



PART 2 RF EXPOSURE EVALUATION REPORT

Applicant Name:

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Element, Morgan Hill, CA, USA

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FCC ID:**BCGA2437****APPLICANT:****APPLE INC.****DUT Type:** Tablet Device**Application Type:** Certification**FCC Rule Part(s):** CFR §2.1093**Model (s):** A2437, A2766**Reference FCC ID:** BCGA2764**Device Serial Numbers:** Pre-Production Samples [H0X9LH, 4M6NLF, Y9GGPX, R36R36QFQP, K9JY4Q, 9YMJ4Q, 7R9FDY]

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 Ortiz
Executive Vice President



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1 DEVICE UNDER TEST

1.1 Device Overview

Band & Mode	Operating Modes	Tx Frequency
UMTS 850	Data	826.40 - 846.60 MHz
UMTS 1750	Data	1712.4 - 1752.6 MHz
UMTS 1900	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 17	Voice/Data	706.5 - 713.5 MHz
LTE Band 13	Voice/Data	779.5 - 784.5 MHz
LTE Band 14	Voice/Data	790.5 - 795.5 MHz
LTE Band 26 (Cell)	Voice/Data	814.7 - 848.3 MHz
LTE Band 5 (Cell)	Voice/Data	824.7 - 848.3 MHz
LTE Band 66 (AWS)	Voice/Data	1710.7 - 1779.3 MHz
LTE Band 4 (AWS)	Voice/Data	1710.7 - 1754.3 MHz
LTE Band 25 (PCS)	Voice/Data	1850.7 - 1914.3 MHz
LTE Band 2 (PCS)	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 48	Voice/Data	3552.5 - 3697.5 MHz
NR Band n71	Data	665.5 - 695.5 MHz
NR Band n12	Data	701.5 - 713.5 MHz
NR Band n14	Data	790.5 - 795.5 MHz
NR Band n5 (Cell)	Data	826.5 - 846.5 MHz
NR Band n26 (Cell)	Data	816.5 - 846.5 MHz
NR Band n70	Data	1697.5 - 1707.5 MHz
NR Band n66 (AWS)	Data	1712.5 - 1777.5 MHz
NR Band n25 (PCS)	Data	1852.5 - 1912.5 MHz
NR Band n2 (PCS)	Data	1852.5 - 1907.5 MHz
NR Band n30	Data	2307.5 - 2312.5 MHz
NR Band n7	Data	2502.5 - 2567.5 MHz
NR Band n41	Data	2506.02 - 2679.99 MHz
NR Band n77 DoD	Data	3455.01 - 3544.98 MHz
NR Band n77 C	Data	3705.0 - 3975.0 MHz
2.4 GHz WLAN	Voice/Data	2412 - 2472 MHz
U-NII-1	Voice/Data	5180 - 5240 MHz
U-NII-2A	Voice/Data	5260 - 5320 MHz
U-NII-2C	Voice/Data	5500 - 5720 MHz
U-NII-3	Voice/Data	5745 - 5825 MHz
U-NII-5	Voice/Data	5955 - 6415 MHz
U-NII-6	Voice/Data	6435 - 6515 MHz
U-NII-7	Voice/Data	6535 - 6875 MHz
U-NII-8	Voice/Data	6895 - 7115 MHz
Bluetooth	Data	2402 - 2480 MHz
NB UNII-1	Data	5162 - 5245 MHz
NB UNII-3	Data	5733 - 5844 MHz

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1.2 Time-Averaging Algorithm for 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 18 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., P_{limit} 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 .

Note that the device uncertainty for sub-6GHz WWAN is 1.0 dB for this DUT, with the reserve power margin per technology being as follows:

For 3G technology: $Reserve_power_margin$ (dB) = $Reserve_power_margin_db_2g_3g_wwan$ for 2G and 3G WWAN technology is 3dB

For 4G and 5G technology: $total_min_exp_budget_linear_4g_5g_wwan$ is 0.5, and $Reserve_power_margin$ (dB) = $-10 * \log_{10}(total_min_exp_budget_linear_4g_5g_wwan)$ = 3 dB.

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.

1.3 Data Reuse

Per manufacturer declaration, there are two models with high degree of similarity, reference model FCC ID: BCGA2764 and variant model ID: BCGA2437. The reference model supports mmW operations, while the variant model has the mmWave components/antennas removed. Both models share the same material, form factor, circuit design, and components, including antennas and their locations. The reference and variant models use the same power tables and have the same tune-up tolerances.

Per Qualcomm 80-w2112-5, Part 2 testing was done fully on the reference model FCC ID: BCGA2764, and data reuse given the mmW depopulation is applicable for model FCC ID: BCGA2437.

