radio2 configuration to transmit at maximum duty cycle for at least 120s to test predominantly radio2 SAR exposure scenario. Then add radio1 configuration to the existing radio2 configuration call, and request both radio1 and radio2 to transmit at maximum duty cycle to test radio1 and radio2 SAR exposure scenario for at least 120s. Then drop (or request low duty cycle) for radio2 configuration to test predominantly radio1 SAR exposure scenario for another at least 120s. Record the conducted Tx powers for both radio1 and radio2 configurations for the entire duration of this test.

   Note: radio1 and radio2 should operate at different bands.

5. Measure and record Tx power versus time.

   a. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1g_or_10g SAR value, see Eq. (1a), using Step 1 result.

   b. Then perform 30s moving average to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 6-2.

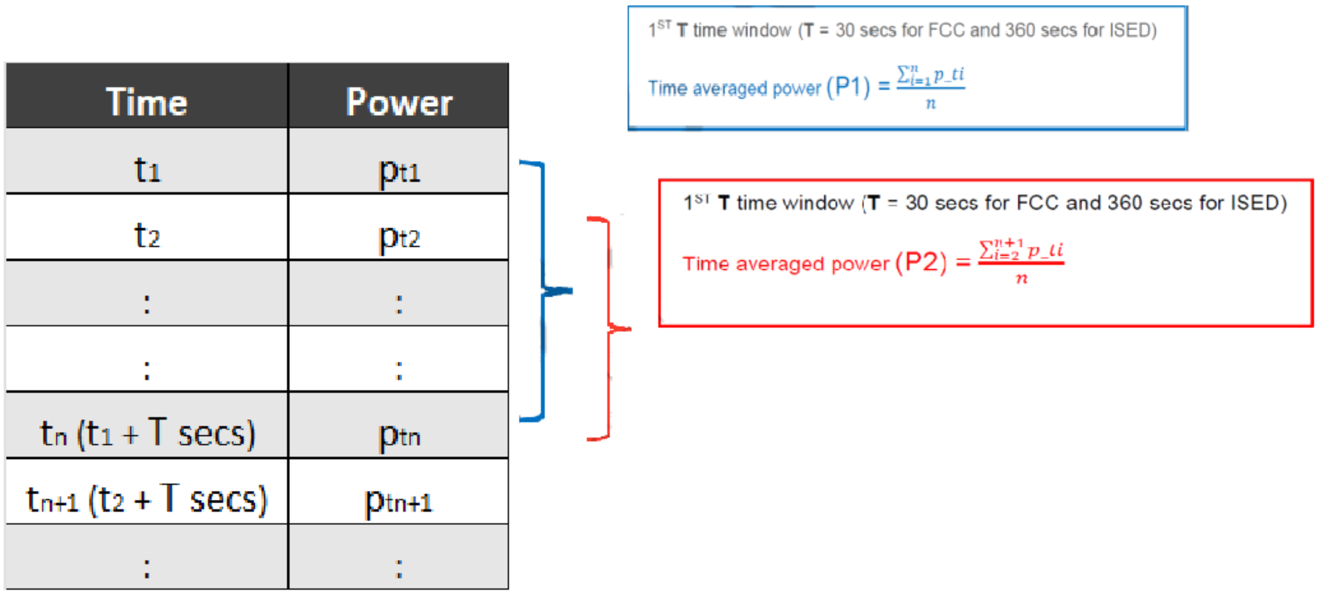


Figure 6-2 Time Running/Moving Average Illustration

The following normalization is used to convert 1g_or_10gSAR exposure using Equation (1a) and (1c) in section 4.4 to validate the continuity of RF exposure limits during the transition. The procedures from step1 and step 2 in this section should be completed for each configuration under test and use below equations to validate the RF exposure during the transition.

- if tested with both radio configurations below 6GHz:

$$1g\_or\_10gSAR_1(t) = \frac{Conducted\_Tx\_power\_1\,(t)}{Conducted\_Tx\_power\_Plim\_1} * 1g\_or\_10gSAR\_\,Plim\,\_1 \qquad (4a)$$

$$1g\_or\_10gSAR_2(t) = \frac{Conducted\_Tx\_power\_2\,(t)}{Conducted\_Tx\_power\_Plim\_2} * 1g\_or\_10gSAR\_\,Plim\,\_2 \qquad (4b)$$

$$\frac{\frac{1}{TSAR}\left[\int_{t-TSAR}^{t_1} 1g\_or\_10gSAR1(t)\,dt + \int_{t-TSAR}^{t} 1g\_or\_10gSAR2(t)\,dt\right]}{FCC\ or\ ICNIRP\ SAR\ limit} \le 1 \qquad (4c)$$

where, conducted_Tx_power_1(t), conducted_Tx_power_ $Plim$ _1, and 1g_or_10gSAR_ $Plim$ _1 correspond to the instantaneous Tx power, conducted Tx power at P_{lim}_1 of DUT, and compliance 1g_or_10gSAR values of Antenna 1 (or Band 1 or DSI1) at P_{lim}_1; conducted_Tx_power_2(t), conducted_Tx_power_ $Plim$ _2, and 1g_or_10gSAR_ $Plim$ _2 correspond to the instantaneous Tx power, conducted Tx power at P_{lim}_2 of DUT, and compliance 1g_or_10gSAR values of Antenna 2 (or Band 2 or DSI2) at P_{lim}_2.

Transition from the Antenna 1 (or Band 1 or DSI1) to the Antenna 2 (or Band 2 or DSI2) happens at time-instant 't_1'.

- if tested with radio configuration: 2.4/5GHz WLAN assessed using SAR + 6GHz WLAN band assessed using APD (e.g., applicable for ISED):

$$1g\_or\_10gSAR_1(t) = \frac{Conducted\_Tx\_power\_1\,(t)}{Conducted\_Tx\_power\_Plim\_1} * 1g\_or\_10gSAR\_\,Plim\_1 \qquad (5a)$$

$$4cm^2\,PD_2(t) = \frac{Conducted\_Tx\_power\_2\,(t)}{Conducted\_Tx\_power\_Plim\_2} * 4cm^2\,PD\_\,Plim\_2 \qquad (5b)$$

$$\frac{\frac{1}{TSAR}[\int_{t-TSAR}^{t_1} 1g\_or\_10gSAR(t)\,dt}{ICNIRP\ SAR\ limit} + \frac{\frac{1}{TSAR}\int_{t-TSAR}^{t} 4cm2\ PD(t)\,dt}{APD\ 4cm^2 PD\ limit} \leq 1 \qquad (5c)$$

where, $conducted\_Tx\_power\_1(t)$, $conducted\_Tx\_power\_\ Plim\_1$ and $1g\_or\_10gSAR\_\ Plim\_1$ correspond to the measured instantaneous conducted Tx power and conducted Tx power at P_{lim}_1 of DUT, and $1g\_or\_10gSAR$ values at P_{lim}_1 for the worst-case radio configuration within the tested 2.4/5GHz WLAN band;

conducted_Tx_power_2(t), conducted_Tx_power_ $Plim$ _2, and $4cm_2$ PD_ $Plim$_2 correspond to the instantaneous Tx power, conducted Tx power at P_{lim}_2 of DUT, and $4cm_2$ PD values (APD) of at P_{lim}_2 for the worst-case radio configuration within the tested 6GHz WLAN band.

Transition from the Band1 to the Band2 happens at time-instant 't_1'.

- if tested with both radio configurations greater than 6GHz bands that are assessed using APD (e.g., applicable for ISED):

$$4cm^2\,PD_1(t) = \frac{Conducted\_Tx\_power\_1\,(t)}{Conducted\_Tx\_power\_Plim\_1} * 4cm^2\,PD\_\,Plim\_1 \qquad (6a)$$

$$4cm^2\,PD_2(t) = \frac{Conducted\_Tx\_power\_2\,(t)}{Conducted\_Tx\_power\_Plim\_2} * 4cm^2\,PD\_\,Plim\_2 \qquad (6b)$$

$$\frac{\frac{1}{TSAR}[\int_{t-TSAR}^{t_1} 4cm2\ PD1(t)\,dt + \int_{t-TSAR}^{t} 4cm2\ PD2(t)\,dt]}{APD\ \ 4cm^2 PD\ limit} \leq 1 \qquad (6c)$$

where, conducted_Tx_power_1(t), conducted_Tx_power_ $Plim$ _1, and $4cm_2$ PD_ $Plim$_1 correspond to the instantaneous Tx power, conducted Tx power at P_{lim}_1 of DUT, and compliance $4cm_2$ PD values (APD) of Band 1 (or Antenna 1) at P_{lim}_1;

conducted_Tx_power_2(t), conducted_Tx_power_ $Plim$ _2, and 4cm2 PD_ $Plim$_2 correspond to the instantaneous Tx power, conducted Tx power at P_{lim}_2 of DUT, and compliance 4cm2 PD values (APD) of Antenna Band 2 (or Antenna 2) at P_{lim}_2.

Transition from the Band 1 (or Antenna 1) to the Band 2 (or Antenna 2) happens at time-instant 't_1'.

6. Make one plot containing:
   a. Computed time-averaged 1g_or_10gSAR (and/or 4cm2 PD) versus time from above procedure.
   b. Corresponding regulatory 1g_or_10gSAR (and/or 4cm2 PD) limit.

The validation criteria is, at all times, the combined time-averaged 1g_or_10gSAR (and/or 4cm2 PD) versus time shall not exceed the regulatory 1g_or_10gSAR limit.

4.7 Test Procedures for WLAN FastConnect Time-Varying SAR Measurement

The pointSAR test is performed only with Time-Varying Test Sequence to provide high confidence in the algorithm validation. The radio configuration for this test is selected by following the selection criteria described in Section 6.4.1.

1. For a given radio configuration:
   a. Enable WLAN connection with callbox **in FastConnect TAS Peak Exposure Mode** and enable high duty cycle Tx while performing the following steps.
   b. Perform the area scan.
   c. Conduct pointSAR measurement at peak location of the area scan for 120s.

This pointSAR value, $pointSAR\_Plim$ corresponds to pointSAR at the measured Plim.

NOTE: The measurement of Peak Exposure Mode should be performed with 70% or higher WLAN duty cycle (for example, using iPerf to generate UL traffic).

2. Conduct pointSAR measurement at peak location of the area scan for 120s.
   a. Perform Time-averaged point SAR measurements at the same peak location as Peak Exposure Point SAR measurement for 120s. Note this includes initial 30s with WLAN with very low duty cycle (or WLAN is disconnected) and 90s of high duty cycle (WLAN has to be connected with high uplink traffic).
   b. Once the measurement is done, extract instantaneous pointSAR versus time data, *pointSAR(t)*
   c. Convert it into instantaneous 1gSAR versus time by using Equation (2a) and (2c) in Section 5.2.4:

$$1g\_or\_10gSAR(t) = \frac{pointSAR\ (t)}{pointSAR\_Plim} * 1g\_or\_10gSAR\_Plim \qquad (2a)$$

   where, $pointSAR\_Plim$ corresponds to the value determined in Step 1, and pointSAR(t) corresponds to instantaneous pointSAR determined in Step 2 in this section.

   d. Then perform 30s moving average to determine time-averaged 1gSAR versus time.

3. Make one plot containing:
    a. Computed time-averaged 1g_or_10gSAR versus time determined from Step 2.
    b. Regulatory *1g*_or_*10gSAR* limit.

The validation criteria for pointSAR measurement is, at all times, the time averaged 1g_or_10gSAR (or 4cm2 PD) versus time shall not exceed the regulatory 1g_or_10gSAR (or 4cm2 PD) limit.

5 MEASUREMENT TEST SETUP

5.1 Conducted Measurement Test setup

Legacy Test Setup

The Rohde & Schwarz CMW500 callbox was used in this test. The test setup schematic is shown in Figure 5-1a (Appendix D – Test Setup Photo 1, 2, 3, 9, and 10) for measurements with a single antenna of DUT, and in Figure 5-1b (Appendix D – Test Setup Photo 6, 7, and 11) for measurements involving antenna switch. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the DUT using a directional coupler. For technology/band switch measurement, one port (RF1 COM) of the callbox used for signaling two different technologies is 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 DUT corresponding to the two antennas of interest. In the setups, power meter is used to tap the directional coupler for measuring the conducted output power of the DUT. For all legacy conducted tests, only RF1 COM port of the callbox is used to communicate with the DUT.

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

Sub6 NR test setup:

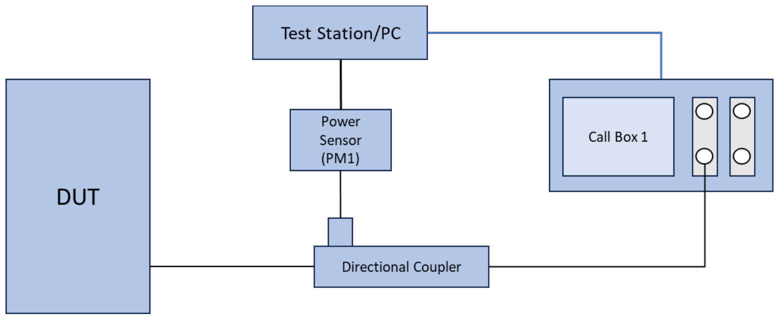
The Anritsu MT8000A callbox was used in this test. The test setup schematic is the same as the Legacy Test Setup shown in Figure 5-1a (Appendix D – Test Setup Photo 4 and 5). One port of the callbox is connected to the RF port of the DUT using a directional coupler. In the setup, the power meter is used to tap the directional coupler for measuring the conducted output power of the DUT.

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

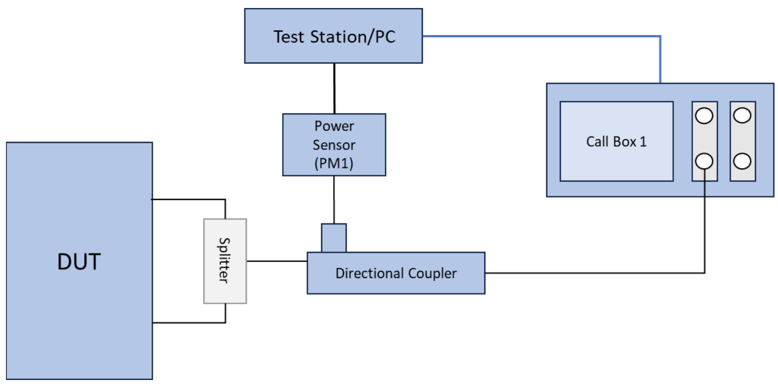
LTE+Sub6 NR test setup:

LTE conducted port and Sub6 NR conducted port are the same on this EUT, therefore, the LTE and Sub6 NR signals for power meter measurement were performed on separate paths as shown below in Figure 5-1c (Appendix D – Test Setup Photo 8).

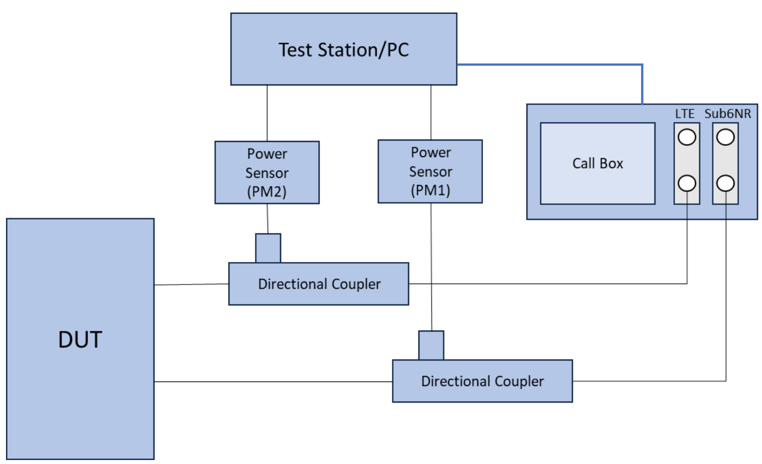
All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.



(a) Appendix D – Test Setup Photo 1, 2, 3, 4, 5, 9, and 10



(b) Appendix D – Test Setup Photo 6, 7, and 11



(c) Appendix D – Test Setup Photo 8

Figure 5-1
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 Tx 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 DUT RF port using the power meter. The commands sent to the callbox to request power are:

- 0dBm for 100 seconds (or 30 seconds for WLAN)
- test sequence 1 or test sequence 2 (defined in Section 4.1 and generated in Section 4.2.1), for 360 seconds (or 90s for WLAN)
- 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 (or 30 seconds for WLAN) is performed in the post-data processing to determine the 100s (or 30s for WLAN) -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 DUT's Tx power at 0dBm for 100 seconds (or 30 seconds for WLAN) while simultaneously starting the 2nd test script runs at the same time to start recording the Tx power measured at DUT RF port using the power meter. After the initial 100 seconds (or 30 seconds for WLAN) since starting the Tx power recording, the callbox is set to request maximum power from the DUT for the rest of the test. Note that the call drop/re-establish, or technology/band/antenna switch or DSI switch is manually performed when the Tx power of DUT is at $P_{reserve}$ level. See Section 4.3 for detailed test procedure of call drop test, technology/band/antenna switch test and DSI switch test.

5.2 SAR Measurement setup

The measurement setup is similar to normal SAR measurements as described in the Part 1 Test Report. The difference in SAR measurement setup for time averaging feature 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 Tx power measurements is also used in this section 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 in Section 4.4, for DUT to follow TPC command sent from the callbox wirelessly, the "path loss" between callbox antenna and the DUT needs to be very well calibrated. Since the SAR chamber is in uncontrolled environment, precautions must be taken to minimize the environmental influences on "path loss". Similarly, in the case of time-varying SAR measurements in Sub6 NR (with LTE as anchor), "path loss" between callbox antenna and the EUT needs to be carefully calibrated for both LTE link as well as for Sub6 NR link.

The DUT is placed in worst-case position according to Table 6-2 and Table 6-3.

6 TEST CONFIGURATIONS

6.1 WWAN (sub-6) and WLAN Transmission

The P_{limit} values, corresponding to 1.0 W/kg (1gSAR) and 2.5 W/kg (10gSAR) of *SAR_design_target*, for technologies and bands supported by DUT are derived in Part 0 report and summarized in Table 8-1. Note all P_{limit} power levels entered in Table 8-1 correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes.

Table 6-1
P_{limit} for supported technologies and bands (P_{limit} in EFS & BDF file)

Exposure Scenario			Maximum Tune-Up Output Power*	Body-Worn or Phablet	Head	Hotspot
Averaging Volume				1g/10g	1g	1g
Spacing				5mm, 0mm	0mm	10mm, 5mm
DSI				0	2	3
Technology/Band	Antenna	Antenna Group	P_{max}	P_{limit}	P_{limit}	P_{limit}
GSM 850	1	AG0	24.3	22.5	24.4	22.5
GSM 1900	2	AG0	21.3	19.5	18.5	19.5
UMTS 850	1	AG0	24.0	23.0	24.9	23.0
UMTS 1750	2	AG0	23.5	19.5	23.5	19.5
UMTS 1900	2	AG0	23.5	19.0	23.5	19.0
LTE Band 71	1	AG0	24.0	25.5	24.4	25.5
LTE Band 12	1	AG0	24.0	24.6	24.5	24.6
LTE Band 13	1	AG0	24.0	23.0	26.0	23.0
LTE Band 14	1	AG0	24.0	23.0	26.2	23.0
LTE Band 26	1	AG0	24.0	23.0	25.4	23.0
LTE Band 5	1	AG0	24.0	23.0	26.0	23.0
LTE Band 66/4	2	AG0	23.5	19.0	23.5	19.0
LTE Band 66/4	4	AG1	23.5	21.0	20.5	21.0
LTE Band 25/2	2	AG0	23.5	19.0	23.5	19.0
LTE Band 25/2	4	AG1	23.0	20.0	18.0	20.0
LTE Band 30	2	AG0	23.0	20.5	24.7	20.5
LTE Band 30	4	AG1	23.0	19.0	14.5	19.0
LTE Band 7	2	AG0	23.5	20.5	24.4	20.5
LTE Band 7	4	AG1	23.0	19.5	17.0	19.5
LTE Band 41/38	2	AG0	21.0	17.0	17.0	17.0
LTE Band 41/38	4	AG1	21.0	17.0	15.0	17.0
LTE Band 48	6	AG1	19.0	11.0	14.0	11.0
NR Band n71	1	AG0	24.0	24.9	24.4	24.9
NR Band n14	1	AG0	23.0	22.0	23.7	22.0
NR Band n5	1	AG0	24.0	21.5	24.9	21.5
NR Band n70	2	AG0	23.5	20.5	24.7	20.5
NR Band n70	4	AG1	23.0	20.0	19.0	20.0
NR Band n66	2	AG0	23.5	19.5	23.5	19.5
NR Band n66	4	AG1	23.0	20.5	19.5	20.5
NR Band n25/n2	2	AG0	23.5	20.0	23.6	20.0
NR Band n25/n2	4	AG1	23.5	21.0	17.0	21.0
NR Band n30	2	AG0	23.0	20.5	23.9	20.5
NR Band n30	4	AG1	23.0	19.0	14.5	19.0
NR Band n41 PC3	2	AG0	23.5	17.0	17.0	17.0
NR Band n41 PC2	2	AG0	26.0	17.0	17.0	17.0
NR Band n48	6	AG1	21.0	12.5	14.0	12.5
NR Band n48	8	AG1	16.0	14.0	15.0	14.0
NR Band n48	2	AG0	20.0	15.0	15.0	15.0
NR Band n48	4	AG1	16.0	15.0	15.0	15.0
NR Band n78 PC3	6	AG1	23.0	14.0	15.0	14.0
NR Band n78 PC3	8	AG1	18.0	17.0	17.0	17.0
NR Band n78 PC3	2	AG0	17.0	17.0	17.0	17.0
NR Band n78 PC3	4	AG1	16.0	15.0	15.0	15.0
NR Band n78 PC2	6	AG1	27.0	14.0	15.0	14.0
NR Band n78 PC2	8	AG1	23.0	17.0	17.0	17.0
NR Band n78 PC2	2	AG0	26.0	17.0	17.0	17.0
NR Band n78 PC2	4	AG1	22.0	15.0	15.0	15.0
NR Band n77 PC3	6	AG1	24.0	14.0	15.0	14.0
NR Band n77 PC3	8	AG1	18.0	17.0	17.0	17.0
NR Band n77 PC3	2	AG0	17.0	17.0	17.0	17.0
NR Band n77 PC3	4	AG1	16.0	15.0	15.0	15.0
NR Band n77 PC2	6	AG1	27.0	14.0	15.0	14.0
NR Band n77 PC2	8	AG1	23.0	17.0	17.0	17.0
NR Band n77 PC2	2	AG0	26.0	17.0	17.0	17.0
NR Band n77 PC2	4	AG1	22.0	15.0	15.0	15.0

Exposure Scenario			Maximum Tune-Up Output Power*	Body-Worn, Hotspot, or Phablet	Head
Averaging Volume				1g/10g	1g
Spacing				5mm, 0mm	0mm
DSI				0	1
Technology/Band	Antenna	Antenna Group	P_{max}	P_{limit}	P_{limit}
2.4 GHz WIFI	5	AGa	17.0	13.0	13.0
2.4 GHz WIFI	MIMO	AGa	17.0	13.0	13.0
5 GHz WIFI	MIMO	AGa	16.0	10.5	10.5
6 GHz WIFI	MIMO	AGa	16.0	10.5	10.5

* Maximum tune up target power, P_{max}, is configured in NV settings in DUT to limit maximum transmitting power. This power is converted into peak power in NV settings for TDD schemes. The DUT maximum allowed output power is equal to P_{max} + 1 dB device uncertainty.