1.4 Bibliography

Report Type	Report Serial Number
BCGA2764 Part 0 SAR Test Report	1C2205090028-25.BCG
BCGA2764 Part 1 SAR Test Report	1C2205090028-26.BCG
BCGA2764 RF Exposure Compliance Summary	1C2205090028-30.BCG

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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 <i>General Population</i> (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT <i>Occupational</i> (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.

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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/m² or mW/cm².

Peak Spatially Averaged Power Density was evaluated over a circular area of 4 cm² 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/cm² is 10 W/m²

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
	6 - 10	30
	10 - 16	14
	16 – 24	8
MPE	24 – 42	4
	42 – 95	2

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3 TIME VARYING TRANSMISSION TEST 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. SAR vs. PD exposure switching during sub-6+mmW transmission: To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance during transitions in SAR dominant exposure, SAR+PD exposure, and PD dominant exposure scenarios.
7. During time window switch: To prove that the Smart Transmit feature correctly handles the transition from one time window to another specified by FCC, and maintains the normalized time-averaged RF exposure to be less than normalized FCC limit of 1.0 at all times.
8. SAR exposure switching between two active radios (radio1 and radio2): To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance when exposure varies among SAR_radio1 only, SAR_radio1 + SAR_radio2, and SAR_radio2 only scenarios.
9. SAR exposure switching between sub6 radios favor modes: To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance when exposure varies among sub6 radio1 + sub6 radio2 and mmW favor mode.

As described in Part 0 report, the RF exposure is proportional to the Tx power for a SAR- and PD-characterized wireless device. Thus, feature validation in Part 2 can be effectively performed through conducted (for $f < 6\text{GHz}$) and radiated (for $f \geq 6\text{GHz}$) power measurement. Therefore, the compliance demonstration under dynamic transmission conditions and feature validation are done in conducted/radiated power measurement setup for transmission scenario 1 through 8.

To add confidence in the 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 $f < 6\text{GHz}$) versus time, and radiated Tx power (EIRP for $f > 10\text{GHz}$) versus time.
 - Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
 - Perform running time-averaging over FCC defined time windows.

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- 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:

$$1ggSAR(t) = \frac{\text{conducted_Tx_power}(t)}{\text{conducted_Tx_power_P}_{\text{limit}}} * 1gSAR_P_{\text{limit}} \quad (1a)$$

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

where, $\text{conducted_Tx_power}(t)$, $\text{conducted_Tx_power_P}_{\text{limit}}$, and $1gSAR_P_{\text{limit}}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit} , and measured $1gSAR$ at P_{limit} corresponding to sub-6 transmission. P_{limit} is a 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.

- 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.
 - 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.
 - 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:

$$1gSAR(t) = \frac{\text{pointSAR}(t)}{\text{pointSAR_P}_{\text{limit}}} * 1gSAR(t)_P_{\text{limit}} \quad (3a)$$

$$\frac{\frac{1}{T_{\text{SAR}}} \int_{t-T_{\text{SAR}}}^t 1gSAR(t) dt}{\text{FCC SAR limit}} \leq 1 \quad (3b)$$

where, $\text{pointSAR}(t)$, $\text{pointSAR_P}_{\text{limit}}$, and $1gSAR_P_{\text{limit}}$ 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.

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4 FCC MEASUREMENT PROCEDURES (FREQ < 6 GHz)

This chapter provides the test plan and test procedure for validating Qualcomm Smart Transmit feature for sub-6 transmission. The 100 seconds time window for operating $f < 3\text{GHz}$ 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 operating $f \geq 3\text{GHz}$.

4.1 Test sequence determination for validation

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

- Test sequence 1: request DUT's Tx power to be at maximum power, measured P_{max}^{\dagger} , 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 - *Reserve_power_margin* in dB) of DUT based on measured P_{limit} .

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

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} .

4.2 Test configuration selection criteria for validating Smart Transmit feature

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

4.2.1 Test configuration selection for time-varying Tx power transmission

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

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

* 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

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next highest level is checked. This process is continued within the technology until the second band for validation testing is determined.

4.2.2 Test configuration selection for change in call

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

- Select 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 Test configuration selection for 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 Test configuration selection for 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 Test configuration selection for change in DS1

The criteria to select a test configuration for DS1 change test is

- Select a technology/band having the $P_{limit} < P_{max}$ within any technology and DS1 group, and for the same technology/band having a different P_{limit} in any other DS1 group. Note that the selected DS1 transition need to be supported by the device.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and DS1 change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

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4.2.6 Test configuration selection for change in time window

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

- 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 Test configuration selection for SAR exposure switching

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

1. SAR exposure switch when two active radios are in the same time window
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. For device supporting LTE + mmW NR, this test is covered in SAR vs PD exposure switch validation.

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 can not 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.

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4.3 Test procedures for conducted power measurements

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 – *Reserve_power_margin* 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 enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value (3dB for this DUT based on Part 1 report) and reset power on DUT to enable Smart Transmit, 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.

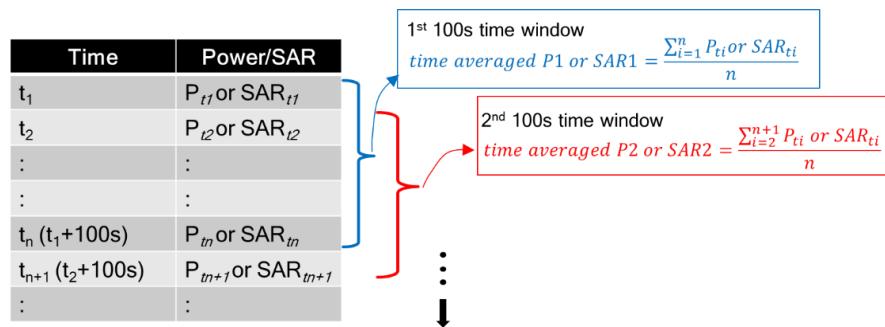


Figure 4-1

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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

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

where $\text{meas. } P_{\text{limit}}$ 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 enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power.
2. Set Reserve_power_margin to actual (intended) value and reset power on DUT to enable Smart Transmit.
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

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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 and band

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

Similar to the change in call test in Section 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:

$$1g_or_10gSAR_1(t) = \frac{\text{conducted_Tx_power_1}(t)}{\text{conducted_Tx_power_P}_{limit_1}} * 1g_or_10gSAR_P_{limit_1} \quad (6a)$$

$$1g_or_10gSAR_2(t) = \frac{\text{conducted_Tx_power_2}(t)}{\text{conducted_Tx_power_P}_{limit_2}} * 1g_or_10gSAR_P_{limit_2} \quad (6b)$$

$$\frac{1}{T_{SAR}} \left[\int_{t-T_{SAR}}^{t_1} \frac{1g_or_10gSAR_1(t)}{FCC\ SAR\ limit} dt + \int_{t-T_{SAR}}^t \frac{1g_or_10gSAR_2(t)}{FCC\ SAR\ limit} dt \right] \leq 1 \quad (6c)$$

where, $\text{conducted_Tx_power_1}(t)$, $\text{conducted_Tx_power_P}_{limit_1}$, 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; $\text{conducted_Tx_power_2}(t)$, $\text{conducted_Tx_power_P}_{limit_2}(t)$, 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 enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power.
2. Set Reserve_power_margin to actual (intended) value and reset power on DUT to enable Smart Transmit
3. Establish radio link with callbox in first technology/band selected.
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

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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.

- 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.

- 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).
- 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,

$$1gSAR_1(t) = \frac{\text{conducted_Tx_power_1}(t)}{\text{conducted_Tx_power_P}_{limit_1}} * 1g\text{ or }10g\text{ SAR }P_{limit_1} \quad (7a)$$

$$1gSAR_2(t) = \frac{\text{conducted_Tx_power_2}(t)}{\text{conducted_Tx_power_P}_{limit_2}} * 1g\text{ or }10g\text{ SAR }P_{limit_2} \quad (7b)$$

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$$\frac{1}{T_{1SAR}} \left[\int_{t-T_{1SAR}}^{t_1} \frac{1g_or\ 10g_SAR_1(t)}{FCC\ SAR\ limit} dt \right] + \frac{1}{T_{2SAR}} \left[\int_{t-T_{2SAR}}^t \frac{1g_or\ 10g_SAR_2(t)}{FCC\ SAR\ limit} dt \right] \leq 1 \quad (7c)$$

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 ' T_{1SAR} '; $conducted_Tx_power_2(t)$, $conducted_Tx_power_P_{limit_2}(t)$, 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 ' T_{2SAR} '. One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window ' T_{1SAR} ' to the second band with time-averaging window ' T_{2SAR} ' happens at time-instant ' t_1 '.

Test procedure

1. Measure P_{limit} for both the technologies and bands selected in Section 4.2.6. Measure P_{limit} with Smart Transmit enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power.
2. Set Reserve_power_margin to actual (intended) value and enable Smart Transmit

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

3. Establish radio link with callbox in the technology/band having 100s time window selected in Section 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.