Based on selection criteria described in Section 4.2 and 4.3, the selected technologies/bands for testing time-varying test sequences are highlighted in yellow in Table 6-1. Per the manufacturer, the *Reserve_power_margin (dB) is set to 3dB for WWAN and 1dB for WLAN.*

The radio configurations used in Part 2 test for selected technologies, bands, DSIs and antennas are listed in Table 6-2 and Table 6-3 . The corresponding worst-case radio configuration 1gSAR values for selected technology/band/DSI are extracted from Part 1 report and are listed in Table 6-2 and Table 6-3.

Based on equations (1a), (2a), (3a) and (4a), it is clear that Part 2 testing outcome is normalized quantity, which implies that it can be applied to any radio configuration within a selected technology/band/DSI. Thus, as long as applying the worst-case SAR obtained from the worst radio configuration in Part 1 testing to calculate time-varying SAR exposure in equations (1a), (2a), (3a) and (4a), the accuracy in compliance demonstration remains the same. Therefore, there may be some differences between the radio configuration selected for Part 2 testing and the radio configuration associated with worst-case SAR obtained in the Part 1 evaluation.

The measured P_{limit} for all the selected radio configurations are listed in below Table 6-2 and Table 6-3. 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 in Section 4.1.

Table 6-2
WWAN Smart Transmit Radio Configurations Selected for Part 2 Test

Test Case #	Test Scenario	Tech	Band	Antenna	DSI	Channel	Frequency [MHz]	Test Configurations	SAR Exposure Scenario	Part 1 Worst Case Measured SAR at Plimit (W/kg)	EFS Plimit [dBm]	Tune-up Pmax [dBm]	Measured Plimit [dBm]	Measured Pmax [dBm]
1	Time Varying Tx Power	GSM	850	1	3	251	848.8	GPRS 4 Tx Slots	Back Side, 5mm	0.710	22.7	24.3	21.80	23.81
2			1900	2	2	661	1880	GPRS 4 Tx Slots	Left Cheek	0.112	18.7	20.8	18.62	21.45
3		WCDMA	2	2	3	9400	1880	RMC	Back Side, 5mm	0.671	19.0	23.5	19.46	24.14
4			5	1	3	4183	836.5	RMC	Back Side, 5mm	0.807	23.0	24.0	23.45	24.43
5		LTE	5	1	3	20525	836.5	QPSK 1/25/10 MHz BW	Back Side, 5mm	0.767	23.0	24.0	23.23	24.56
6			48	6	3	55340	3560	QPSK 1/50/20 MHz BW	Back Side, 5mm	0.358	11.0	19.0	10.81	18.07
7		NR	n14 SA	1	3	158600	793	DFT-S-OFDM, QPSK 1/1/10 MHz BW	Back Side, 5mm	0.726	22.0	23.0	22.19	23.18
8			n48 SA	6	3	641666	3625	DFT-S-OFDM, QPSK 1/1/40 MHz BW	Back Side, 5mm	0.552	12.5	21.0	11.57	20.10
9	Change in Call	LTE	48	6	3	55340	3560	QPSK 1/50/20 MHz BW	Back Side, 5mm	0.358	11.0	19.0	10.81	18.07
10	Change in Technology/Band/Antenna	LTE	5	1	3	20525	836.5	QPSK 1/25/10 MHz BW	Back Side, 5mm	0.767	23.0	24.0	23.23	24.56
		WCDMA	2	2	3	9400	1880	RMC	Back Side, 5mm	0.671	19.0	23.5	19.46	24.14
11	Change in Time Window	LTE	25	4	3	26365	1882.5	QPSK 1/50/20 MHz BW	Back Side, 5mm	0.515	20.0	23.0	19.92	23.01
			48	6	3	55340	3560	QPSK 1/50/20 MHz BW	Back Side, 5mm	0.358	11.0	19.0	10.81	18.07
12	WWAN SAR Exposure Switching (EN-DC) Same time-window	LTE	5	1	3	20525	836.5	QPSK 1/25/10 MHz BW	Back Side, 5mm	0.767	23.0	24.0	23.23	24.56
		Sub6 NR	n66	2	3	349000	1745	DFT-S-OFDM, QPSK 1/1/40 MHz BW	Back Side, 5mm	0.590	19.5	23.5	20.12	24.18
13	Exposure Category Switch	LTE	48	6	2	55340	3560	QPSK 1/50/20 MHz BW	Right Cheek	0.309	14.0	19.0	13.77	18.07
					3	55340	3560	QPSK 1/50/20 MHz BW	Back Side, 5mm	0.358	11.0	19.0	10.81	18.07

Note: The device uncertainty of P_{max} is +/- 1 dB as provided by manufacturer.

Note: Multi-Tx factor is set to 1.0 per the manufacturer.

Table 6-3
WLAN FastConnect Radio Configurations Selected for Part 2 Test

Test Case #	Test Scenario	Tech	Band	Antenna	DSI	Channel	Frequency [MHz]	Test Configurations	SAR Exposure Scenario	Part 1 Worst Case Measured SAR at Plimit (W/kg)	BDF Plimit [dBm]	Tune-up Pmax [dBm]	Measured Plimit [dBm]	Measured Pmax [dBm]
1	Time Varying Test Sequence	WLAN	2.4	5	1	6	2437	802.11b 20 MHz BW DSSS	Right Cheek	0.302	13.0	17.0	12.83	17.72
2			5	7	1	40	5200	802.11a 20 MHz BW DSSS	Right Cheek	0.233	10.5	16.0	10.37	15.60
3	Change in Antenna / Band		6	7	1	40	5200	802.11ax 20 MHz BW DSSS	Right Cheek	0.193	10.5	15.0	10.62	15.12
			2.4	5	1	6	2437	802.11ac 20 MHz BW DSSS	Right Cheek	0.302	13.0	16.0	12.83	16.04
4	Change in Antenna / Band		2.4	5	1	6	2437	802.11ac 20 MHz BW DSSS	Right Cheek	0.302	13.0	16.0	12.83	16.04
			5	7	1	40	5200	802.11ac 20 MHz BW DSSS	Right Cheek	0.233	10.5	15.0	10.37	14.78

Note: The device uncertainty of P_{max} is +/- 1 dB as provided by manufacturer.

Table 6-4
DSI and Corresponding Exposure Scenarios for Qualcomm® Smart Transmit algorithm

Scenario	Description	SAR Test Cases
Head (DSI = 2)	▪ Device positioned next to head ▪ Receiver Active	*Head SAR per KDB Publication 648474 D04*
Hotspot mode (DSI = 3)	▪ Device transmits in hotspot mode near body ▪ Hotspot Mode Active	*Hotspot SAR per KDB Publication 941225 D06*
Phablet (DSI = 0)	▪ Device is held with hand	*Phablet SAR per KDB Publication 648474 D04 & KDB Publication 616217 D04*
Body-worn (DSI = 0)	▪ Device being used with a body-worn accessory	*Body-worn SAR per KDB Publication 648474 D04*

Table 6-5
DSI and Corresponding Exposure Scenarios for Qualcomm® FastConnect TAS feature

Scenario	Description	SAR Test Cases
Head (DSI = 1)	▪ Device positioned next to head ▪ Receiver Active	*Head SAR per KDB Publication 648474 D04*
Phablet (DSI = 0)	▪ Device is held with hand	*Phablet SAR per KDB Publication 648474 D04 & KDB Publication 616217 D04*
Body-worn (DSI = 0)	▪ Device being used with a body-worn accessory	*Body-worn SAR per KDB Publication 648474 D04*
Hotspot mode (DSI = 0)	▪ Device transmits in hotspot mode near body ▪ Hotspot Mode Active	*Hotspot SAR per KDB Publication 941225 D06*

Based on the selection criteria described in Section 4.2, the WWAN radio configurations for the Tx varying transmission test cases listed in Section 3.1 are:

1. Technologies and bands for time-varying Tx power transmission: The test case 1~8 listed in Table 6-2 are selected to test with the test sequences defined in Section 4.1 in both time-varying conducted power measurement and time-varying SAR measurement.
2. Technology and band for change in call test: LTE Band 48 PC3 antenna 6, DSI=3, having the lowest P_{limit} among all technologies and bands (test case 9 in Table 6-2), is selected for performing the call drop test in conducted power setup.
3. Technologies and bands for change in technology/band/Antenna test: Following the guidelines in Section 4.2.3, test case 10 in Table 6-2 is selected for handover test from a technology/band/Antenna within one technology group (LTE Band 5, DSI = 3, antenna 1), to a technology/band in the same DSI within another technology group (WCDMA Band 2, DSI = 3, antenna 2) in conducted power setup.
4. Technologies and bands for change in time-window: Based on selection criteria in Section 4.2.6, for a given DSI = 3, test case 11 in Table 6-2 is selected for time window switch between 60s window (LTE Band 48, antenna 6) and 100s window (LTE Band 25, antenna 4) in conducted power setup.

5. Technologies and bands for switch in SAR exposure: Based on selection criteria in Section 4.2.7 Scenario 1, test case 12 in Table 6-2 is selected for SAR exposure switching test in one of the supported simultaneous WWAN transmission scenario, i.e., LTE + Sub6 NR active in the same 100s time window, in conducted power setup.
6. Technologies and bands for switch in exposure category: Based on selection criteria in Section 4.2.8, test case 13 in Table 6-2 is selected for switch in exposure category test by establishing a call in LTE Band 48, antenna 6 in DSI=2 (head exposure) and then handing over to DSI=3 (non-head exposure) scenario in conducted power setup, and vice versa.

Based on the selection criteria described in Section 4.5, the WLAN radio configurations for the Tx varying transmission test cases listed in Section 3.2 are:

1. Technologies and bands for time-varying Tx power transmission: The test case 1~2 listed in 6-3 are selected to test with the test sequences defined in Section 3.2 in both time-varying conducted power measurement and time-varying SAR measurement.
2. Technologies and bands for change in Antenna/Band test: Following the guidelines in Section 4.5.4, test case 3 and 4 in Table 6-3 is selected for handover test from a band (WLAN 2.4 GHz, DSI = 2, antenna 5), to a band in the same DSI within one antenna group (WLAN 5 GHz, DSI = 2, antenna 7) in conducted power setup.

   NOTE: This device does not support simultaneous transmission DBS or HBS

   NOTE: Change in DSI is excluded for same Plimit and Pmax values apply to each antenna.

6.2 EFS v20 Verification

Per Qualcomm's 80-w2112-5 document, embedded file system (EFS) version 20 products are required to be verified for Smart Tx generation for relevant MCC settings. It was confirmed that this DUT contains embedded file system (EFS) version 20 configured for Smart Tx second generation (GEN2) for Sub6 with MCC settings for the US market.

EFS v20 Generation	MCC
GEN2_Sub6	310

7 WWAN CONDUCTED TX CASES

7.1 Time-varying Tx Power Case

The measurement setup is shown in Figure 6-1.The purpose of the time-varying Tx power measurement is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged Tx power when represented in time-averaged 1gSAR or 10gSAR values does not exceed FCC limit as shown in Eq. (1a) and (1b), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \quad (1b)$$

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* and *10gSAR* values at P_{limit} reported in Part 1 test (listed in Table 6-2 of this report as well).

Following the test procedure in Section 4.3, the conducted Tx power measurement for all selected configurations are reported in this section. In all the conducted Tx power plots, the green curve represents time-averaged power and red line represents the conducted power limit that corresponds to FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

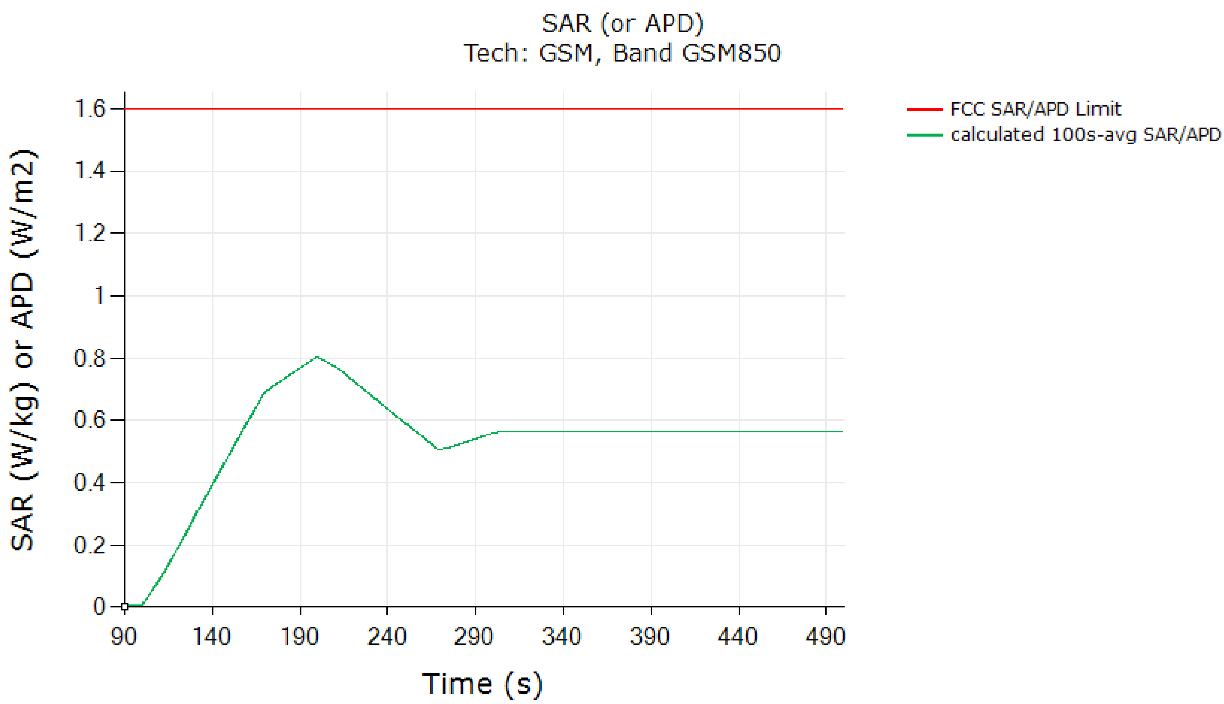
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Time-varying Tx power measurements were conducted on test cases #1 ~ #8 in Table 6-2, by generating test sequence 1 and test sequence 2 given in APPENDIX E: using measured P_{limit} and measured P_{max} (last two columns of Table 6-2) for each of these test cases. Measurement results for test cases #1 ~ #8 are given in Sections 7.1.1-7.1.8.

7.1.1 GSM/GPRS/EDGE 850, Antenna 1

<u>Test result for test sequence 1:</u>

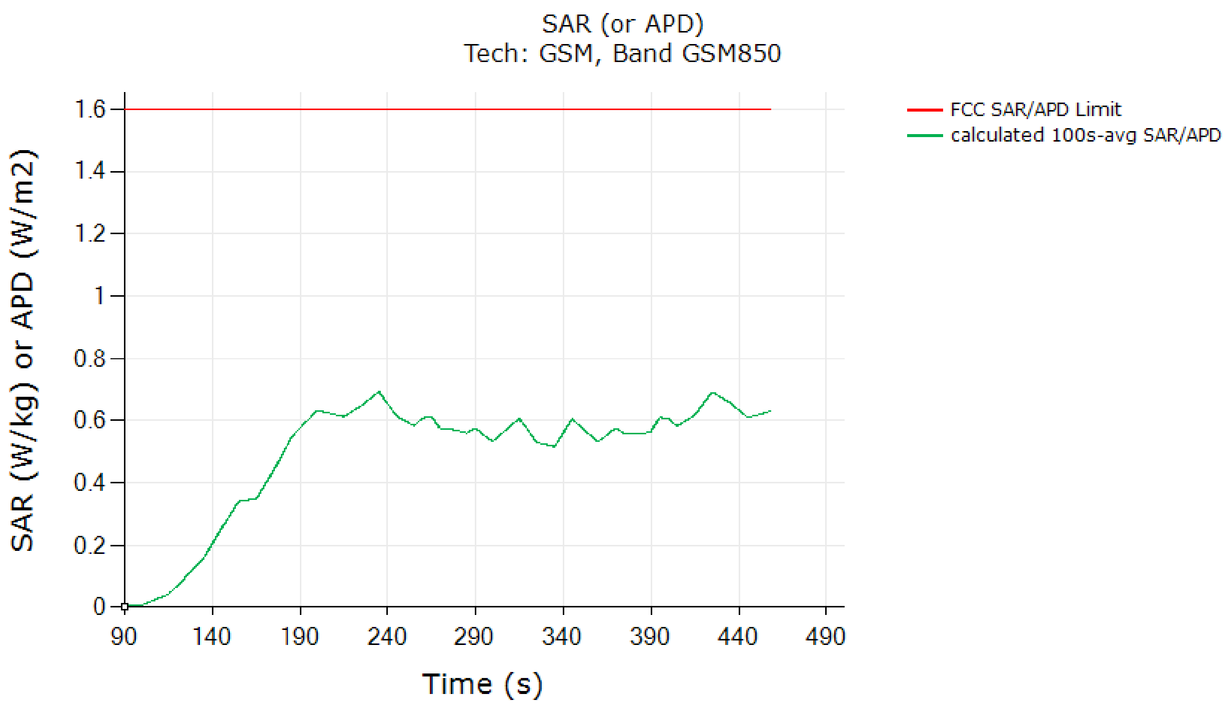
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.805
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

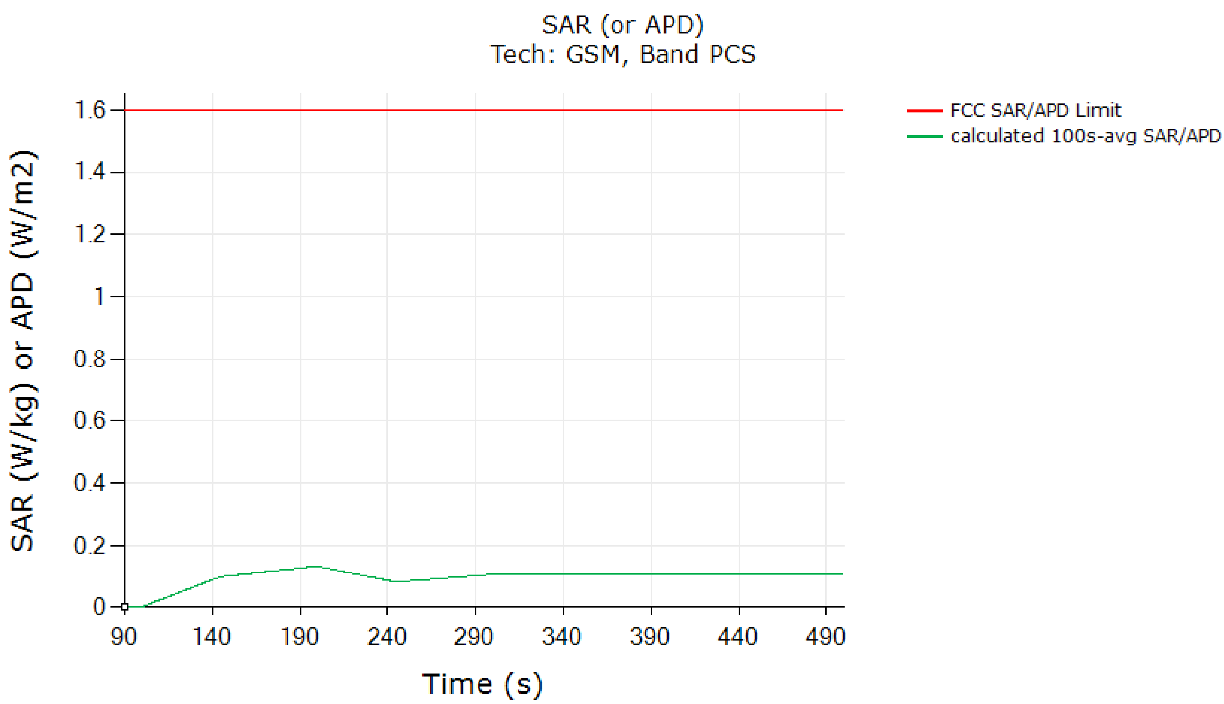


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.692
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.2 GSM/GPRS/EDGE 1900, Antenna 2

Test result for test sequence 1:

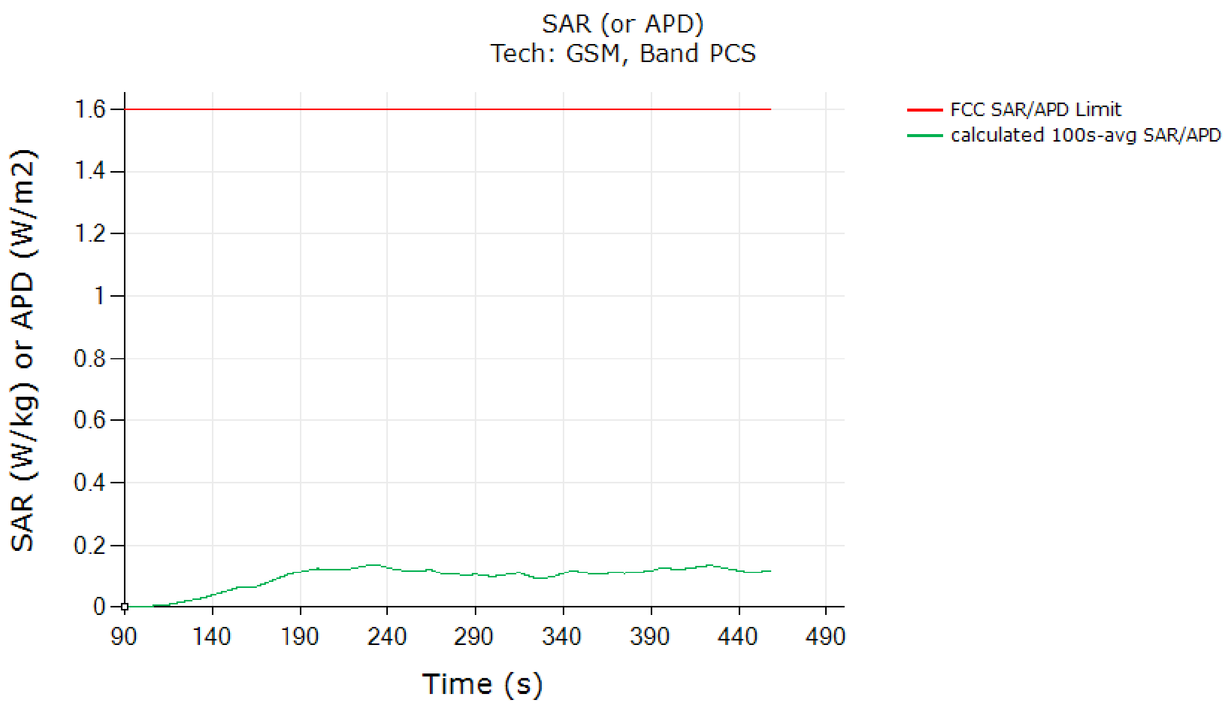
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.133
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