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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 C.

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 enabled and Reserve_power_margin set to 0 dB, 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 Reserve_power_margin to actual (intended) value, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call, and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one time window. After one time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one time window, and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR 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.
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.

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

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5 MEASUREMENT TEST SETUP (FREQ < 6 GHZ)

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 A – Test Setup Photo 1) for measurements with a single antenna of DUT, and in Figure 5-1b (Appendix A – Test Setup Photo 4) for measurements involving switching between different antennas/technologies/time-windows. 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. For Inter-band ULCA measurements, two ports, (RF1 COM & RF3 COM) of the callbox used for signaling the PCC band and SCC band respectively are each connected to the PCC and SCC RF ports of the DUT using two directional couplers, shown in figure 5-1c (Appendix A – Test Setup Photo 5). In the setups, power meters are used to tap the directional couplers for measuring the conducted output power of the DUT. In the setups, a 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.

Sub6 NR test setup:

The Anritsu MT8000A and the Keysight UXM callboxes were used in these tests. The test setup schematic is the same as the Legacy Test Setup shown in Figure 5-1a (Appendix A – Test Setup Photos 2 and 3). 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.

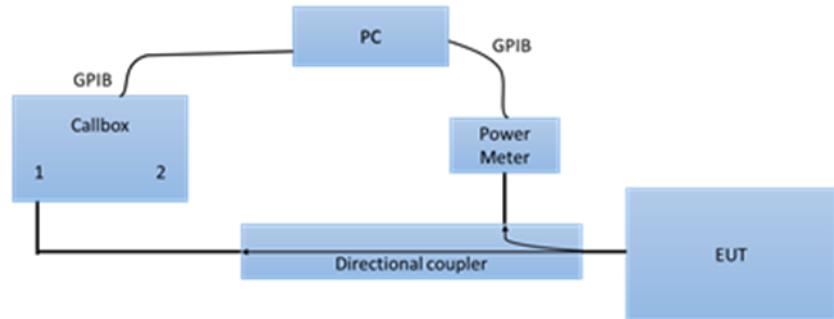
All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

LTE+Sub6 NR test setup:

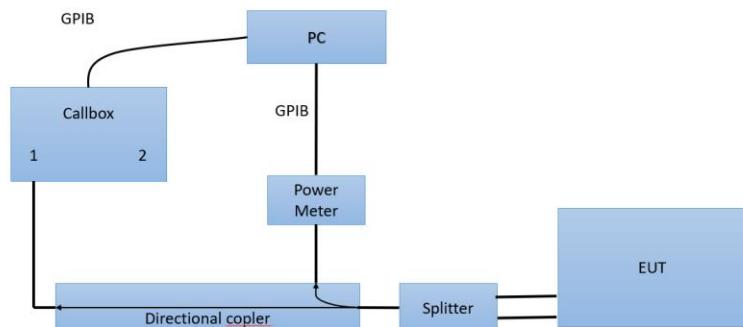
LTE conducted port and Sub6 NR conducted port are the same on this EUT, therefore, the LTE and Sub6 NR signals for power meter measurement are performed on separate paths as shown below in Figure 5-1c (Appendix A – Test Setup Photo 6).

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.

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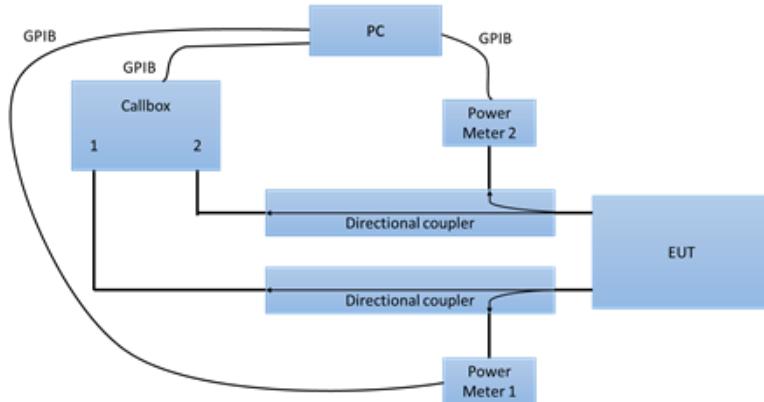


(a) Appendix A – Test Setup Photo 1, 2 and 3



(b) Appendix A – Test Setup Photo 4

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(c) Appendix A – Test Setup Photo 5, and 6

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
- test sequence 1 or test sequence 2 (defined in Section 4.1 and generated in Section 4.2.1), for 360 seconds.
- stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

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

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

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6 TEST CONFIGURATIONS (FREQ < 6 GHZ)

6.1 WWAN (sub-6) transmission

The P_{limit} values, corresponding to 0.8 W/kg (1gSAR) of *SAR_design_target*, for technologies and bands supported by DUT are derived in Part 0 report and summarized in Table 6-1. Note all P_{limit} power levels entered in Table 6-1 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 file)

Exposure Scenario:	Ant 1 Body	Ant 1 Maximum Tune-up	Ant 2a/2b Body	Ant 2a/2b Maximum Tune-up	Ant 3 Body	Ant 3 Maximum Tune- up	Ant 4b Body	Ant 4 Maximum Tune-up
Averaging Volume:	1g		1g		1g		1g	
Spacing:	0 mm		0 mm		0 mm		0 mm	
DSI:	1		1		1		1	
Technology/Band	P_{limit} corresponding to 0.8 W/kg	Pmax	P_{limit} corresponding to 0.8 W/kg	Pmax	P_{limit} corresponding to 0.8 W/kg	Pmax	P_{limit} corresponding to 0.8 W/kg	Pmax
UMTS 850	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
UMTS 1750	16.10	22.00	14.30	22.00	16.00	24.50	13.30	25.00
UMTS 1900	16.40	22.00	13.70	22.00	15.90	24.50	12.20	25.00
LTE Band 71	20.30	23.20	N/A	N/A	20.50	25.00	N/A	N/A
LTE Band 12	20.10	23.20	N/A	N/A	19.50	25.00	N/A	N/A
LTE Band 17	20.10	23.20	N/A	N/A	19.50	25.00	N/A	N/A
LTE Band 13	19.60	23.20	N/A	N/A	19.90	25.00	N/A	N/A
LTE Band 14	19.60	23.20	N/A	N/A	19.90	25.00	N/A	N/A
LTE Band 26 (Cell)	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
LTE Band 5 (Cell)	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
LTE Band 5 ULCA (Cell)	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
LTE Band 66 (AWS)	16.10	25.00	14.30	24.50	16.00	23.50	13.30	24.00
LTE Band 4 (AWS)	16.10	25.00	14.30	24.50	16.00	24.50	13.30	25.00
LTE Band 25 (PCS)	16.40	22.00	13.70	22.00	15.90	24.50	12.20	25.00
LTE Band 2 (PCS)	16.40	22.00	13.70	22.00	15.90	24.50	12.20	25.00
LTE Band 30	13.60	21.50	13.60	21.50	14.90	24.50	12.10	21.80
LTE Band 7	13.50	21.50	13.90	21.50	15.50	24.50	12.20	25.00
LTE Band 7 ULCA	13.50	21.50	13.90	21.50	15.50	24.50	12.20	25.00
LTE Band 41 PC3	12.7	23.0	14.0	23.0	13.1	23.0	11.8	23.0
LTE Band 41 ULCA PC3	12.7	23.0	14.0	23.0	13.1	23.0	11.8	23.0
LTE Band 41 PC2	12.7	24.4	14.0	23.9	13.1	22.9	11.8	23.4
LTE Band 41 ULCA PC2	12.7	24.4	14.0	23.9	13.1	22.9	11.8	23.4
LTE Band 48	11.2	17.6	11.4	18.0	11.8	16.7	10.9	19.0
LTE Band 48 ULCA	11.2	17.6	11.4	18.0	11.8	16.7	10.9	19.0
NR Band n71	20.30	23.20	N/A	N/A	20.50	25.00	N/A	N/A
NR Band n12	20.10	23.20	N/A	N/A	19.50	25.00	N/A	N/A
NR Band n14	19.60	23.20	N/A	N/A	19.90	25.00	N/A	N/A
NR Band n5 (Cell)	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
NR Band n26 (Cell)	17.70	23.20	N/A	N/A	18.40	25.00	N/A	N/A
NR Band n66 (AWS)	16.10	25.00	14.30	24.50	16.00	24.50	13.30	25.00
NR Band n70	16.10	25.00	14.30	24.50	16.00	23.50	13.30	24.00
NR Band n25 (PCS)	16.40	22.00	13.70	22.00	15.90	24.50	12.20	25.00
NR Band n2 (PCS)	16.40	22.00	13.70	22.00	15.90	24.50	12.20	25.00
NR Band n30	13.60	21.50	13.60	21.50	14.90	24.50	12.10	21.80
NR Band n7	13.50	21.50	13.90	21.50	15.50	24.50	12.20	25.00
NR Band n41 PC3	12.70	25.00	14.00	25.00	13.10	25.00	11.80	25.00
NR Band n41 PC2	12.70	28.00	14.00	27.50	13.10	26.50	11.80	27.00
NR Band n77 PC3	11.20	22.50	11.00	22.50	11.20	24.70	10.80	24.70
NR Band n77 PC2	11.20	22.50	11.00	22.50	11.20	26.50	10.80	26.50

* 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 $P_{max} + 0.7$ dB upper tolerance for frequencies below 3GHz, and +1 dB for frequencies above 3GHz.