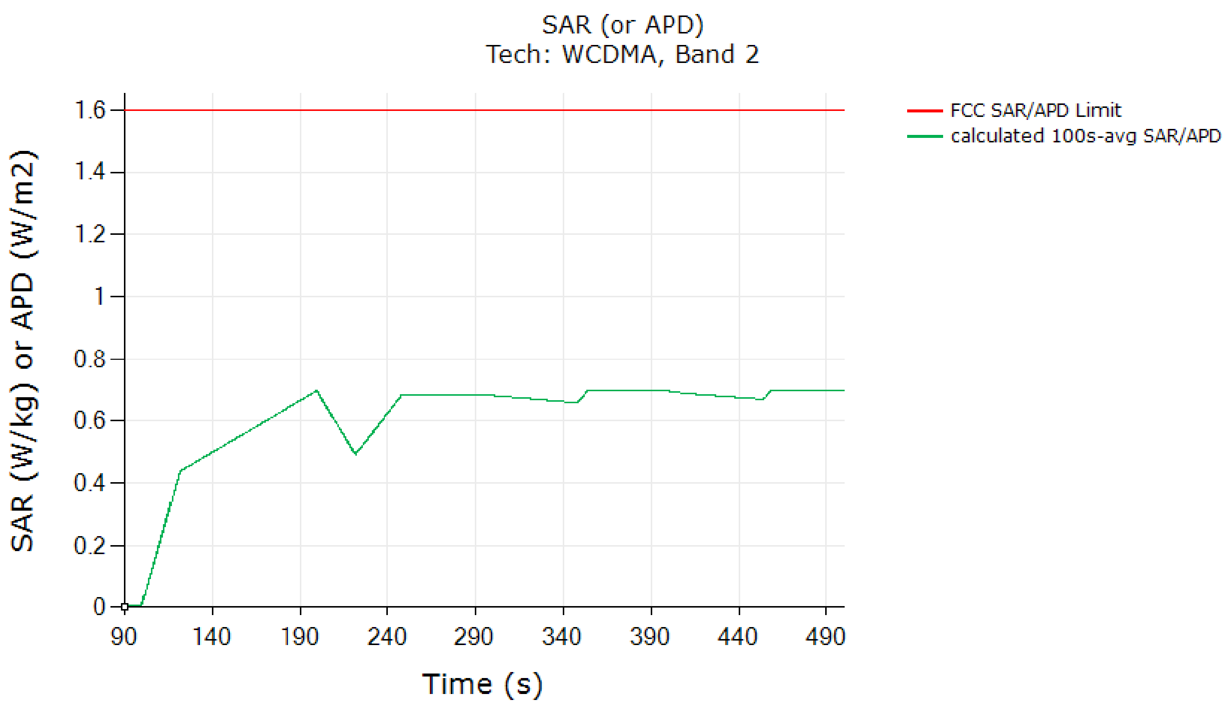


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.135
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.3 WCDMA Band 2, Antenna 2

Test result for test sequence 1:

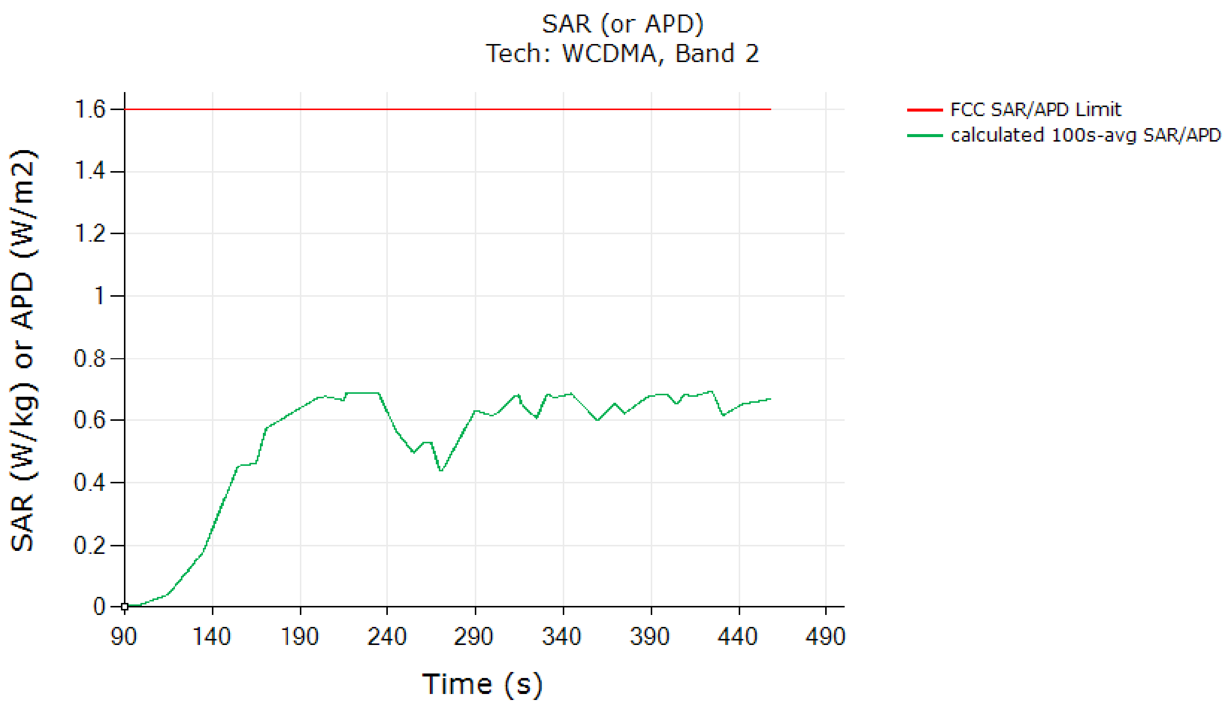
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.697
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

<u>Test result for test sequence 2:</u>

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

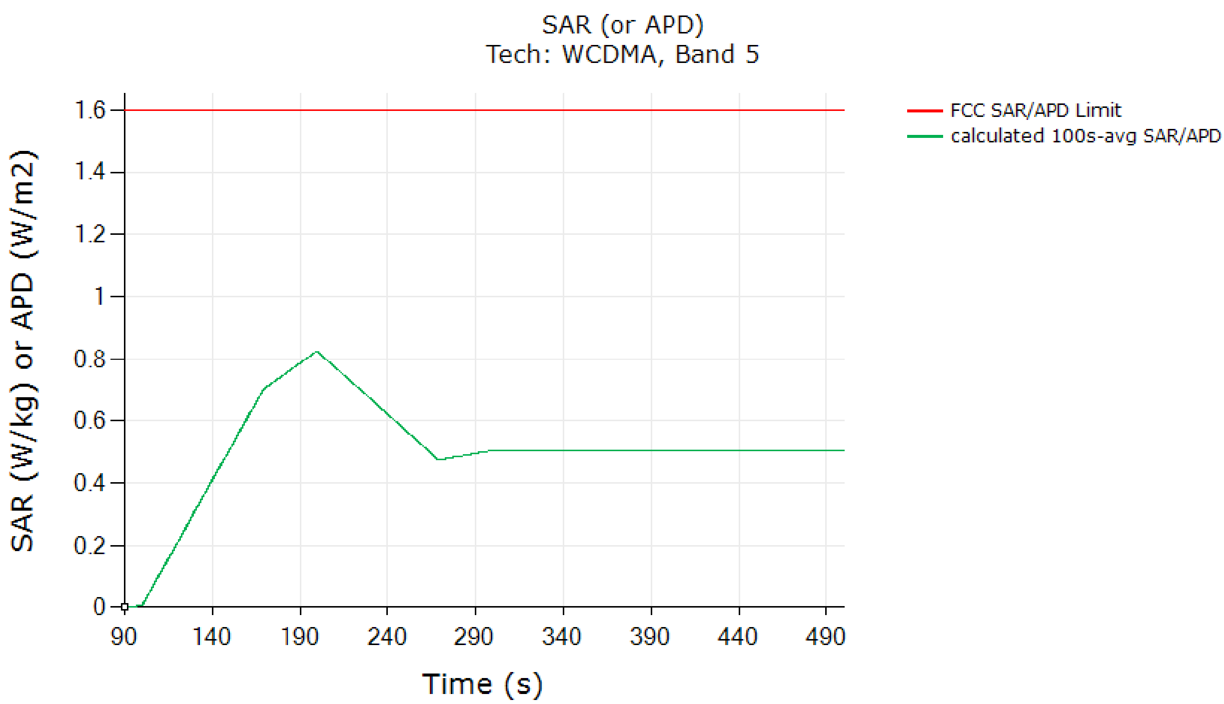


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.694
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.4 WCDMA Band 5, Antenna 1

<u>Test result for test sequence 1:</u>

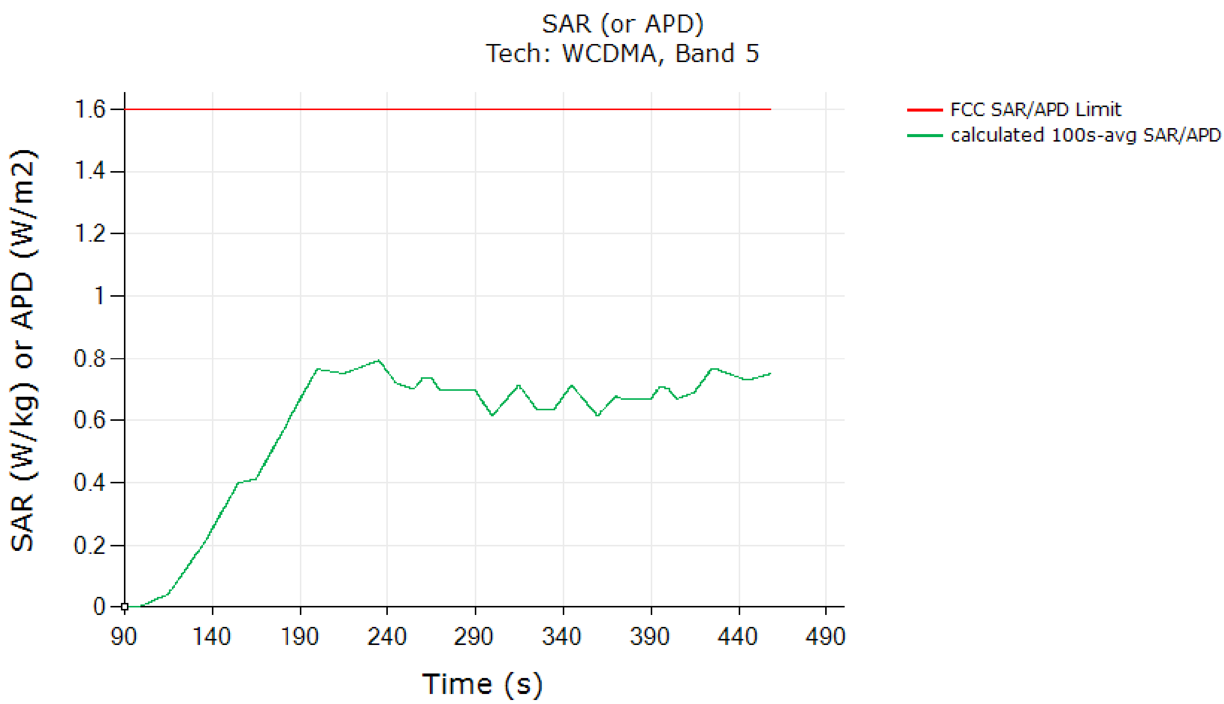
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.824
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

<u>Test result for test sequence 2:</u>

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

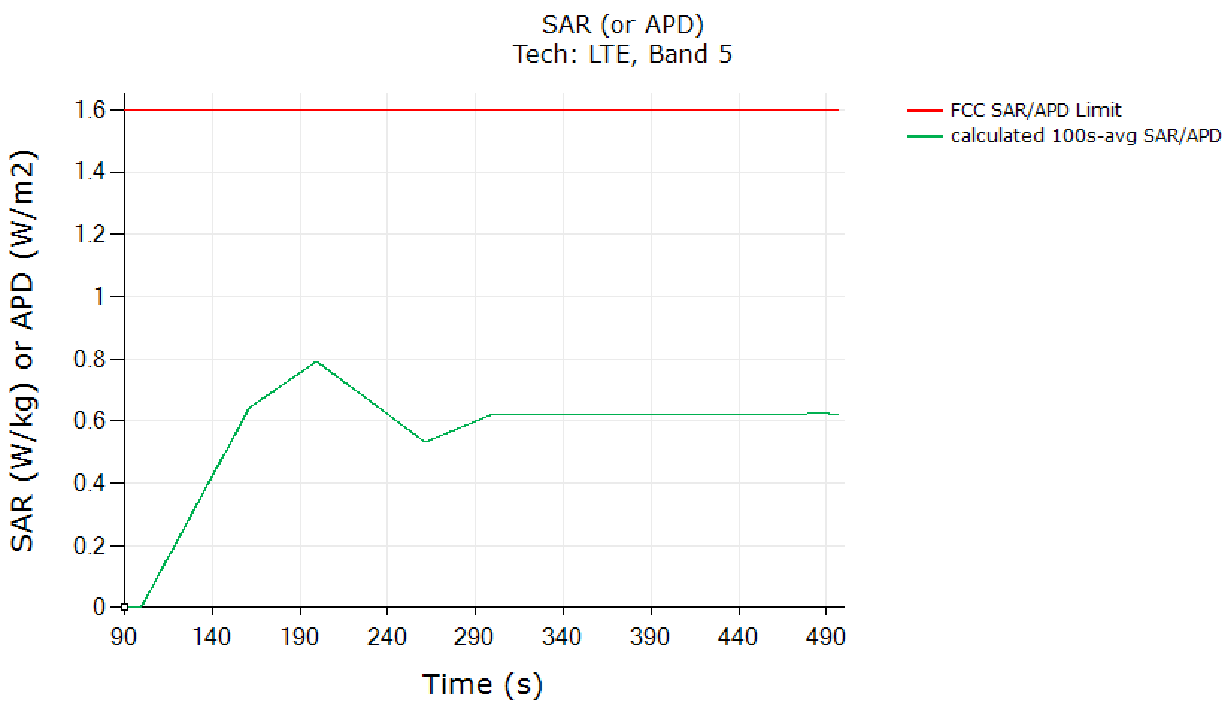


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.792
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.5 LTE Band 5, Antenna 1

Test result for test sequence 1:

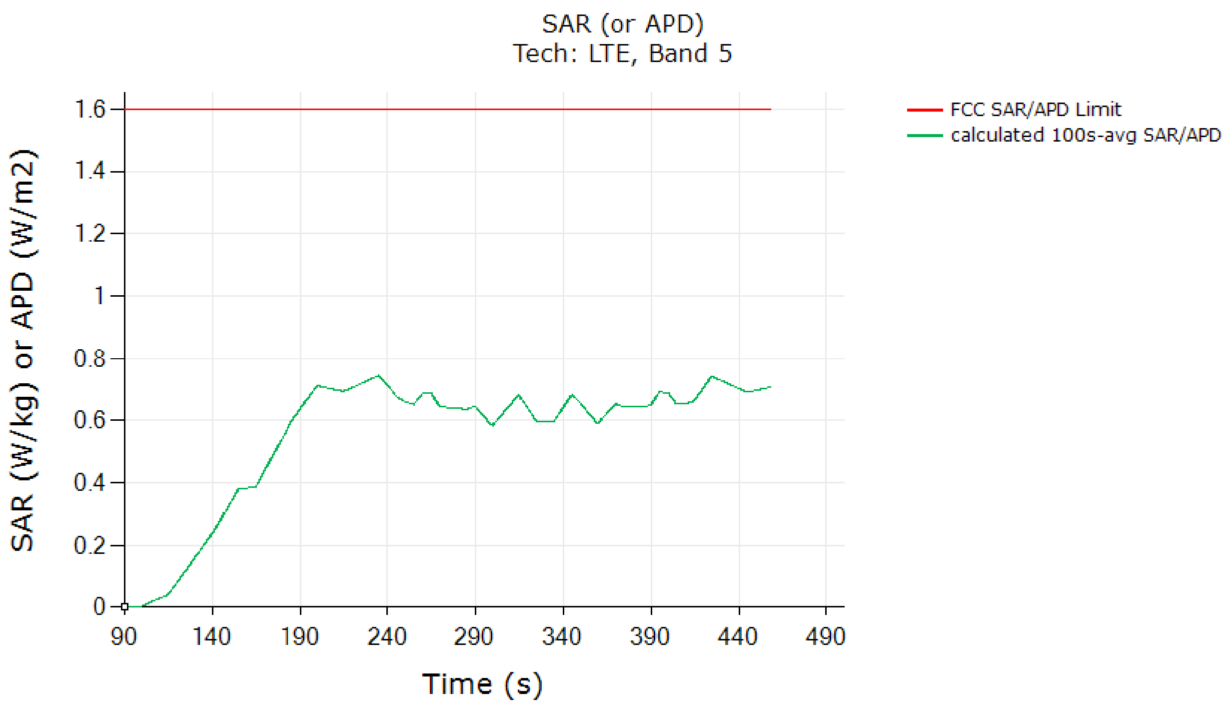
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.791
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

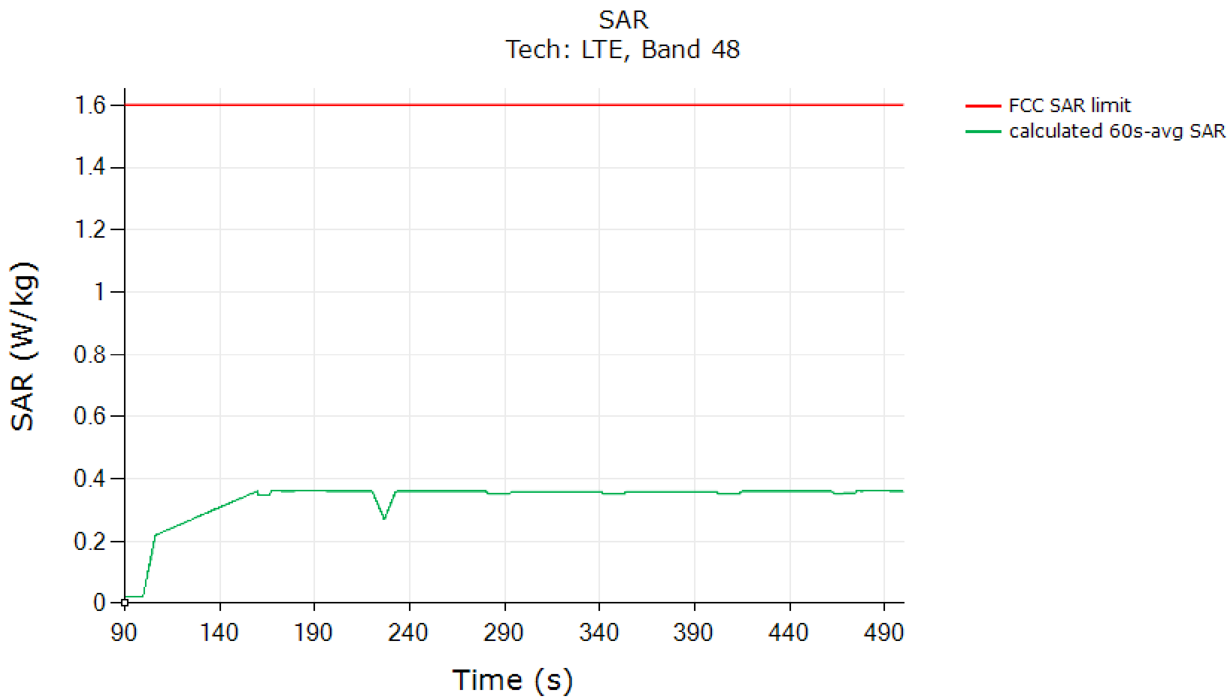


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.743
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.6 LTE Band 48, Antenna 6

Test result for test sequence 1:

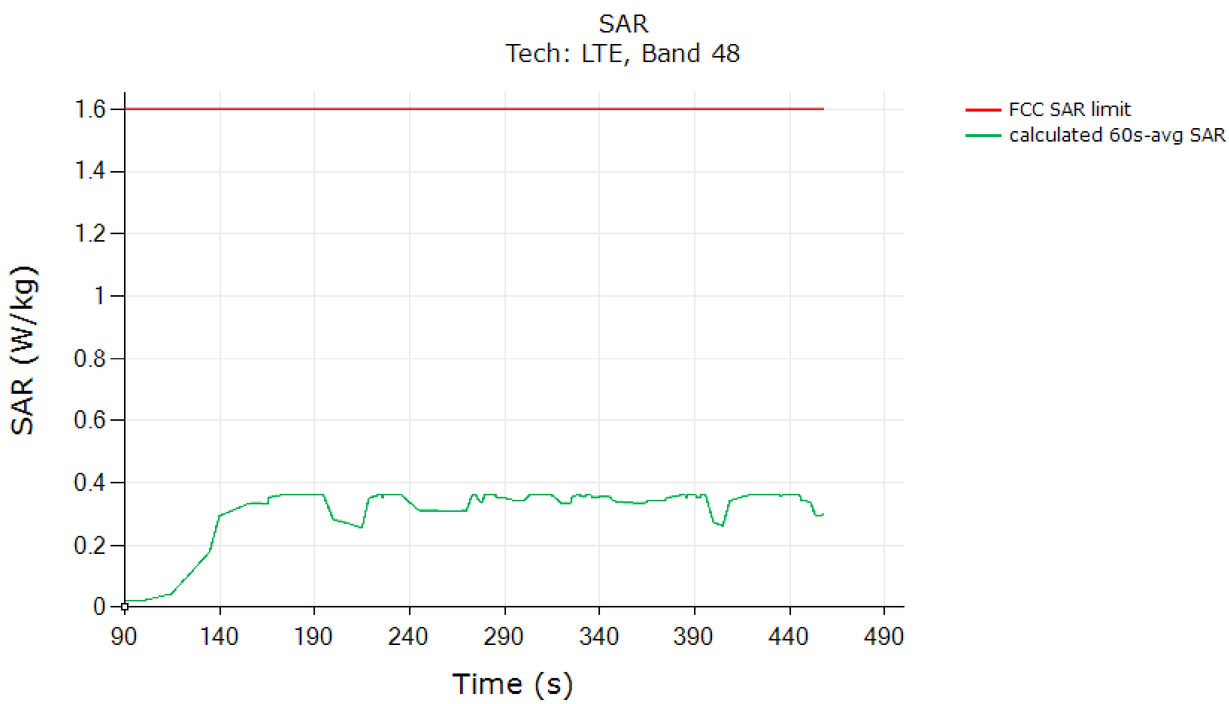
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.360
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

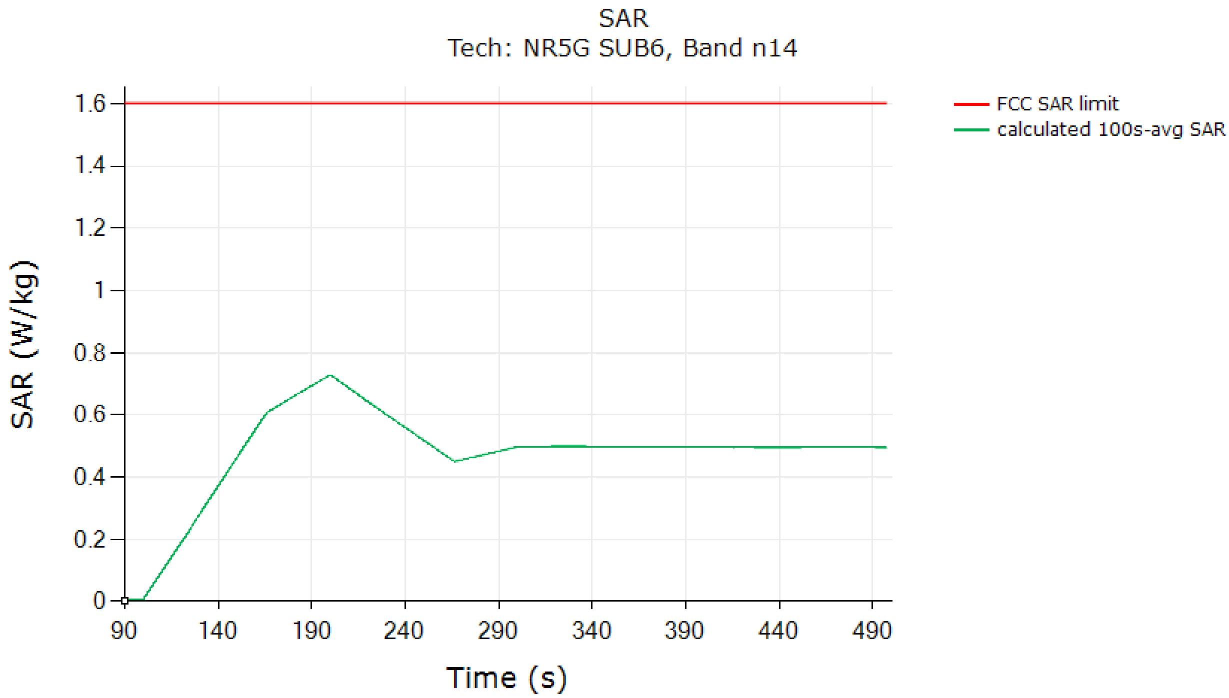


	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.363
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.7 NR n14 SA, Antenna 1

<u>Test result for test sequence 1:</u>

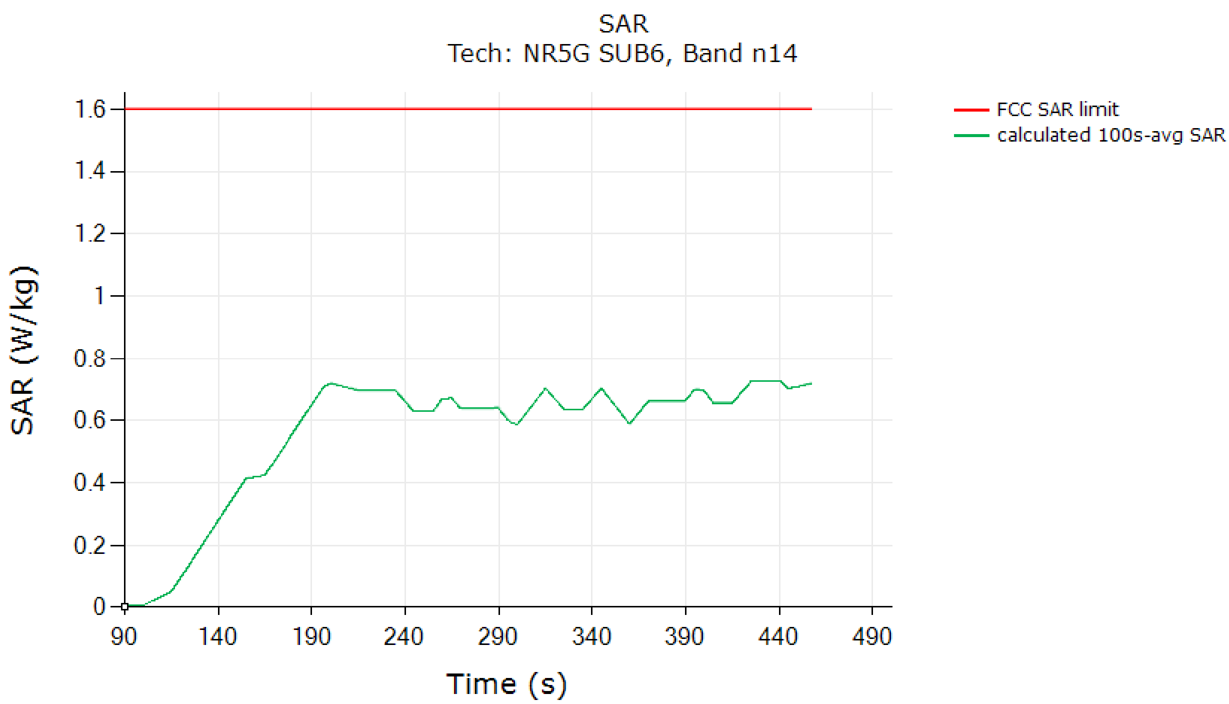
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.728
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

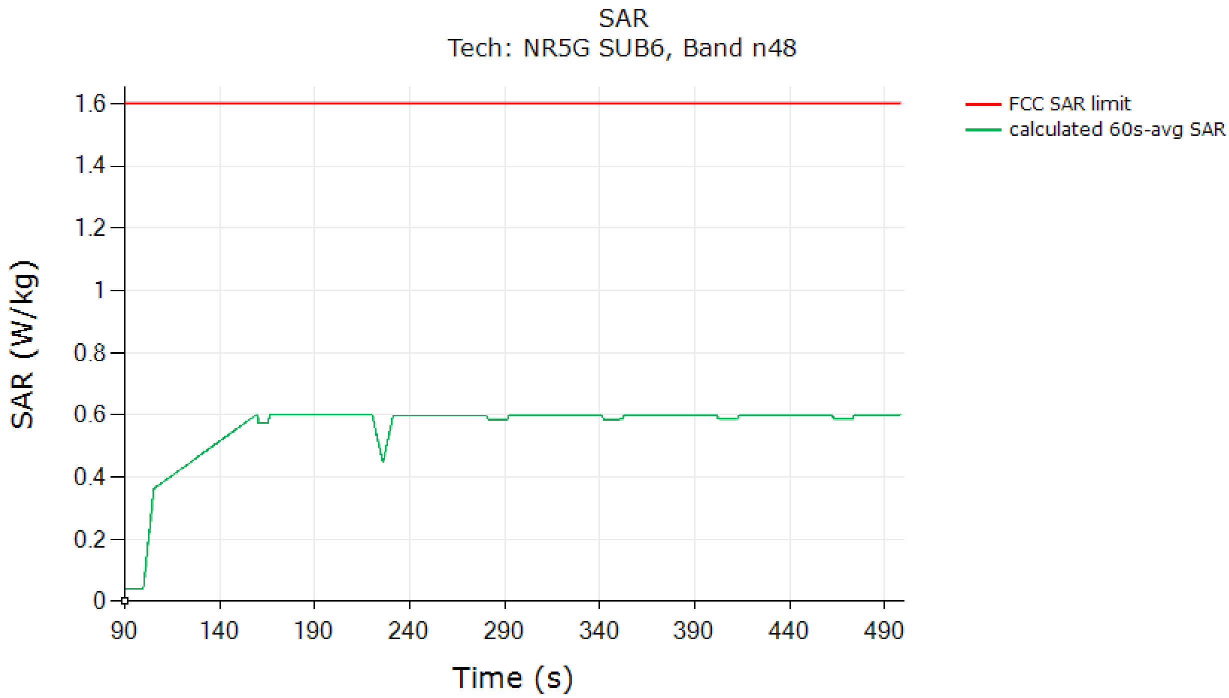


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.726
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.1.8 NR n48 SA, Antenna 6

<u>Test result for test sequence 1:</u>

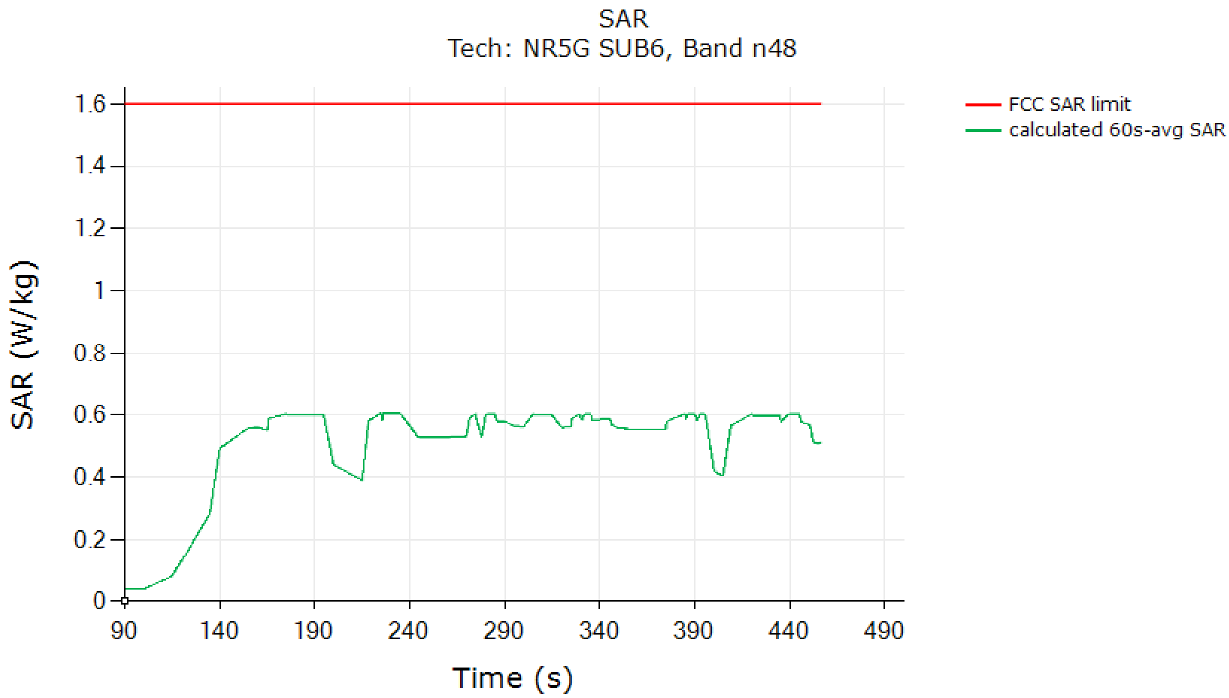
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.601
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

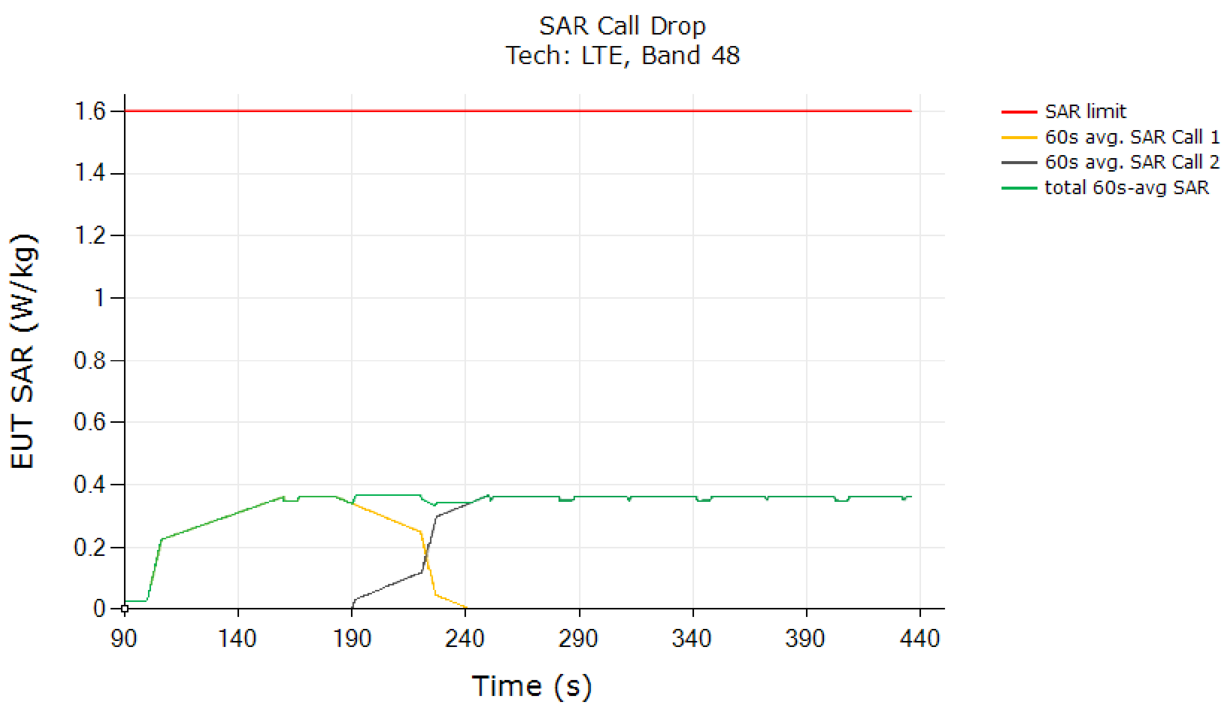


	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.605
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

7.2 Call Drop Test Case

This test was measured LTE Band 48, Antenna 6, DSI = 3, and with callbox requesting maximum power. The call drop was manually performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below. The measurement setup is shown in Figure 6-1. The detailed test procedure is described in Section 4.3.2.

Call drop test result:
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.365
Validated	

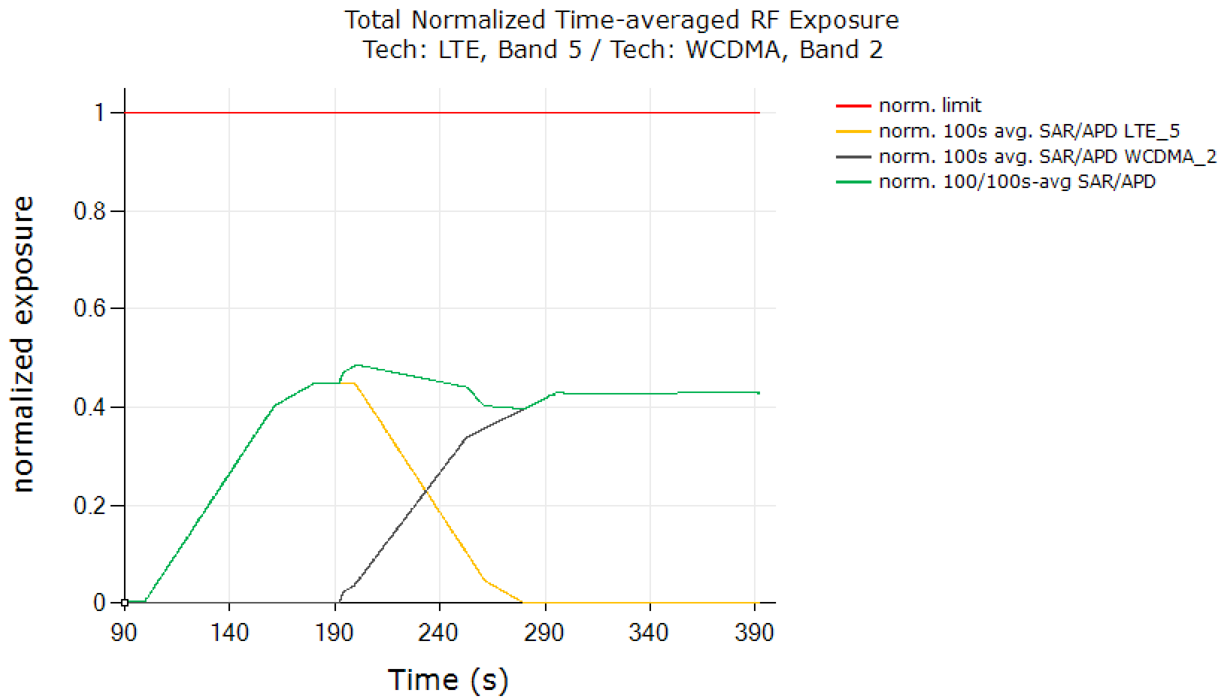
The test result validated the continuity of power limiting in call change scenario.

7.3 Change in Technology/Band/Antenna Test Case

This test was conducted with callbox requesting maximum power, and with a technology switch from LTE Band 5, Antenna 1, DSI = 3 to WCDMA Band 2, Antenna 2, DSI = 3. Following procedure detailed in Section 4.3.3, and using the measurement setup shown in Figure 5-1, the technology/band switch was performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below.

Test result for change in technology/band/Antenna:

Time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (6a), (6b) and (6c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the normalized FCC limit of 1.0:



	(W/kg)
FCC normalized SAR limit	1.0
Max 100s-time averaged normalized SAR (green curve)	0.487
Validated	

The test result validated the continuity of power limiting in technology/band/Antenna switch scenario.

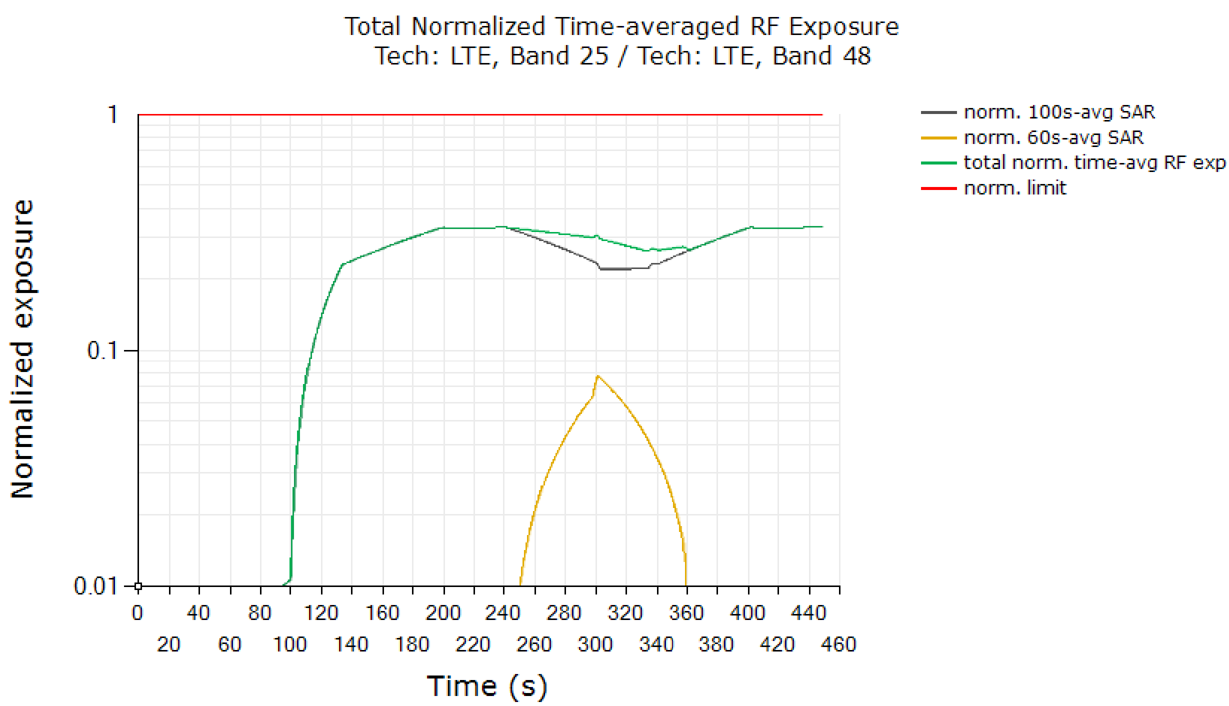
7.4 Change in Time Window Test Case

This test was conducted with callbox requesting maximum power, and with time-window/antenna switch between LTE Band 25, Antenna 4, DSI = 3 (100s window) and LTE Band 48, Antenna 6, DSI = 3 (60s window). Following procedure detailed in Section 4.3.6, and using the measurement setup shown in Figure 6-1(b), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level.

7.4.1 Test case 1: transition from LTE Band 25 to LTE Band 48 (i.e., 100s to 60s), then back to LTE Band 25

<u>Test result for change in time-window (from 100s to 60s to 100s):</u>

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 60s-averaged normalized SAR in LTE Band 48 as shown in orange curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in black curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



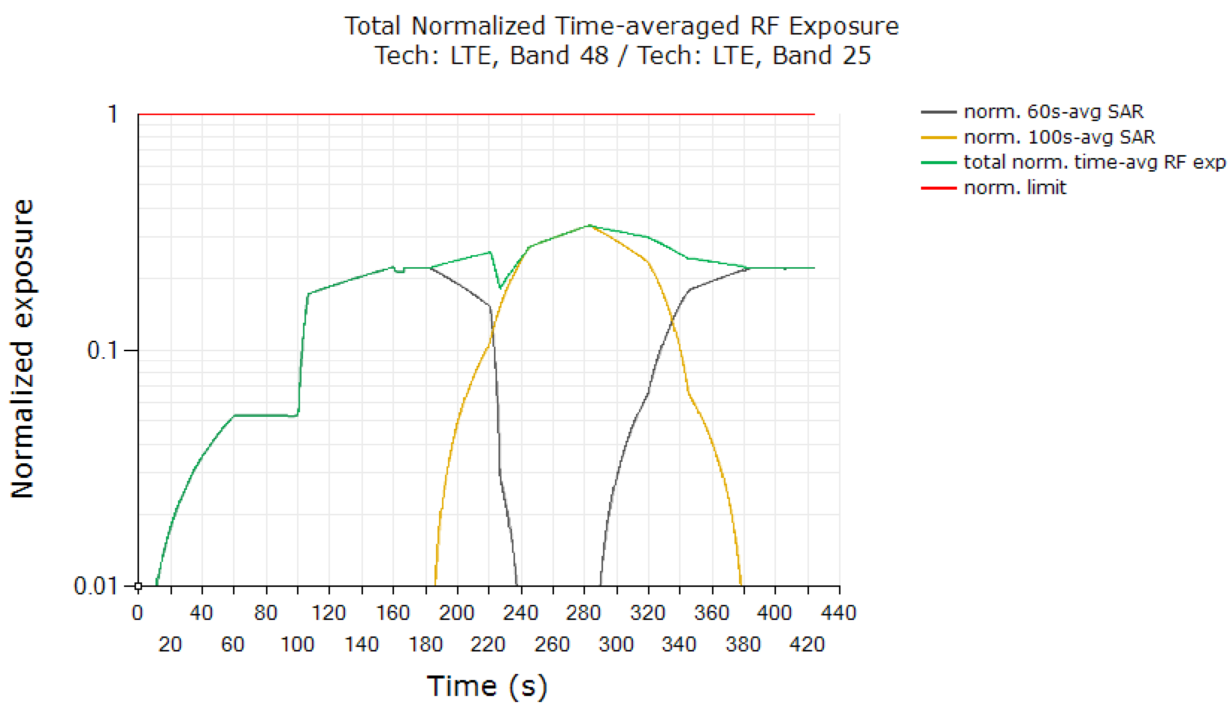
	(W/kg)
FCC normalized total exposure limit	1.0
Max time averaged normalized SAR (green curve)	0.334
Validated	

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 100s-to-60s window at ~241s time stamp, and from 60s-to-100s window at ~302s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.334 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

7.4.2 Test case 2: transition from LTE Band 48 to LTE Band 25 (i.e., 60s to 100s), then back to LTE Band 48

Test result for change in time-window (from 60s to 100s to 60s):

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 60s-averaged normalized SAR in LTE Band 48 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



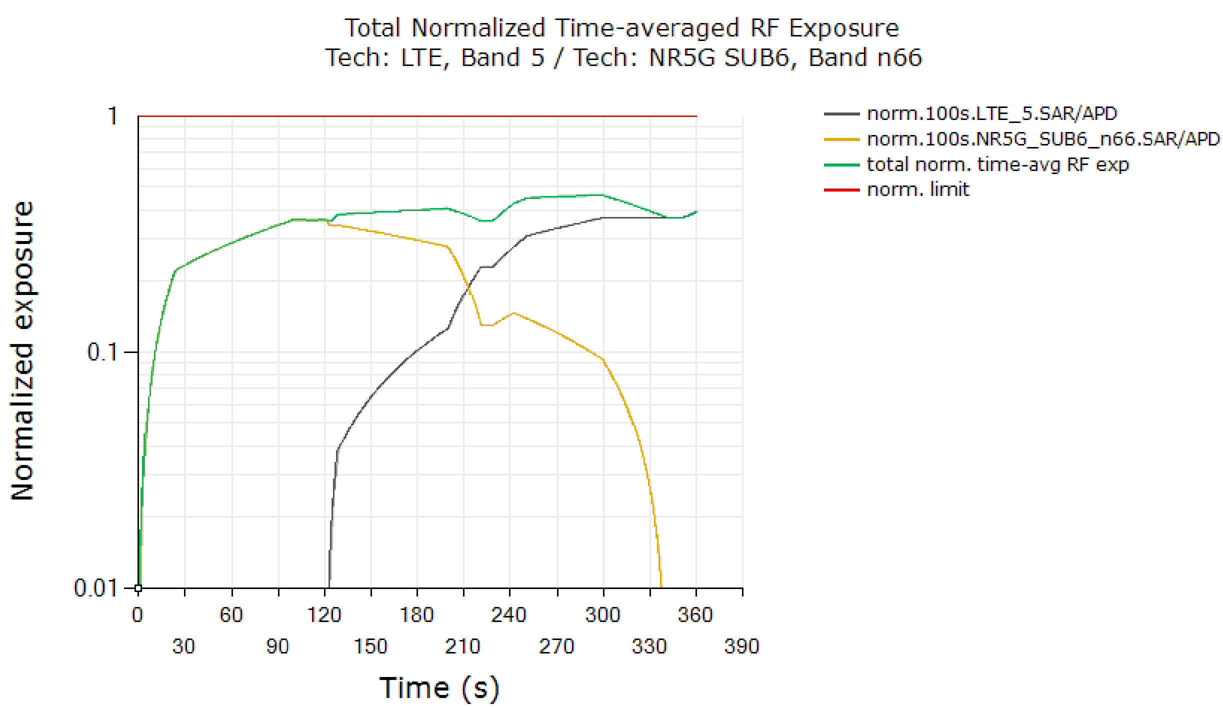
	(W/kg)
FCC normalized total exposure limit	1.0
Max time averaged normalized SAR (green curve)	0.338
Validated	

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 60s-to-100s window at ~183s time stamp, and from 100s-to-60s window at ~285s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.338 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

7.5 Switch in SAR exposure EN-DC Same Time Window test results

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 5 + Sub6 NR Band n66 call. Following procedure detailed in Section 4.3.7 and Appendix F.2, and using the measurement setup shown in Figure 6-1(c) since LTE and Sub6 NR are sharing diferrent antenna port, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, i.e., in SAR_{sub6NR} only scenario (t =0s ~120s), SAR_{su6NR} + SAR_{LTE} scenario (t =120s ~ 240s) and SAR_{LTE} only scenario (t > 240s).