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Based on selection criteria described in Section 4.2.1, 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 in EFS and is used in Part 2 test.

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

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.

Table 6-2
Radio configurations selected for Part 2 test

Test Case #	Test Scenario	Tech	Band	Antenna	DSI	Channel	Frequency [MHz]	RB/RB Offset/Bandwidth (MHz)	Mode	SAR Exposure Scenario	Part 1 Worst Case Measured SAR at Plimit (W/kg)
1	Test Sequence 1	WCDMA	2	4B	1	9400	1880	-	RMC	Backside, 0mm	0.801
	Test Sequence 2					9400	1880	-	RMC		
2	Test Sequence 1	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Top Edge, 0mm	0.722
	Test Sequence 2					133297	680.5	1/50/20 MHz	QPSK		
3	Test Sequence 1	NR	n71	3	1	136100	680.5	1/1/20 MHz BW	DFT-S-OFDM, QPSK	Backside, 0mm	0.577
	Test Sequence 2					136100	680.5	1/1/20 MHz BW	DFT-S-OFDM, QPSK		
4	Call Drop	LTE	48	4B	1	56207	3646.7	1/50/20 MHz	QPSK	Top Edge, 0mm	0.650
5	Tech/Band Switch	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Top Edge, 0mm	0.722
						9400	1880	-	RMC		
6	Antenna Switch	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Top Edge, 0mm	0.722
						1	1	133297	680.5		
7	Time Window Switch	LTE	71	1	1	133297	680.5	1/50/20 MHz	QPSK	Backside, 0mm	0.673
						48	1	56207	3646.7		
8	SAR1 vs SAR2 SSR 0.2 Same Time Window	LTE	2	1	1	18900	1880	1/50/20 MHz BW	QPSK	Backside, 0mm	0.736
						Sub6 NR	n5	3	167300		
9	SAR1 vs SAR2 SSR 0.8 Same Time Window	LTE	2	1	1	18900	1880	1/50/20 MHz BW	QPSK	Backside, 0mm	0.736
						Sub6 NR	n5	3	167300		
10	SAR1 vs SAR2 SSR 0.2 Different Time Window	LTE	48	1	1	56207	3646.7	1/50/20 MHz BW	QPSK	Backside, 0mm	0.767
						Sub6 NR	n5	3	167300		
11	SAR1 vs SAR2 SSR 0.8 Different Time Window	LTE	48	1	1	56207	3646.7	1/50/20 MHz BW	QPSK	Backside, 0mm	0.767
						Sub6 NR	n5	3	167300		
12	Interband ULCA SSR 0.2	PCC LTE	2	4B	1	18900	1880	1/50/20 MHz BW	QPSK	Backside, 0mm	0.757
						SCC LTE	5	3	20525		
13	Interband ULCA SSR 0.8	PCC LTE	2	4B	1	18900	1880	1/50/20 MHz BW	QPSK	Backside, 0mm	0.704
						SCC LTE	5	3	20525		

Note: This device does not support multiple DSI states corresponding to portable use conditions, therefore, no change in DSI testing was performed.

- Technologies and bands for time-varying Tx power transmission:** The test case 1~3 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.
- Technology and band for change in call test:** LTE Band 48, having the lowest P_{limit} among all technologies and bands (test case 4 in Table 6-2), is selected for performing the call drop test in conducted power setup.
- Technologies and bands for change in technology/band test:** Following the guidelines in Section 4.2.3, test case 5 in Table 6-2 is selected for handover test from a technology/band (LTE Band 71,

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DSI=1, antenna 3), to a technology/band in the same DSI (WCDMA Band 2, DSI=1, antenna 4B) in conducted power setup.