Plot Notes: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 5 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in Sub6 NR n66 as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



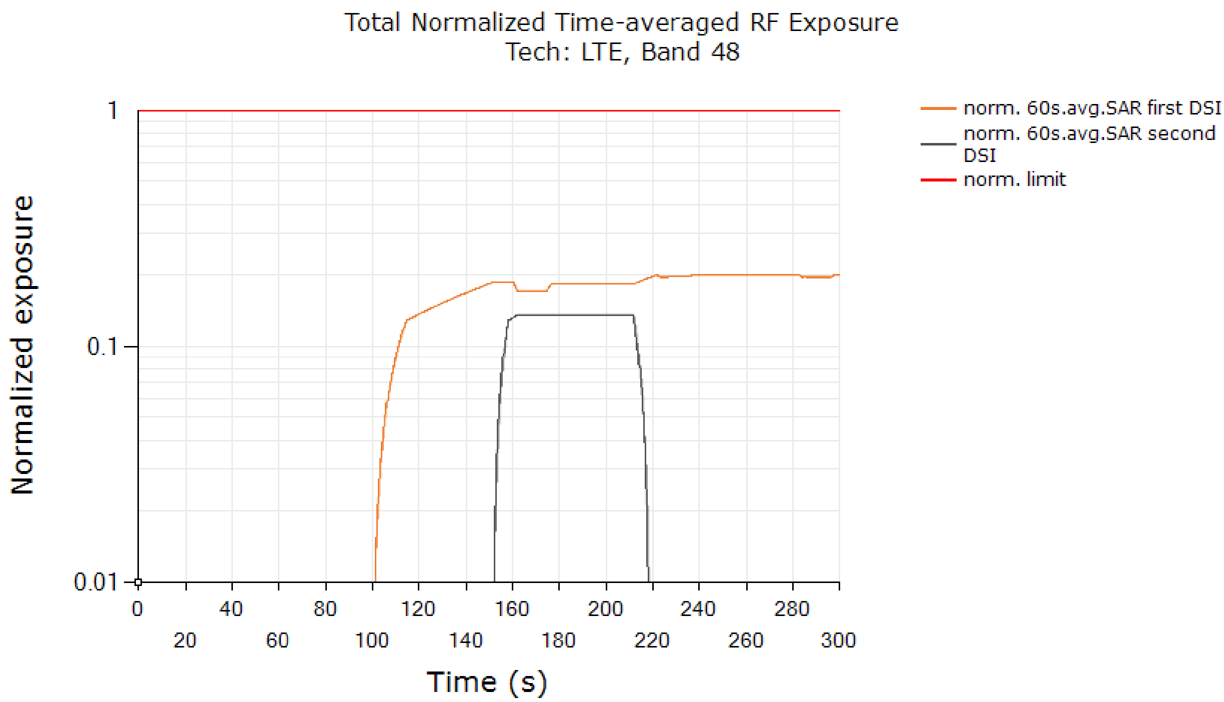
	(W/kg)
FCC normalized total exposure limit	1.0
Max time averaged normalized SAR (green curve)	0.462
Validated	

Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and in LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. Here, Smart Transmit allocates a maximum of 100% of exposure margin (based on 3dB reserve margin setting) for Sub6 NR. This corresponds to a normalized 1gSAR exposure value = 100% * 0.767 W/kg measured SAR at Sub6 NR *Plimit* / 1.6W/kg limit = 0.479 ± 1dB device related uncertainty (see orange curve between 120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin (based on 3dB reserve margin setting) for LTE. This corresponds to a normalized 1gSAR exposure value = 100% * 0.590 W/kg measured SAR at LTE *Plimit* / 1.6W/kg limit = 0.369 ± 1dB device related uncertainty (see black curve after t = 240s). Additionally, in SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.462 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

7.6 Exposure Category Switch

This test was conducted with callbox requesting maximum power, and with exposure category switch between LTE Band 48, Antenna 6, DSI = 2 (Head) and LTE Band 48, Antenna 6, DSI = 3 (Non-Head). Following procedure detailed in Section 4.3.8 and using the measurement setup shown in Figure 6-1a, the exposure category switch was performed when the EUT is transmitting at $P_{reserve}$ level.

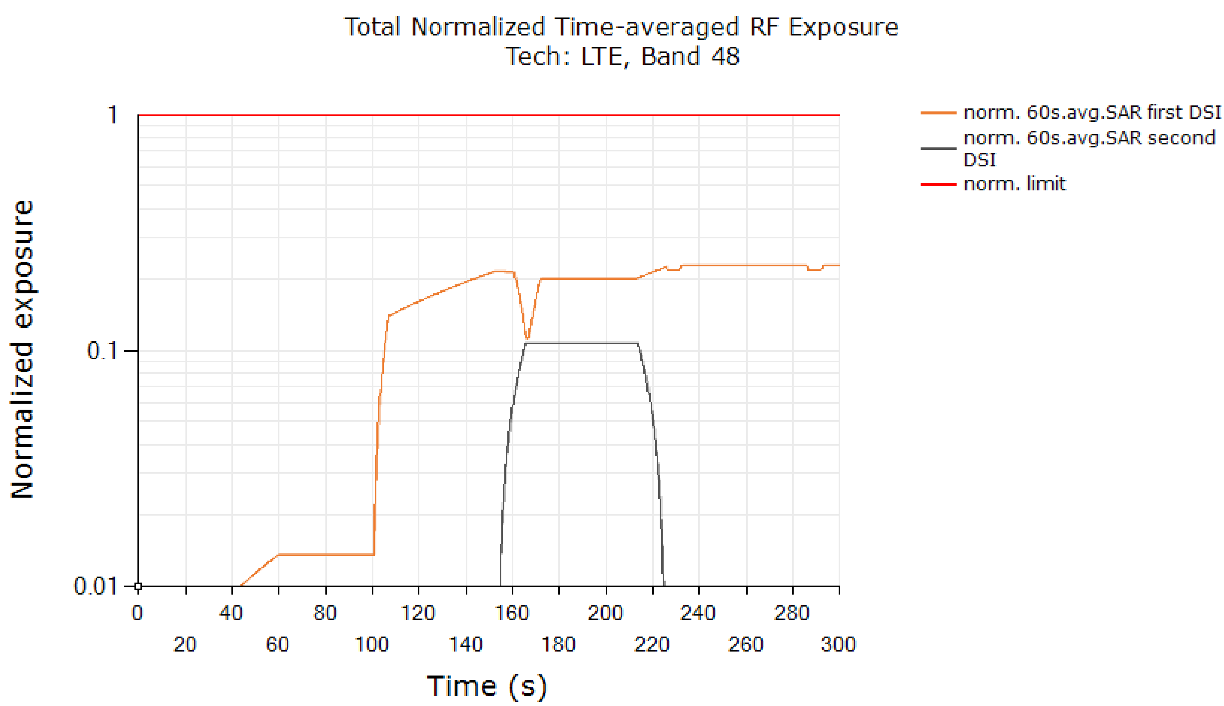
7.6.1 Test case 1: Transition from LTE B48 DSI=2 (Head) to LTE B48 DSI=3 (Non-Head), then back to DSI=2 (Head)



	(W/kg)
FCC normalized total exposure limit	1.0
Max 100s-time averaged normalized SAR (first DSI, orange curve)	0.200
Validated	

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, time-averaged exposure in head DSI gradually increases until t~152s where the device is switched from head exposure DSI (first DSI, orange curve) to non-head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t~152s and t~162s. At t~162s, device is switched back from non-head exposure to head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized SAR of 0.200 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), validating the exposure continuity when switching between head exposure and non-head exposure categories.

7.6.2 Test case 2: Transition from LTE B48 DSI=3 (Non-Head) to DSI=2 (Head), then back to LTE B48 DSI=3 (Non-Head)



	(W/kg)
FCC normalized total exposure limit	1.0
Max 100s-time averaged normalized SAR (first DSI, orange curve)	0.230
Validated	

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, time-averaged exposure in head DSI gradually increases until t~153s where the device is switched from head exposure DSI (first DSI, orange curve) to non-head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t~153s and t~166s. At t~166s, device is switched back from non-head exposure to head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized SAR of 0.230 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), validating the exposure continuity when switching between head exposure and non-head exposure categories.

8 WLAN CONDUCTED TX CASES

8.1 Time-varying Tx Power Case

The measurement setup is shown in Figure 6-1.The purpose of the time-varying Tx power measurement is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged Tx power when represented in time-averaged 1gSAR or 10gSAR values does not exceed FCC limit as shown in Eq. (1a) and (1b), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \qquad (1b)$$

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* and *10gSAR* values at P_{limit} reported in Part 1 test (listed in Table 6-2 of this report as well).

Following the test procedure in Section 4.6, the conducted Tx power measurement for all selected configurations are reported in this section. In all the conducted Tx power plots, the green curve represents time-averaged power and red line represents the conducted power limit that corresponds to FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

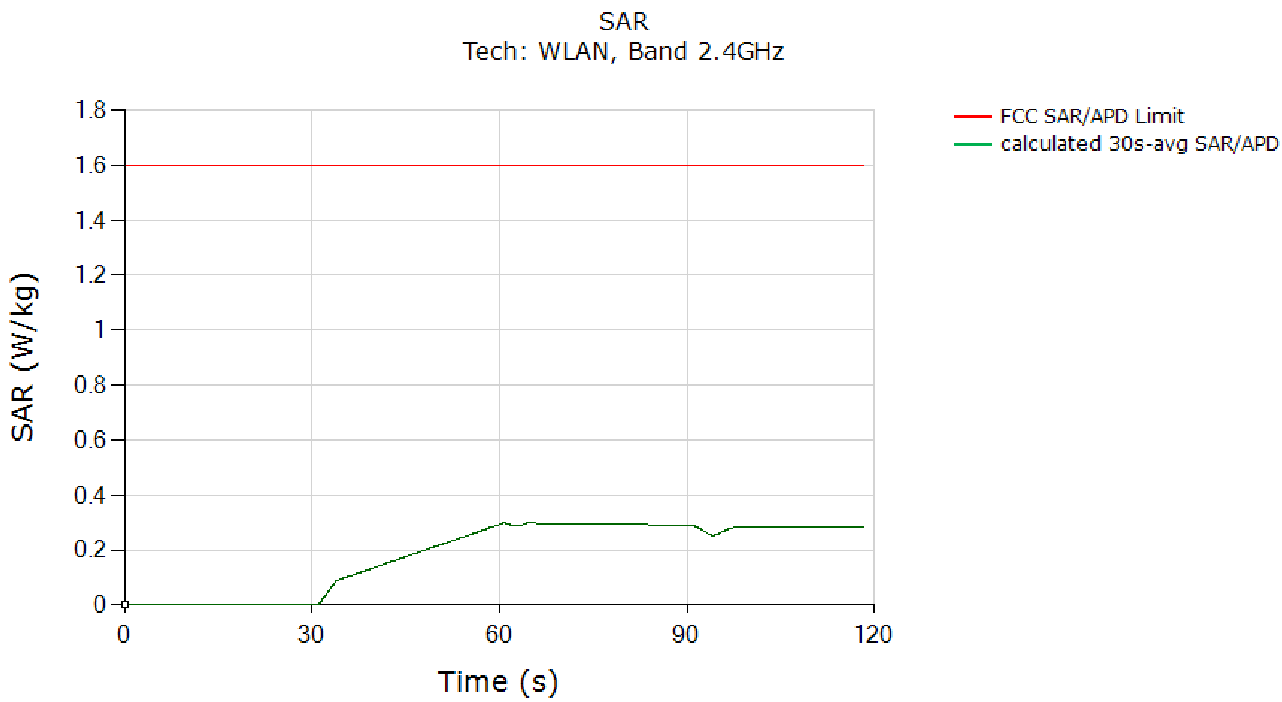
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 30s/30s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Time-varying Tx power measurements were conducted on test cases #1 ~ #2 in Table 6-3, by generating test sequence 1 given in APPENDIX E: using measured P_{limit} and measured P_{max} for each of these test cases. Measurement results for test cases #1 ~ #2 are given in Sections 8.1.1-8.1.2.

8.1.1 WLAN Band 2.4 GHz, Antenna 5

Test result for test sequence 1:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

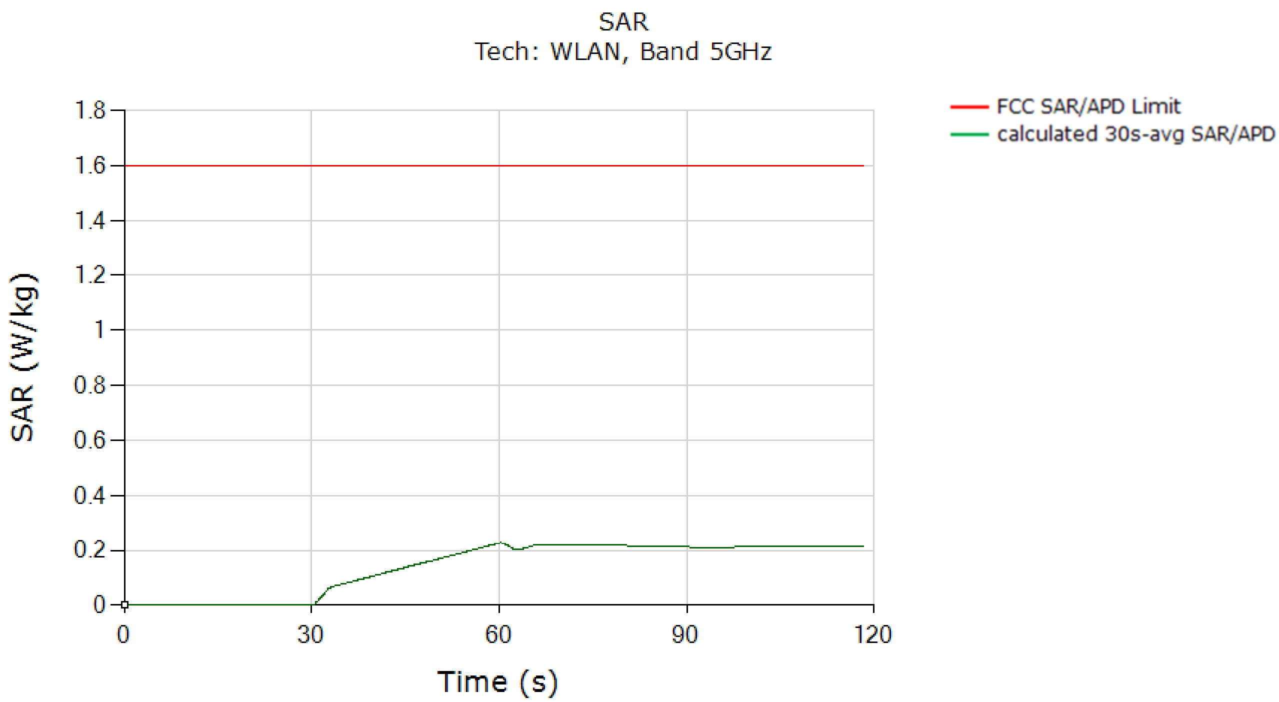


	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged 1gSAR (green curve)	0.300
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-3).	

8.1.2 WLAN Band 5 GHz, Antenna 7

Test result for test sequence 1:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



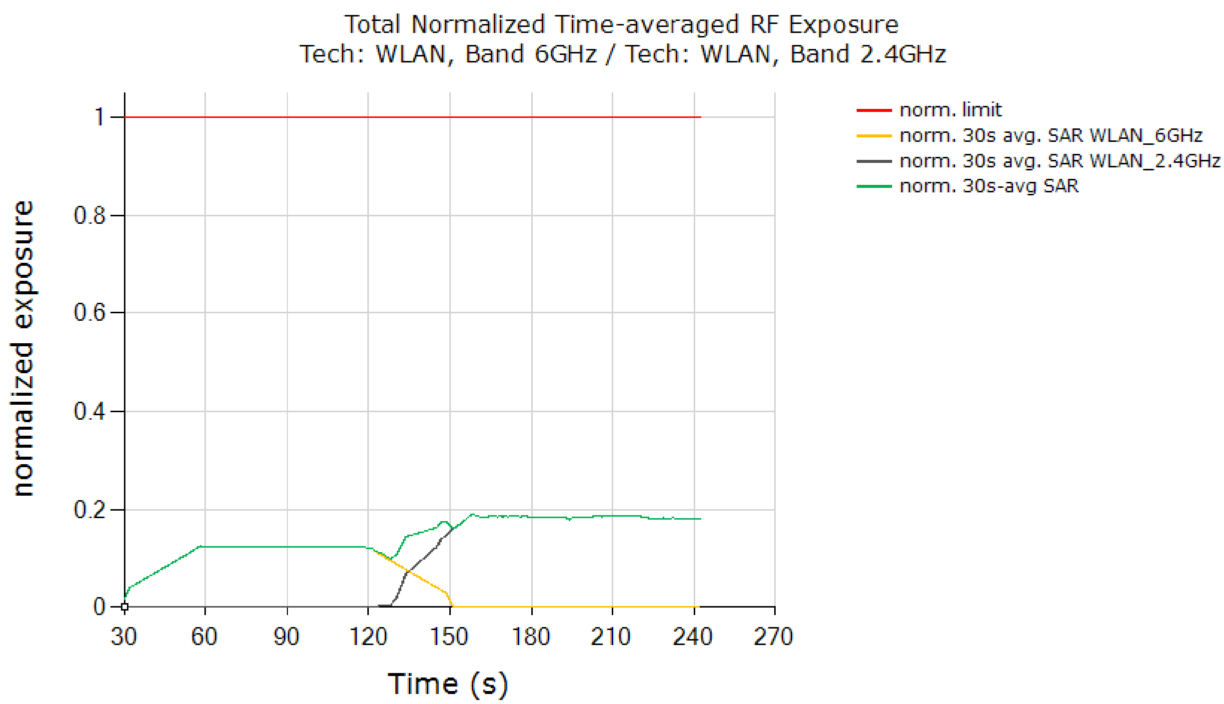
	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged 1gSAR (green curve)	0.228
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-3).	

8.2 Change in Antenna/Band Test Case

This test was conducted with a callbox requesting maximum power, and with an Antenna/band switch WLAN Band 6 GHz, DSI = 1, antenna 7 to WLAN Band 2.4 GHz, DSI = 1, antenna 5. Following procedure detailed in Section 4.6 and using the measurement setup shown in Figure 5-1, the technology/band switch was performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below.

Test result for change in Antenna/band:

Time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (4a), (4b) and (4c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the normalized FCC limit of 1.0:



	(W/kg)
FCC normalized SAR limit	1.0
Max 30s-time averaged normalized SAR (green curve)	0.190
Validated	

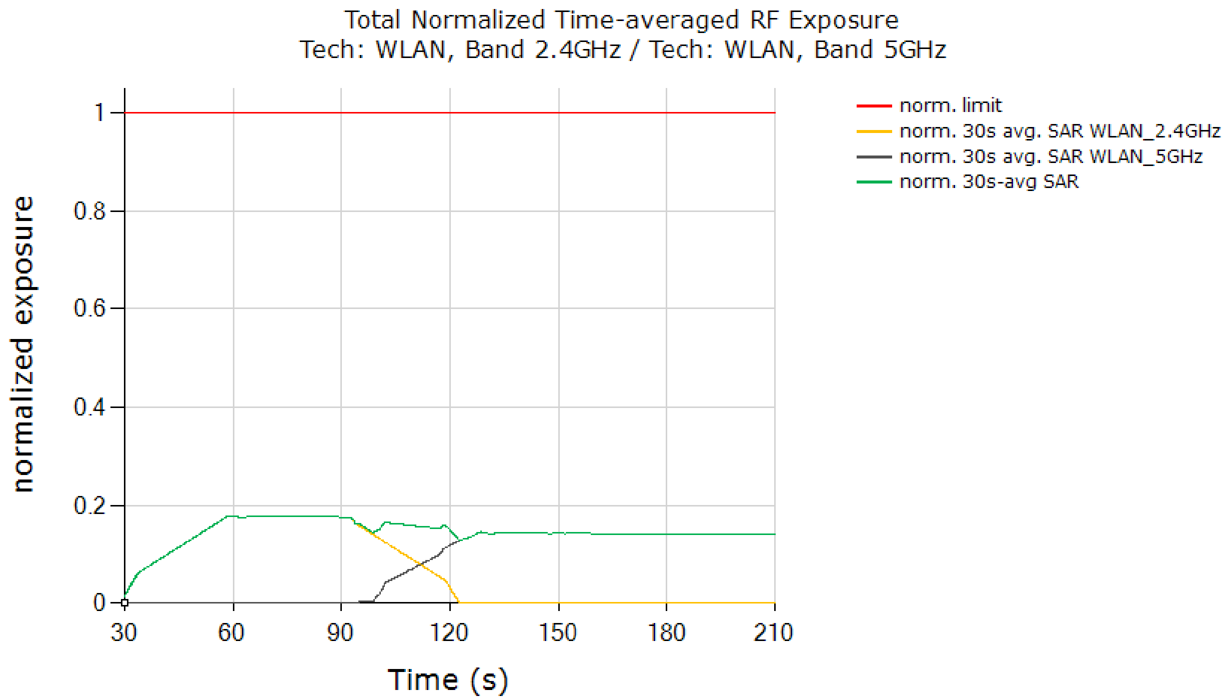
The test result validated the continuity of power limiting in Antenna/band switch scenario.

8.3 Change in Antenna/Band Test Case

This test was conducted with a callbox requesting maximum power, and with an Antenna/band switch WLAN Band 2.4 GHz, DSI = 1, antenna 5 to WLAN Band 5 GHz, DSI = 1, antenna 7. Following procedure detailed in Section 4.6 and using the measurement setup shown in Figure 5-1, the technology/band switch was performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below.

Test result for change in Antenna/band:

Time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (4a), (4b) and (4c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the normalized FCC limit of 1.0:



	(W/kg)
FCC normalized SAR limit	1.0
Max 30s-time averaged normalized SAR (green curve)	0.178
Validated	

The test result validated the continuity of power limiting in Antenna/band switch scenario.

9 SYSTEM VERIFICATION (FREQ < 6 GHZ)

9.1 Tissue Verification

Table 9-1
Measured Tissue Properties

Calibrated for Tests Performed on:	Tissue Type	Tissue Temp During Calibration (°C)	Measured Frequency (MHz)	Measured Conductivity, σ (S/m)	Measured Dielectric Constant, ε	TARGET Conductivity, σ (S/m)	TARGET Dielectric Constant, ε	% dev σ	% dev ε
2/25/2025	750 Head	22.6	680	0.88	41.76	0.89	42.31	-1.13%	-1.29%
			695	0.88	41.71	0.89	42.23	-0.67%	-1.22%
			710	0.89	41.66	0.89	42.15	-0.22%	-1.15%
			725	0.89	41.62	0.89	42.07	0.34%	-1.08%
			750	0.90	41.52	0.89	41.94	0.89%	-1.01%
			770	0.91	41.45	0.90	41.84	1.56%	-0.92%
			785	0.91	41.41	0.90	41.76	2.01%	-0.85%
			800	0.92	41.36	0.90	41.68	2.45%	-0.77%
2/25/2025	835 Head	22.6	815	0.93	41.32	0.90	41.59	3.01%	-0.67%
			820	0.93	41.30	0.90	41.58	3.11%	-0.67%
			835	0.93	41.26	0.90	41.50	3.78%	-0.58%
			850	0.94	41.22	0.92	41.50	2.62%	-0.68%
2/25/2025	1900 Head	22.6	1850	1.44	39.04	1.40	40.00	2.71%	-2.40%
			1860	1.44	39.03	1.40	40.00	3.07%	-2.43%
			1880	1.45	39.01	1.40	40.00	3.79%	-2.48%
			1900	1.46	38.99	1.40	40.00	4.50%	-2.54%
			1905	1.47	38.98	1.40	40.00	4.71%	-2.55%
			1910	1.47	38.97	1.40	40.00	4.93%	-2.57%
3/1/2025	2450 Head	22.0	2300	1.66	41.23	1.67	39.50	-0.54%	4.37%
			2310	1.67	41.22	1.68	39.48	-0.66%	4.40%
			2320	1.68	41.21	1.69	39.46	-0.65%	4.43%
			2400	1.74	41.12	1.76	39.29	-1.14%	4.67%
			2450	1.78	41.09	1.80	39.20	-1.33%	4.82%
			2480	1.80	41.04	1.83	39.16	-1.85%	4.80%
			2500	1.81	41.00	1.86	39.14	-2.21%	4.77%
3/3/2025	3600 Head	19.0	3300	2.70	38.71	2.71	38.16	-0.22%	1.45%
			3350	2.74	38.58	2.76	38.10	-0.54%	1.25%
			3450	2.85	38.35	2.86	37.99	-0.31%	0.95%
			3500	2.91	38.28	2.91	37.93	-0.03%	0.92%
			3550	2.96	38.13	2.96	37.87	-0.17%	0.69%
			3560	2.98	38.11	2.97	37.86	0.03%	0.67%
			3600	3.01	38.07	3.02	37.81	-0.13%	0.67%
			3650	3.07	37.94	3.07	37.76	0.20%	0.47%
			3690	3.12	37.88	3.11	37.71	0.35%	0.44%
			3700	3.12	37.85	3.12	37.70	0.06%	0.40%
			3750	3.17	37.72	3.17	37.64	0.16%	0.21%
			3900	3.34	37.42	3.32	37.47	0.48%	-0.13%
			3930	3.38	37.32	3.35	37.44	0.75%	-0.31%
			4100	3.56	36.97	3.53	37.24	0.99%	-0.74%
			4150	3.64	36.89	3.58	37.19	1.56%	-0.80%
2/28/2025	5250 Head	23.2	5150	4.41	37.51	4.61	36.05	-4.41%	4.05%
			5160	4.42	37.47	4.62	36.04	-4.37%	3.97%
			5170	4.43	37.45	4.63	36.03	-4.41%	3.94%
			5180	4.44	37.44	4.64	36.01	-4.29%	3.97%
			5190	4.45	37.42	4.65	36.00	-4.26%	3.95%
			5200	4.46	37.40	4.66	35.99	-4.19%	3.93%
			5210	4.47	37.39	4.67	35.98	-4.14%	3.92%
			5220	4.48	37.37	4.68	35.96	-4.13%	3.92%
			5240	4.51	37.34	4.70	35.94	-4.05%	3.91%
			5250	4.52	37.33	4.71	35.93	-4.02%	3.90%

The above measured tissue parameters were used in the DASY software. The DASY software was used to perform interpolation to determine the dielectric parameters at the SAR test device frequencies (per KDB Publication 865664 D01v01r04 and IEEE 1528-2013 6.6.1.2). The tissue parameters listed in the SAR test plots may slightly differ from the table above due to significant digit rounding in the software.

9.2 Test System Verification

Prior to SAR assessment, the system is verified to ±10% of the SAR measurement on the reference dipole at the time of calibration by the calibration facility. Full system validation status and result summary can be found in Appendix C.

Table 9-2
System Verification Results

System Verification TARGET & MEASURED													
SAR System #	Tissue Frequency (MHz)	Tissue Type	Date	Amb. Temp (°C)	Liquid Temp (°C)	Input Power (W)	Source SN	Probe SN	DAE	Measured SAR_{1g} (W/kg)	1 W Target SAR_{1g} (W/kg)	1 W Normalized SAR_{1g} (W/kg)	Deviation$_{1g}$ (%)
N	750	Head	2/25/2025	21.3	22.6	0.200	1161	7410	1213	1.730	8.360	8.650	3.47%
N	835	Head	2/25/2025	21.3	22.6	0.200	4d132	7410	1213	2.120	9.840	10.600	7.72%
N	1900	Head	2/25/2025	21.3	22.6	0.100	5d080	7410	1213	4.250	39.600	42.500	7.32%
S	2450	Head	3/1/2025	23.3	22.0	0.100	797	7803	1583	5.300	52.000	53.000	1.92%
M	3500	Head	3/3/2025	21.0	19.0	0.100	1059	7661	1558	6.900	64.900	69.000	6.32%
M	3700	Head	3/3/2025	21.0	19.0	0.100	1018	7661	1558	6.850	65.100	68.500	5.22%
S	5250	Head	2/28/2025	23.2	23.2	0.050	1057	7803	1583	3.900	79.400	78.000	-1.76%

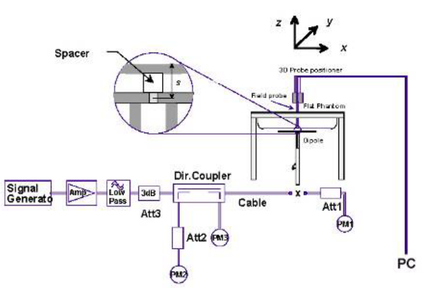


Figure 9-1
System Verification Setup Diagram

Figure 9-2
System Verification Setup Photo

10 WWAN SAR TEST RESULTS

10.1 Time-varying Tx Power Case

Following Section 4.4 procedure, time-averaged SAR measurements are conducted using a SAR probe at peak location of area scan over 500 seconds. cDASY6 system verification for SAR measurement is provided in Section 10, and the associated SPEAG certificates are attached in Appendix G.

SAR probe integration times depend on the communication signal being tested as defined in the probe calibration parameters.

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the number of points in 100s interval is determined from the scan duration setting in cDASY6 time-average pointSAR measurement by (100s cDASY6_scan_duration * total number of pointSAR values recorded). Running average is performed over these number of points in excel spreadsheet to obtain 100s averaged point SAR.

Following Section 4.4, for each of selected technology/band (listed in Table 6-2):

3. With *Reserve_power_margin* set to 0 dB, area scan is performed at P_{limit}, and time-averaged pointSAR measurements are conducted to determine the pointSAR at P_{limit} at peak location, denoted as *point*SAR$_{Plimit}$.
4. With *Reserve_power_margin* set to actual (intended) value, two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

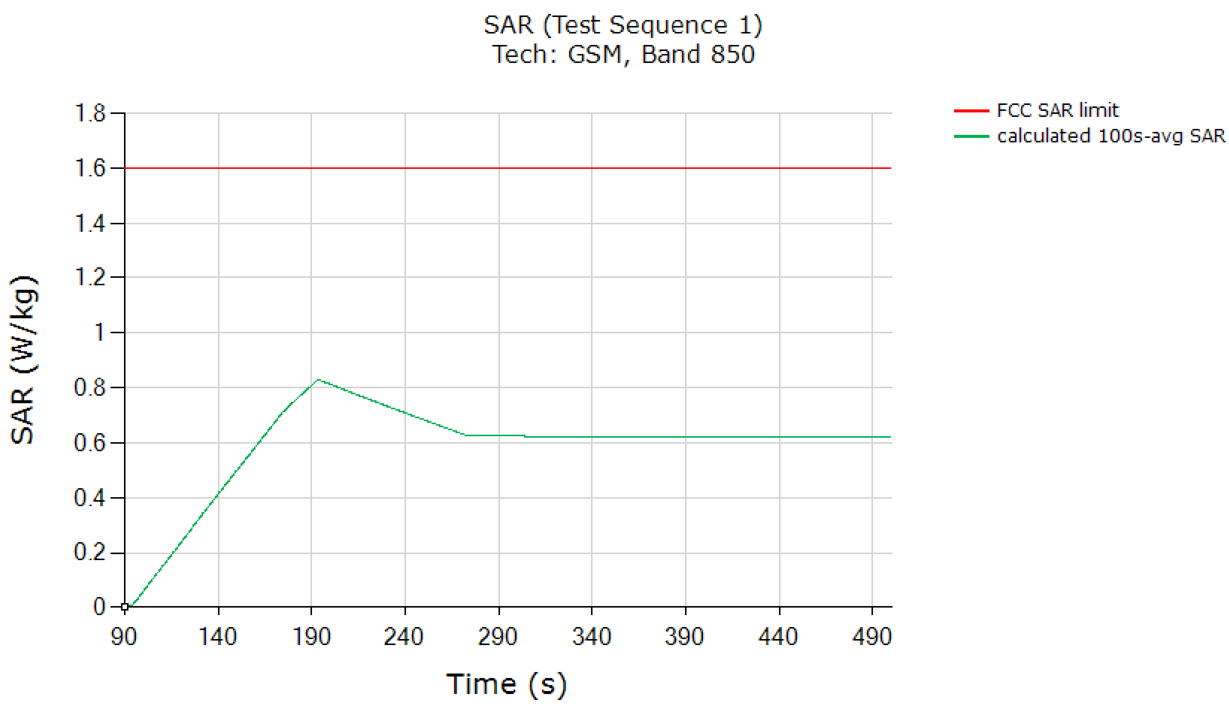
To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (3a), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (3a)$$

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} from above step 1 and 2, and measured *1gSAR* or 10gSAR values at P_{limit} obtained from Part 1 report and listed in Table 6-2 of this report.

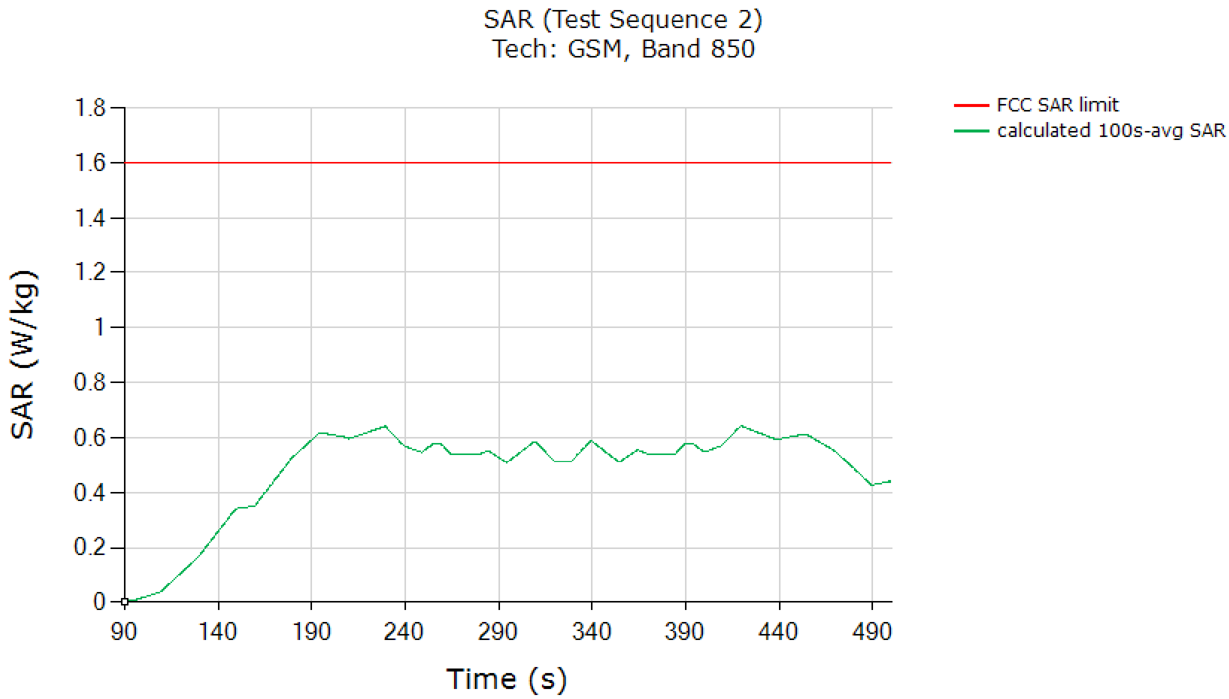
10.1.1 GSM/GPRS/EDGE 850, Antenna 1

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.829
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

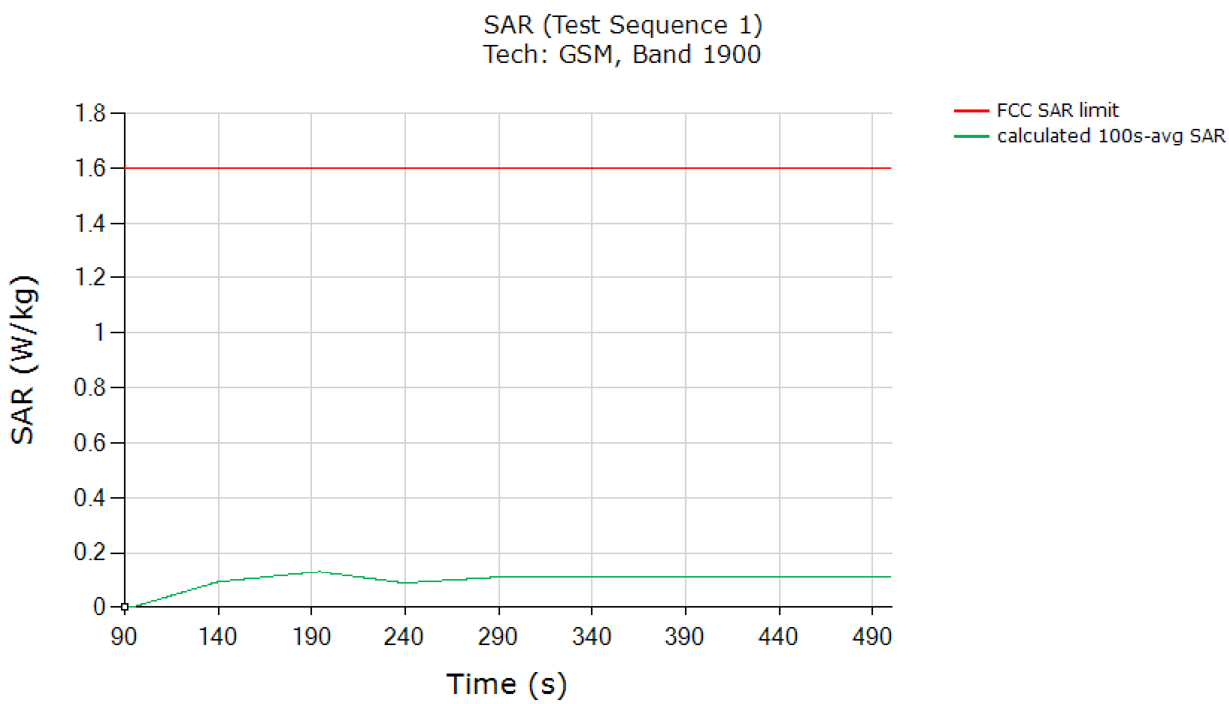
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.641
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

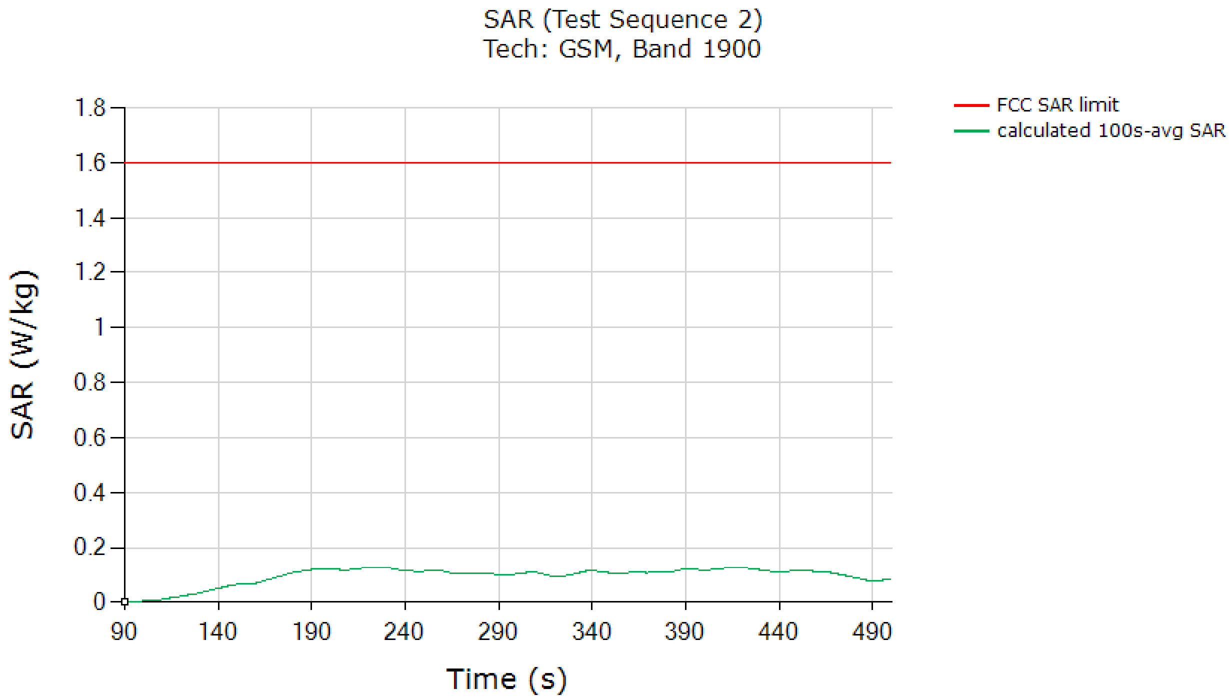
10.1.2 GSM/GPRS/EDGE 1900, Antenna 2

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.130
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

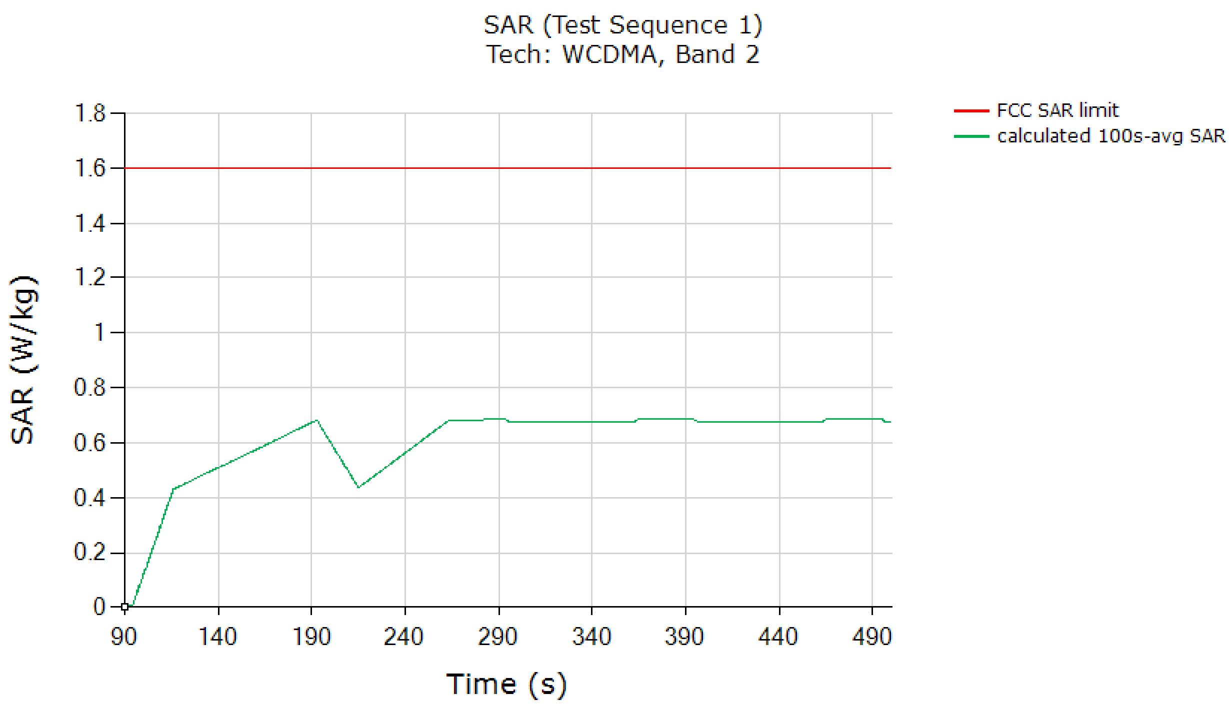
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.129
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