4. **Technologies and bands for change in antenna:** Based on selection criteria in Section 4.2.4, for a given DSI=1, test case 6 in Table 6-2 is selected for antenna switch between one antenna (LTE B71, DSI=1, antenna 3) and another antenna (LTE B71, DSI=1, antenna 1) in conducted power setup.
5. **Technologies and bands for change in time-window:** Based on selection criteria in Section 4.2.6, for a given DSI=1, test case 7 in Table 6-2 is selected for time window switch between 60s window (LTE B48, Antenna 1) and 100s window (LTE B71, Antenna 1) in conducted power setup.
6. **Technologies and bands for switch in SAR exposure (ENDC):** Based on selection criteria in Section 4.2.7 Scenario 1, test case 8, 9, 10, and 11 in Table 6-2 are selected for SAR exposure switching test in the supported simultaneous WWAN transmission scenarios, i.e., LTE + Sub6 NR active in the same 100s time window, and LTE + Sub6 NR in different time windows, in conducted power setup.
7. **Technologies and bands for switch in SAR exposure (ULCA):** Based on selection criteria in Section 4.2.7 Scenario 1, test case 12 & 13 in Table 6-2 are selected for SAR exposure switching test in one of the supported simultaneous WWAN transmission scenarios, i.e., Two non-contiguous LTE component carriers active in the same 100s time window, in conducted power setup.

Note: This device does not support antenna grouping, thus Favor Mode Switch is not required.

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

The measured P_{limit} for all the selected radio configurations given in Table 6-2 are listed in below Table 6-4. 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 6-3
Measured P_{limit} and P_{max} of selected radio configurations

Test Case #	Test Scenario	Tech	Band	Antenna	DSI	Channel	Frequency [MHz]	RB/RB Offset/Bandwidth (MHz)	Mode	SAR Exposure Scenario	EFS Plimit [dBm]	Tune-up Pmax [dBm]	Measured Plimit [dBm]	Measured Pmax [dBm]
1	Test Sequence 1	WCDMA	2	4B	1	9400	1880	-	RMC	Body	12.2	25.0	12.68	25.57
	Test Sequence 2					9400	1880	-	RMC		12.2	25.0	12.68	25.57
2	Test Sequence 1	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Body	20.5	25.0	20.82	25.33
	Test Sequence 2					133297	680.5	1/50/20 MHz	QPSK		20.5	25.0	20.82	25.33
3	Test Sequence 1	NR	n71	3	1	136100	680.5	1/1/20 MHz BW	DFT-S-OFDM, QPSK	Body	20.5	25.0	20.91	24.48
	Test Sequence 2					136100	680.5	1/1/20 MHz BW	DFT-S-OFDM, QPSK		20.5	25.0	20.91	24.48
4	Call Drop	LTE	48	4B	1	56207	3646.7	1/50/20 MHz	QPSK	Body	10.9	19.0	11.09	18.91
5	Tech/Band Switch	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Body	20.5	25.0	20.82	25.33
						9400	1880	-	RMC		12.2	25.0	12.68	25.57
6	Antenna Switch	LTE	71	3	1	133297	680.5	1/50/20 MHz	QPSK	Body	20.5	25.0	20.82	25.33
7	Time Window Switch	LTE	71	1	1	133297	680.5	1/50/20 MHz	QPSK	Body	20.3	23.2	20.65	23.56
						56207	3646.7	1/50/20 MHz	QPSK		20.3	23.2	20.69	23.56
8	SAR1 vs SAR2 SSR 0.2	LTE	2	1	1	18900	1880	1/50/20 MHz BW	QPSK	Body	11.2	17.6	12.01	18.06
	Same Time Window					Sub6 NR n5	3	1	167300		16.4	22.0	16.57	22.10
9	SAR1 vs SAR2 SSR 0.8	LTE	2	1	1	18900	1880	1/50/20 MHz BW	QPSK	Body	18.4	25.0	18.70	25.20
	Same Time Window					Sub6 NR n5	3	1	167300		16.4	22.0	16.14	21.77
10	SAR1 vs SAR2 SSR 0.2	LTE	48	1	1	56207	3646.7	1/50/20 MHz BW	QPSK	Body	18.4	25.0	18.85	24.48
	Different Time Window					Sub6 NR n5	3	1	167300		11.2	17.6	11.75	17.58
11	SAR1 vs SAR2 SSR 0.8	LTE	48	1	1	56207	3646.7	1/50/20 MHz BW	QPSK	Body	18.4	25.0	18.70	25.20
	Different Time Window					Sub6 NR n5	3	1	167300		11.2	17.6	11.75	17.58
12	Interband ULCA SSR 0.2	PCC LTE	2	4B	1	18900	1880	1/50/20 MHz BW	DFT-S-OFDM, QPSK	Body	18.4	25.0	18.70	25.20
	SCC LTE					20525	836.5	1/25/10 MHz BW	QPSK		12.2	25.0	12.74	25.27
13	Interband ULCA SSR 0.8	PCC LTE	2	4B	1	18900	1880	1/50/20 MHz BW	QPSK	Body	18.4	25.0	18.69	25.27
	SCC LTE					20525	836.5	1/25/10 MHz BW	QPSK		18.4	25.0	18.69	25.27

Note: The Tolerance of P_{max} is $+0.7$ dB/ -1.0 dB for frequencies below 3GHz, and ± 1 dB for frequencies greater than 3GHz as provided by manufacturer.