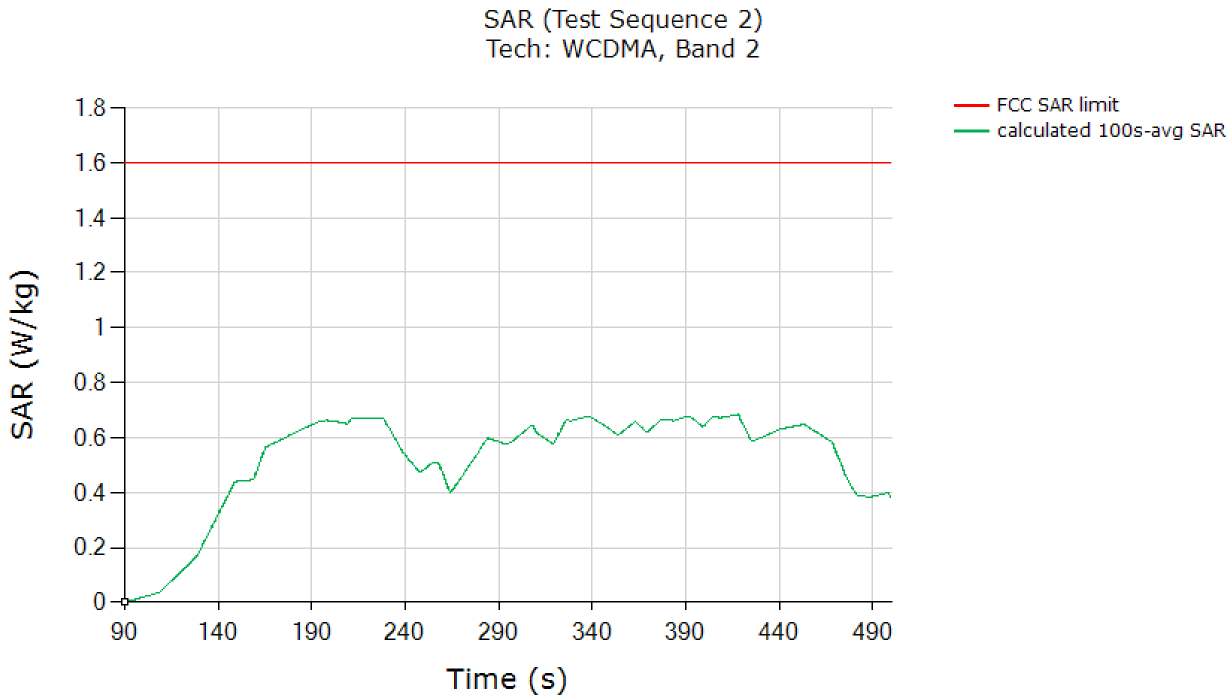
10.1.3 WCDMA Band 2, Antenna 2

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.686
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

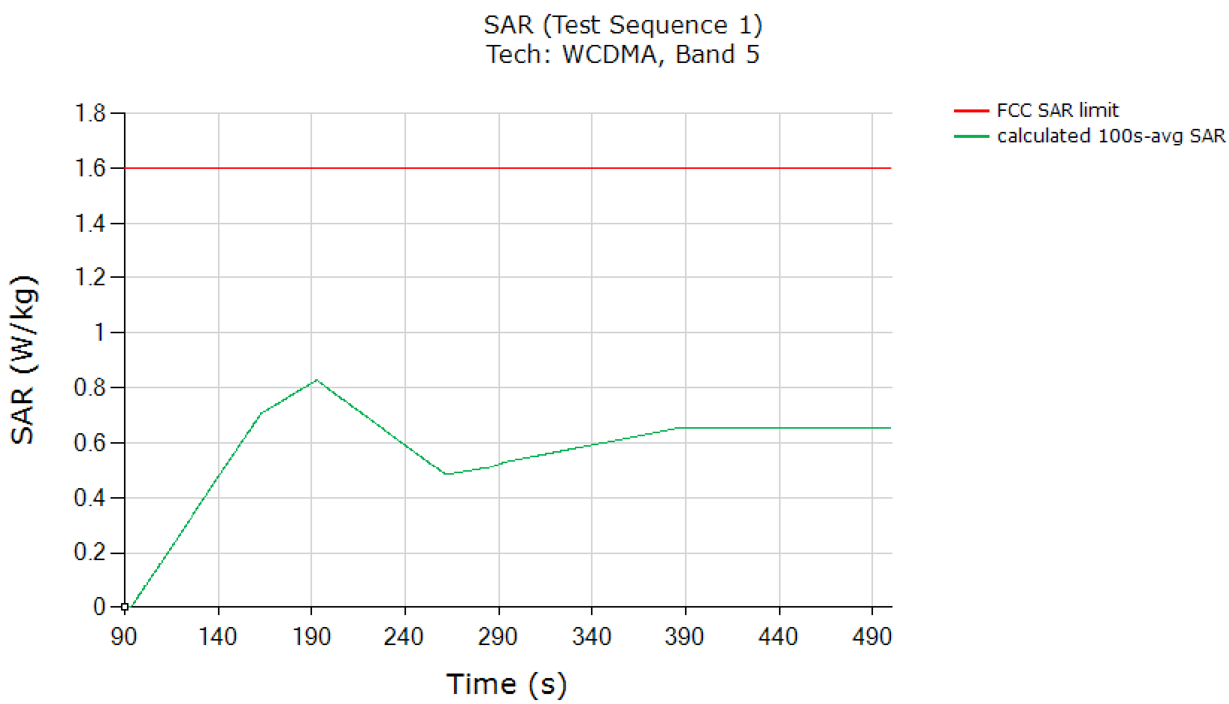
<u>SAR test results for test sequence 2:</u>



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.684
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

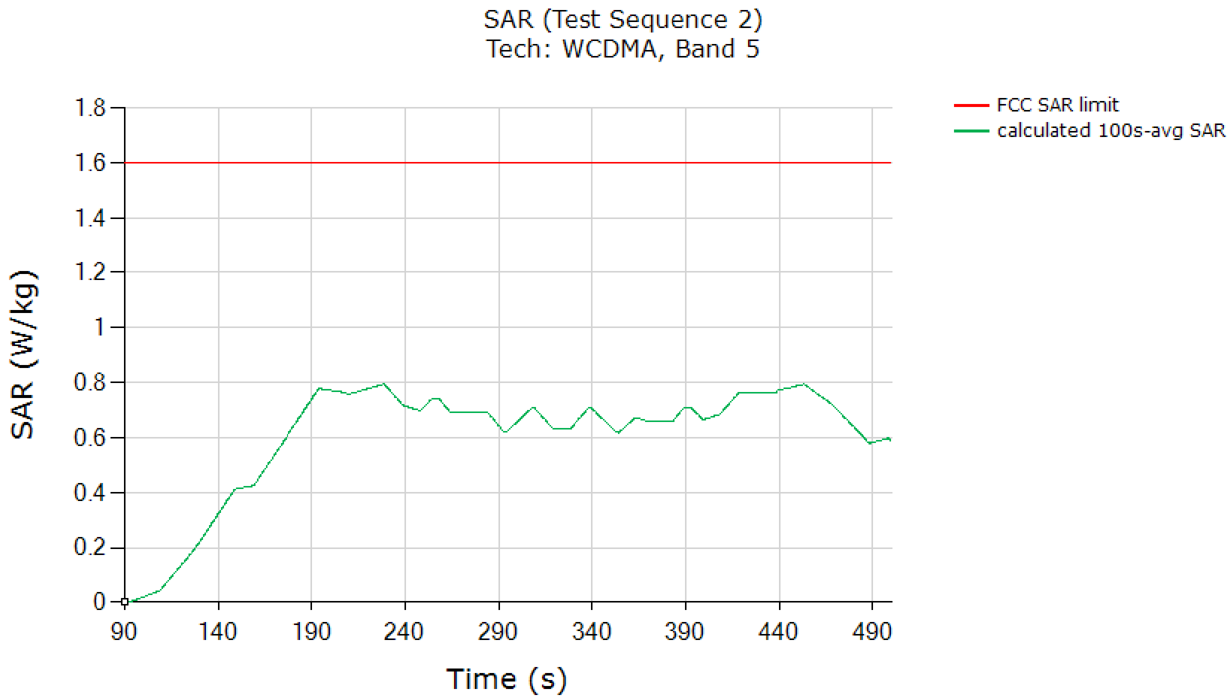
10.1.4 WCDMA Band 5, Antenna 1

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.827
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

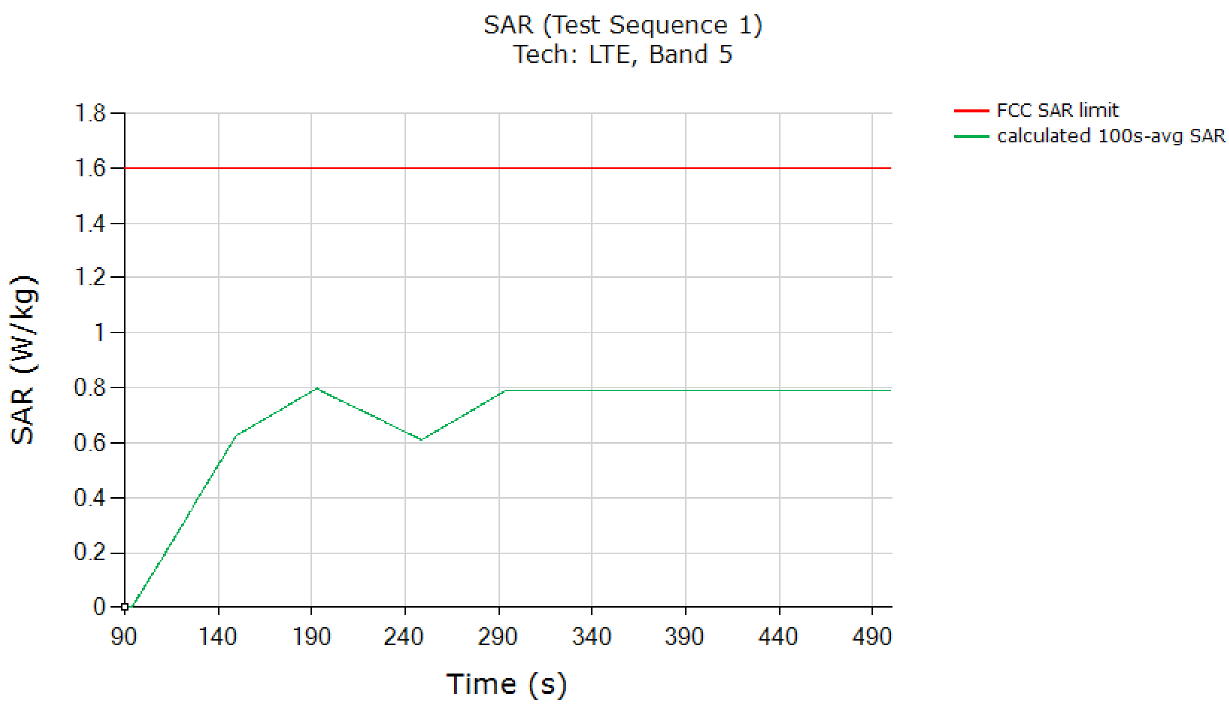
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.793
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

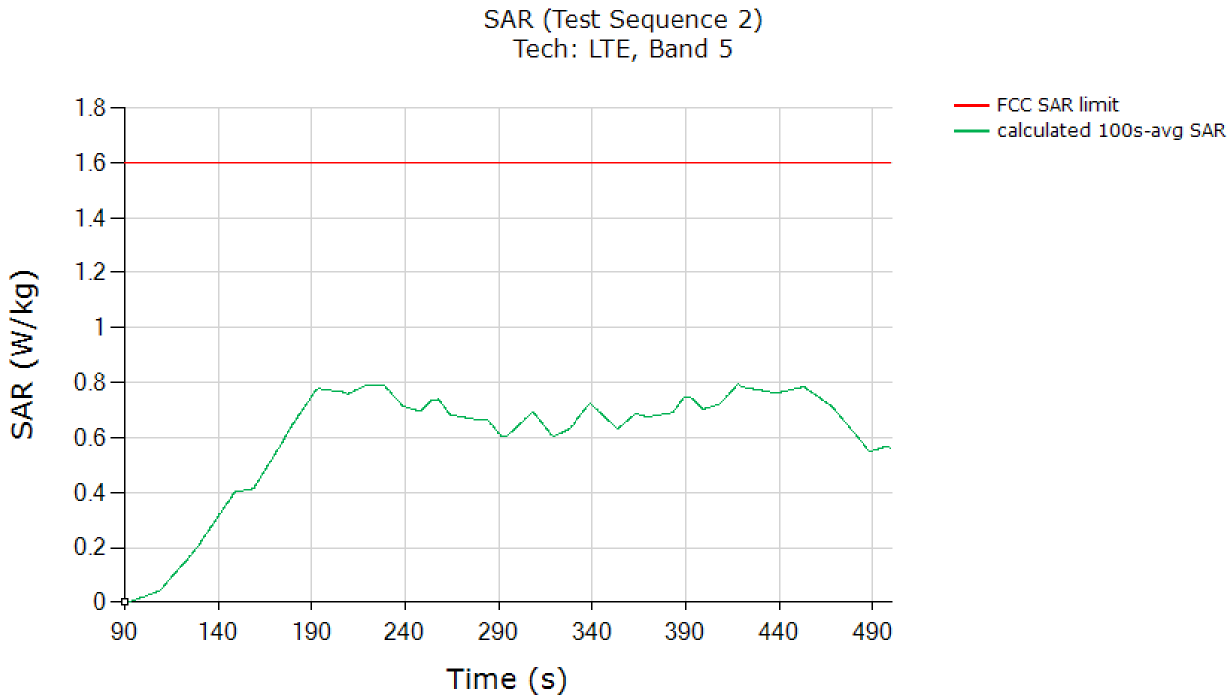
10.1.5 LTE Band 5, Antenna 1

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.798
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

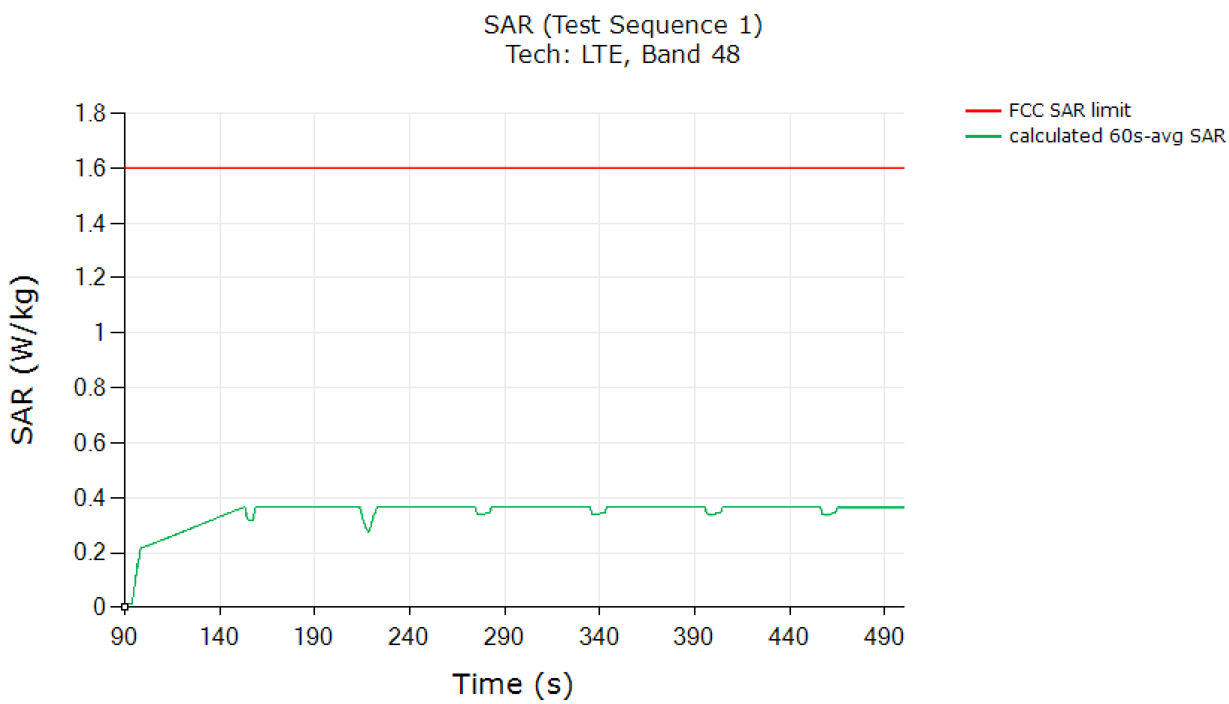
SAR test results for test sequence 2:



	(W/kg)
FCC 10gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.794
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

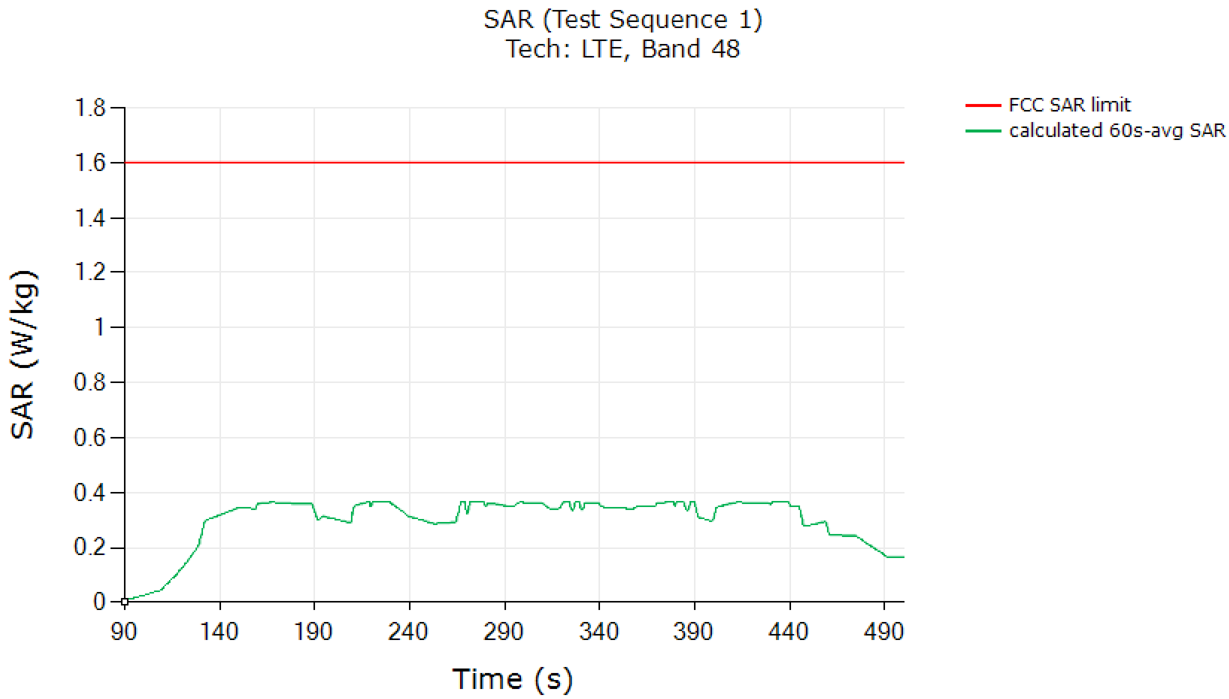
10.1.6 LTE Band 48, Antenna 6

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged point 1gSAR (green curve)	0.367
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

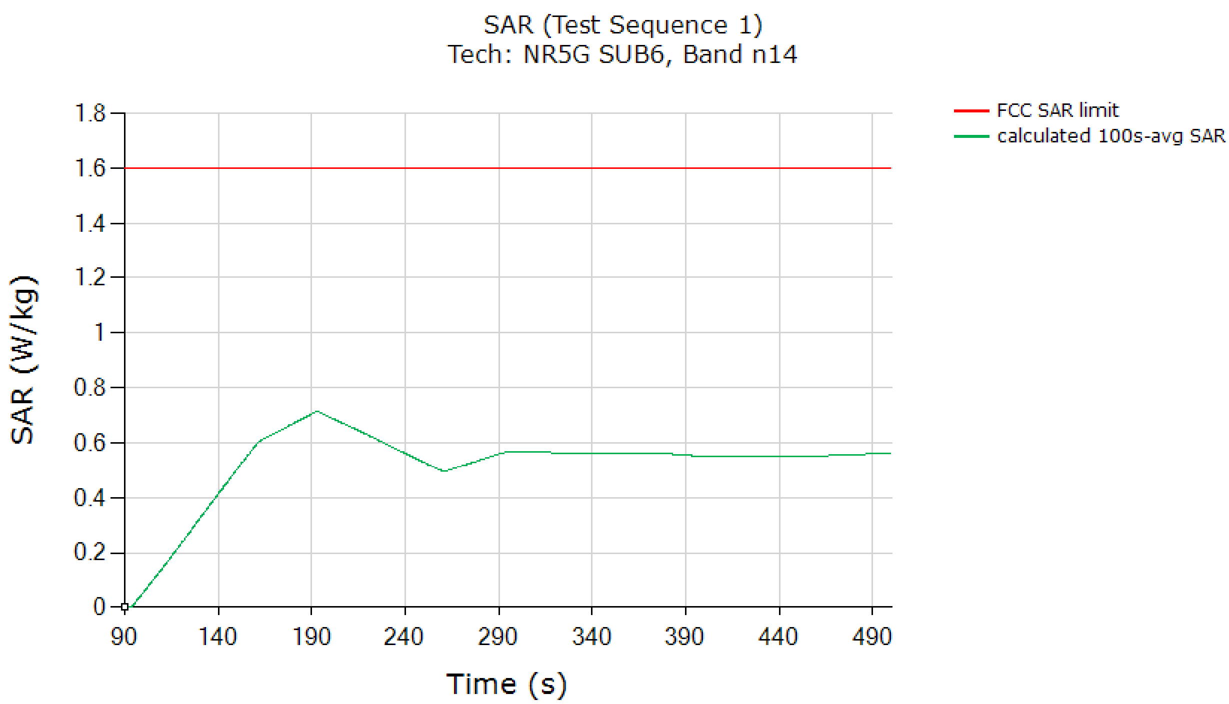
<u>SAR test results for test sequence 2:</u>



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged point 1gSAR (green curve)	0.367
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

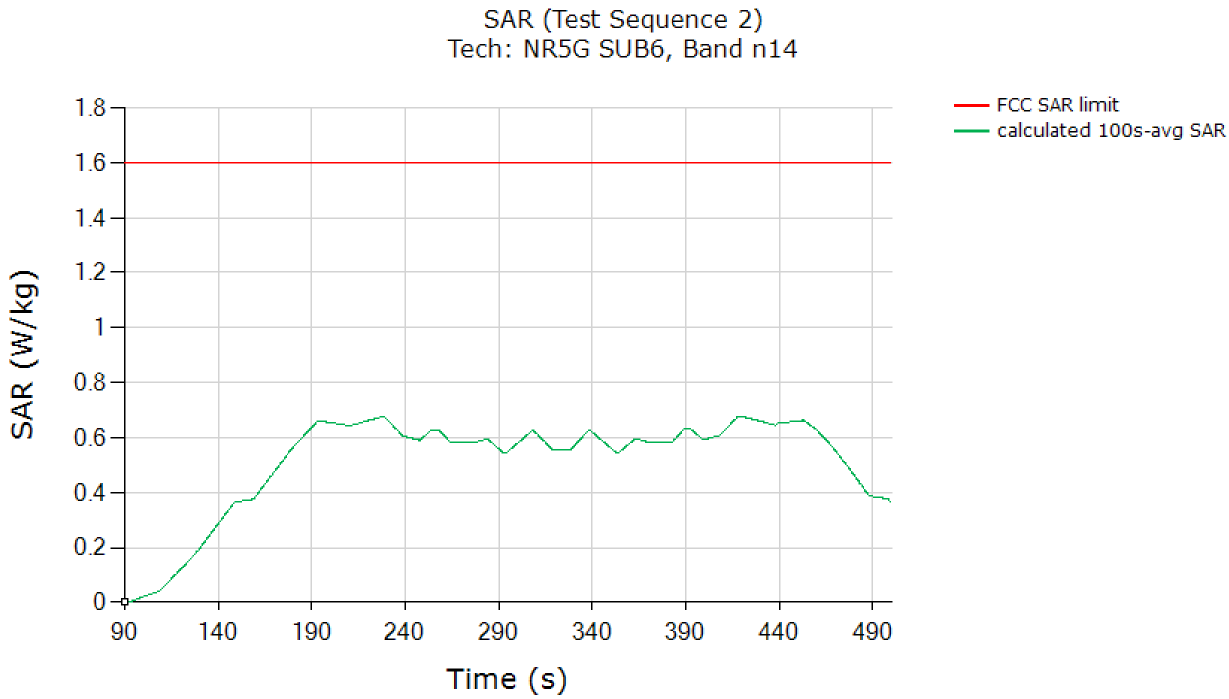
10.1.7 NR n14 SA, Antenna 1

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.714
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

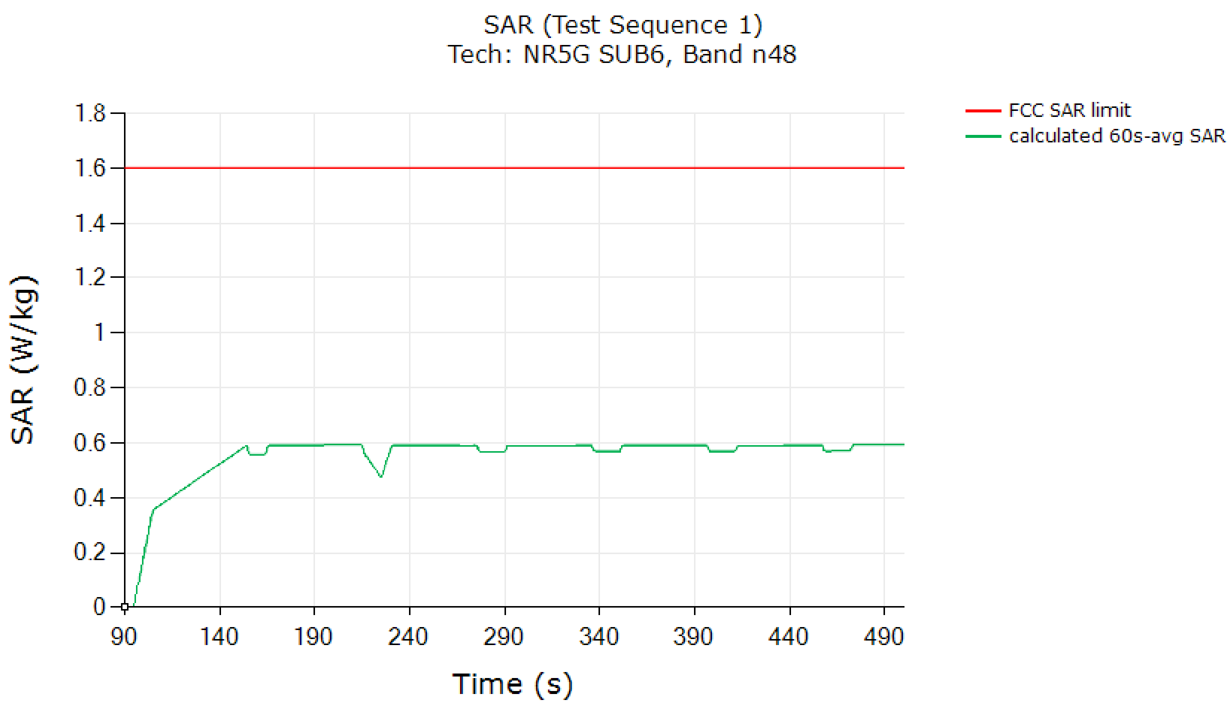
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged point 1gSAR (green curve)	0.678
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

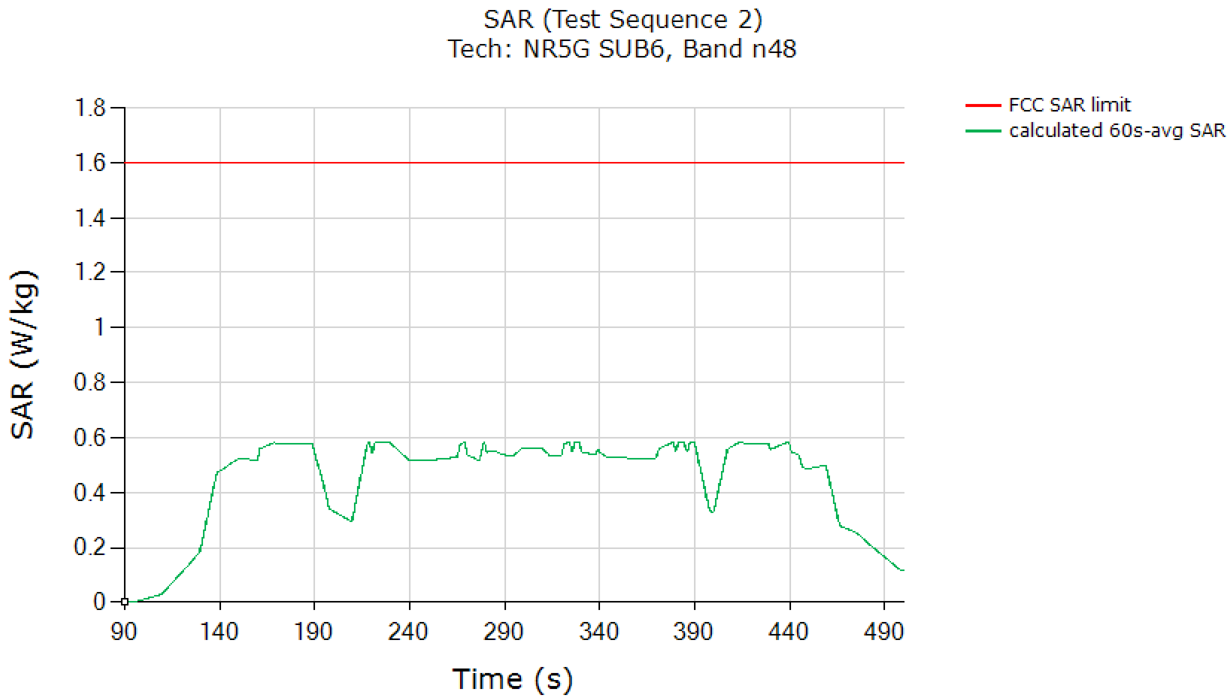
10.1.8 NR n48 SA, Antenna 6

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged point 1gSAR (green curve)	0.596
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged point 1gSAR (green curve)	0.585
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-2).	

11 WLAN SAR TEST RESULTS

11.1 Time-varying Tx Power Case

Following Section 4.7 procedure, time-averaged SAR measurements are conducted using a SAR probe at peak location of area scan over 120 seconds. cDASY6 system verification for SAR measurement is provided in Section 9, and the associated SPEAG certificates are attached in Appendix F.

SAR probe integration times depend on the communication signal being tested as defined in the probe calibration parameters.

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the number of points in 30s interval is determined from the scan duration setting in cDASY6 time-average pointSAR measurement by (30s cDASY6_scan_duration * total number of pointSAR values recorded). Running average is performed over these number of points in excel spreadsheet to obtain 30s averaged point SAR.

Following Section 4.7, for each of selected technology/band (listed in Table 6-3):

5. With *Reserve _margin* set to 0 dB, area scan is performed at P_{limit}, and time-averaged pointSAR measurements are conducted to determine the pointSAR at P_{limit} at peak location, denoted as *point*SAR$_{Plimit}$.
6. With *Reserve _margin* set to actual (intended) value, two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

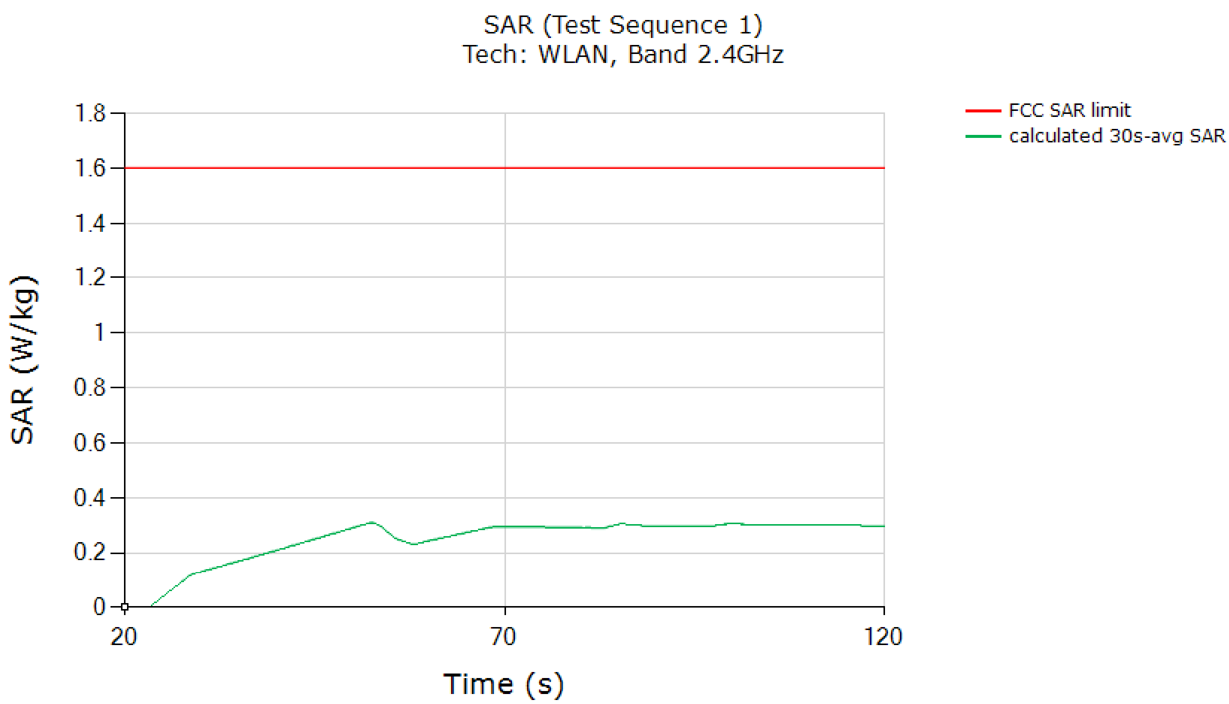
To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (3a), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (3a)$$

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} from above step 1 and 2, and measured *1gSAR* or 10gSAR values at P_{limit} obtained from Part 1 report and listed in Table 6-2 of this report.

11.1.1 WLAN Band 2.4 GHz, Antenna 5

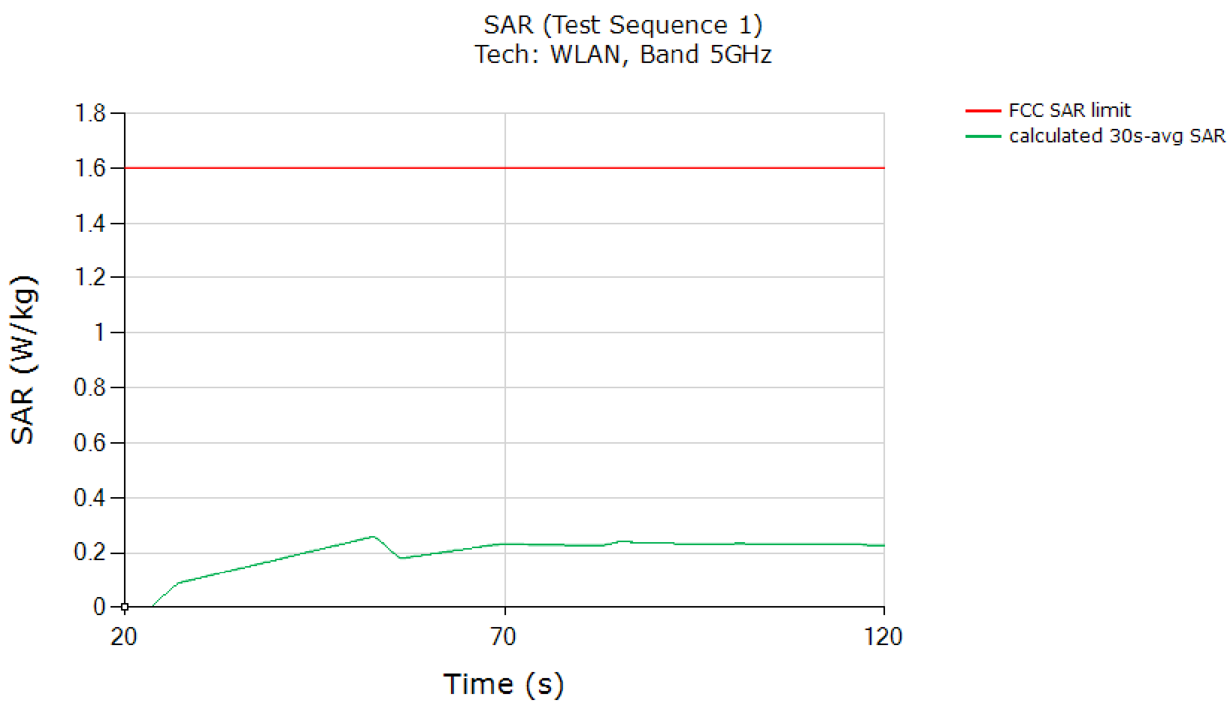
SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged point 1gSAR (green curve)	0.308
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-3).	

11.1.2 WLAN Band 5 GHz, Antenna 7

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 30s-time averaged point 1gSAR (green curve)	0.257
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (worst case SAR at Plim column in Table 6-3).	

12 EQUIPMENT LIST

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Agilent	E4404B	Spectrum Analyzer	N/A	N/A	N/A	MY45113242
Agilent	E4438C	ESG Vector Signal Generator	10/23/2024	Annual	10/23/2025	MY45093852
Agilent	E4438C	ESG Vector Signal Generator	11/15/2024	Annual	11/15/2025	MY45092078
Agilent	N5182A	MXG Vector Signal Generator	3/15/2024	Annual	3/15/2025	MY47420651
Agilent	N5182A	MXG Vector Signal Generator	3/7/2024	Annual	3/7/2025	MY47420603
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433972
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433974
Anritsu	MT8000A	Radio Communication Test Station	4/10/2024	Annual	4/10/2025	6261987983
Anritsu	MT8821C	Radio Communication Analyzer MT8821C	5/15/2024	Annual	5/15/2025	6262150047
Anritsu	MA24106A	USB Power Sensor	7/9/2024	Annual	7/9/2025	1244512
Anritsu	MA24106A	USB Power Sensor	4/15/2024	Annual	4/15/2025	1827528
Anritsu	ML2496A	Power Meter	7/15/2024	Annual	7/15/2025	1138001
Anritsu	MA2411B	Pulse Power Sensor	7/1/2024	Annual	7/1/2025	1911105
COMTECH	AR85729-5/5759B	Solid State Amplifier	CBT	N/A	CBT	M3W1A00-1002
COMTech	AR85729-5	Solid State Amplifier	CBT	N/A	CBT	M1S5A00-009
Control Company	4052	Long Stem Thermometer	2/27/2024	Biennial	2/27/2026	240174346
Control Company	4040	Therm./ Clock/ Humidity Monitor	4/15/2024	Biennial	4/15/2026	240310280
Control Company	4052	Long Stem Thermometer	2/27/2024	Biennial	2/27/2026	240171096
K & L	11SH10-1300/U4000	High Pass Filter	CBT	N/A	CBT	11SH10-1300/U4000 - 2
Keysight Technologies	772D	Dual Directional Coupler	CBT	N/A	CBT	MY52180215
Keysight Technologies	E7770A	Common Interface Unit	CBT	N/A	CBT	MY58290483
Krytar	110067006	Directional Coupler, 10 - 67 GHz	CBT	N/A	CBT	200391
MCL	BW-N6W5+	6dB Attenuator	CBT	N/A	CBT	1139
Mini Circuits	ZA2PD2-63-S+	Power Splitter	CBT	N/A	CBT	SUU64901930
Mini Circuits	ZAPD-2-272-S+	Power Splitter	CBT	N/A	CBT	SF702001405
MIniCircuits	NLP-1200+	Low Pass Filter	CBT	N/A	CBT	VUU78201318
MiniCircuits	SLP-2400+	Low Pass Filter	CBT	N/A	CBT	R8979500903
MiniCircuits	VLF-6000+	Low Pass Filter	CBT	N/A	CBT	N/A
Mini-Circuits	BW-N20W5+	DC to 18 GHz Precision Fixed 20 dB Attenuator	CBT	N/A	CBT	N/A
Mini-Circuits	NLP-2950+	Low Pass Filter DC to 2700 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	NLP-1200+	Low Pass Filter DC to 1000 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	BW-N20W5	Power Attenuator	CBT	N/A	CBT	1226
Narda	4216-10	Directional Coupler, 0.5 to 8.0 GHz, 10 dB	CBT	N/A	CBT	1492
Narda	4216-10	Directional Coupler, 0.5 to 8.0 GHz, 10 dB	CBT	N/A	CBT	1493
Narda	4772-3	Attenuator	CBT	N/A	CBT	9406
Narda	BW-S3W2	Attenuator	CBT	N/A	CBT	120
Narda	BW-S10W2+	Attenuator	CBT	N/A	CBT	831
Narda	4014C-6	4 - 8 GHz SMA 6 dB Directional Coupler	CBT	N/A	CBT	N/A
Newmark System	NSC-G2	Motion Controller	CBT	N/A	CBT	1007-D
Pasternack	PE2208-6	Bidirectional Coupler	CBT	N/A	CBT	N/A
Pasternack	PE2209-10	Bidirectional Coupler	CBT	N/A	CBT	N/A
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	1/6/2025	Annual	1/6/2026	150117
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	1/6/2025	Annual	1/6/2026	131454
Rohde & Schwarz	NRP8S	3 Path Dipole Power Sensor	10/28/2024	Annual	10/28/2025	109956
Rohde & Schwarz	NRP8S	3 Path Dipole Power Sensor	2/24/2025	Annual	2/24/2026	109961
Rohde & Schwarz	NRP8S	3-Path Dipole Power Sensor	9/24/2024	Annual	9/24/2025	109958
Rohde & Schwarz	NRP50S	3-Path Dipole Power Sensor	2/24/2025	Annual	2/24/2026	109959
SPEAG	D750V2	750 MHz SAR Dipole	10/7/2024	Triennial	10/7/2025	1161
SPEAG	D835V2	835 MHz SAR Dipole	1/18/2024	Biennial	1/18/2026	4d132
SPEAG	D1900V2	1900 MHz SAR Dipole	8/8/2022	Triennial	8/8/2025	5d080
SPEAG	D2450V2	2450 MHz SAR Dipole	11/15/2022	Triennial	11/15/2025	797
SPEAG	D3500V2	3500 MHz SAR Dipole	1/12/2024	Biennial	1/12/2026	1059
SPEAG	D3700V2	3700 MHz SAR Dipole	1/9/2024	Biennial	1/9/2026	1018
SPEAG	D5GHzV2	5 GHz SAR Dipole	2/21/2024	Biennial	2/21/2026	1057
SPEAG	DAE4	Dasy Data Acquisition Electronics	12/4/2024	Annual	12/4/2025	1213
SPEAG	DAE4	Dasy Data Acquisition Electronics	7/8/2024	Annual	7/8/2025	1583
SPEAG	DAE4	Dasy Data Acquisition Electronics	6/11/2024	Annual	6/11/2025	1558
SPEAG	EX3DV4	SAR Probe	12/5/2024	Annual	12/5/2025	7410
SPEAG	EX3DV4	SAR Probe	6/28/2024	Annual	6/28/2025	7803
SPEAG	EX3DV4	SAR Probe	6/14/2024	Annual	6/14/2025	7661

Notes:

1. CBT (Calibrated Before Testing). Prior to testing, the measurement paths containing a cable, amplifier, attenuator, coupler, or filter were connected to a calibrated source (i.e. a signal generator) to determine the losses of the measurement path The power meter offset was then adjusted to compensate for the measurement system losses. This level offset is stored within the power meter before measurements are made. This calibration verification procedure applies to the system verification and output power measurements. The calibrated reading is then taken directly from the power meter after compensation of the losses for all final power measurements.
2. Each equipment item is used solely within its respective calibration period.

13 MEASUREMENT UNCERTAINTIES

For SAR Measurements

a	c	d	e= f(d,k)	f	g	h = c x f/e	i = c x g/e	k
Uncertainty Component	Tol. (± %)	Prob. Dist.	Div.	c_i 1gm	c_i 10 gms	1gm u_i (± %)	10gms u_i (± %)	v_i
Measurement System								
Probe Calibration	6.55	N	1	1.0	1.0	6.6	6.6	∞
Axial Isotropy	0.25	N	1	0.7	0.7	0.2	0.2	∞
Hemishperical Isotropy	1.3	N	1	0.7	0.7	0.9	0.9	∞
Boundary Effect	2.0	R	1.73	1.0	1.0	1.2	1.2	∞
Linearity	0.3	N	1	1.0	1.0	0.3	0.3	∞
System Detection Limits	0.25	R	1.73	1.0	1.0	0.1	0.1	∞
Readout Electronics	0.3	N	1	1.0	1.0	0.3	0.3	∞
Response Time	0.8	R	1.73	1.0	1.0	0.5	0.5	∞
Integration Time	2.6	R	1.73	1.0	1.0	1.5	1.5	∞
RF Ambient Conditions - Noise	3.0	R	1.73	1.0	1.0	1.7	1.7	∞
RF Ambient Conditions - Reflections	3.0	R	1.73	1.0	1.0	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	0.4	R	1.73	1.0	1.0	0.2	0.2	∞
Probe Positioning w/ respect to Phantom	6.7	R	1.73	1.0	1.0	3.9	3.9	∞
Extrapolation, Interpolation & Integration algorithms for Max. SAR Evaluation	4.0	R	1.73	1.0	1.0	2.3	2.3	∞
Test Sample Related								
Test Sample Positioning	2.7	N	1	1.0	1.0	2.7	2.7	35
Device Holder Uncertainty	1.67	N	1	1.0	1.0	1.7	1.7	5
Output Power Variation - SAR drift measurement	5.0	R	1.73	1.0	1.0	2.9	2.9	∞
SAR Scaling	0.0	R	1.73	1.0	1.0	0.0	0.0	∞
Phantom & Tissue Parameters								
Phantom Uncertainty (Shape & Thickness tolerances)	7.6	R	1.73	1.0	1.0	4.4	4.4	∞
Liquid Conductivity - measurement uncertainty	4.2	N	1	0.78	0.71	3.3	3.0	10
Liquid Permittivity - measurement uncertainty	4.1	N	1	0.23	0.26	1.0	1.1	10
Liquid Conductivity - Temperature Uncertainty	3.4	R	1.73	0.78	0.71	1.5	1.4	∞
Liquid Permittivity - Temperature Unceritainty	0.6	R	1.73	0.23	0.26	0.1	0.1	∞
Liquid Conductivity - deviation from target values	5.0	R	1.73	0.64	0.43	1.8	1.2	∞
Liquid Permittivity - deviation from target values	5.0	R	1.73	0.60	0.49	1.7	1.4	∞
Combined Standard Uncertainty (k=1)		RSS				11.5	11.3	60
Expanded Uncertainty (95% CONFIDENCE LEVEL)		k=2				23.0	22.6	

14 CONCLUSION

14.1 Measurement Conclusion

The SAR evaluation indicates that the DUT complies with the RF radiation exposure limits of the FCC and Innovation, Science, and Economic Development Canada, with respect to all parameters subject to this test. These measurements were taken to simulate the RF effects of RF exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests. The results and statements relate only to the item(s) tested.

Please note that the absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape, and size of the body, the orientation of the body with respect to the field vectors, and the electrical properties of both the body and the environment. Other variables that may play a substantial role in possible biological effects are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease). Because various factors may interact with one another to vary the specific biological outcome of an exposure to electromagnetic fields, any protection guide should consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables. [3]

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