Note: NR TDD P_{max} and P_{lim} are measured at 95% duty cycle.

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6.3 EFS v18 Verification

Per Qualcomm's 80-w2112-5 document, embedded file system (EFS) version 18 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 18 configured for Smart Tx second generation (GEN2) for Sub6 and mmWave with MCC settings for the US market.

EFS v18 Generation	MCC
GEN2_Sub6	310

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7 CONDUCTED TX CASES (FREQ < 6 GHZ)

7.1 Time-varying Tx Power Case

The measurement setup is shown in Figure 5-1. 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:

$$1gSAR(t) = \frac{\text{conducted_Tx_power}(t)}{\text{conducted_Tx_power_P}_{\text{limit}}} * 1gSAR_P_{\text{limit}} \quad (1a)$$

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

where, *conducted_Tx_power(t)*, *conducted_Tx_power_P_{limit}*, and *1gSAR_P_{limit}* correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at *P_{limit}*, and measured 1gSAR 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.

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.

Time-varying Tx power measurements were conducted on test cases #1 ~ #3 in Table 6-2, by generating test sequence 1 and test sequence 2 given in APPENDIX D: using measured *P_{limit}* and measured *P_{max}* (last two columns of Table 6-4) for each of these test cases. Measurement results for test cases #1 ~ #3 are given in Sections 7.1.1-7.1.3.

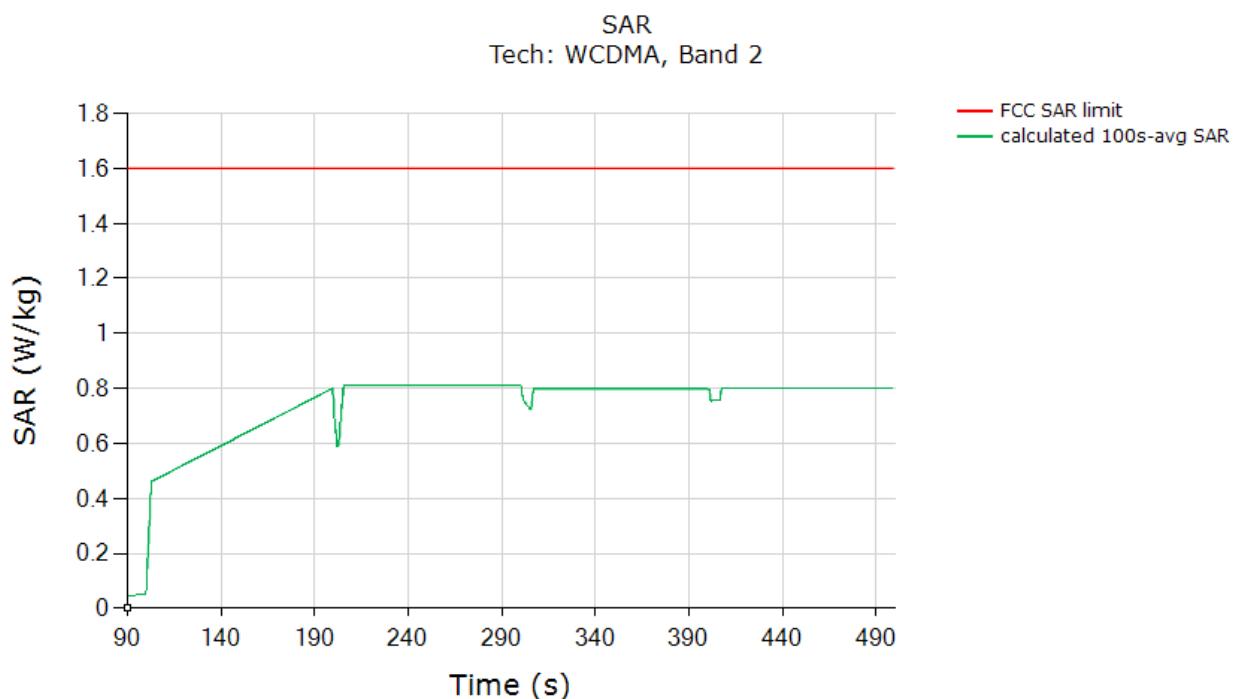
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7.1.1

WCDMA Band 2 Antenna 4B

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:

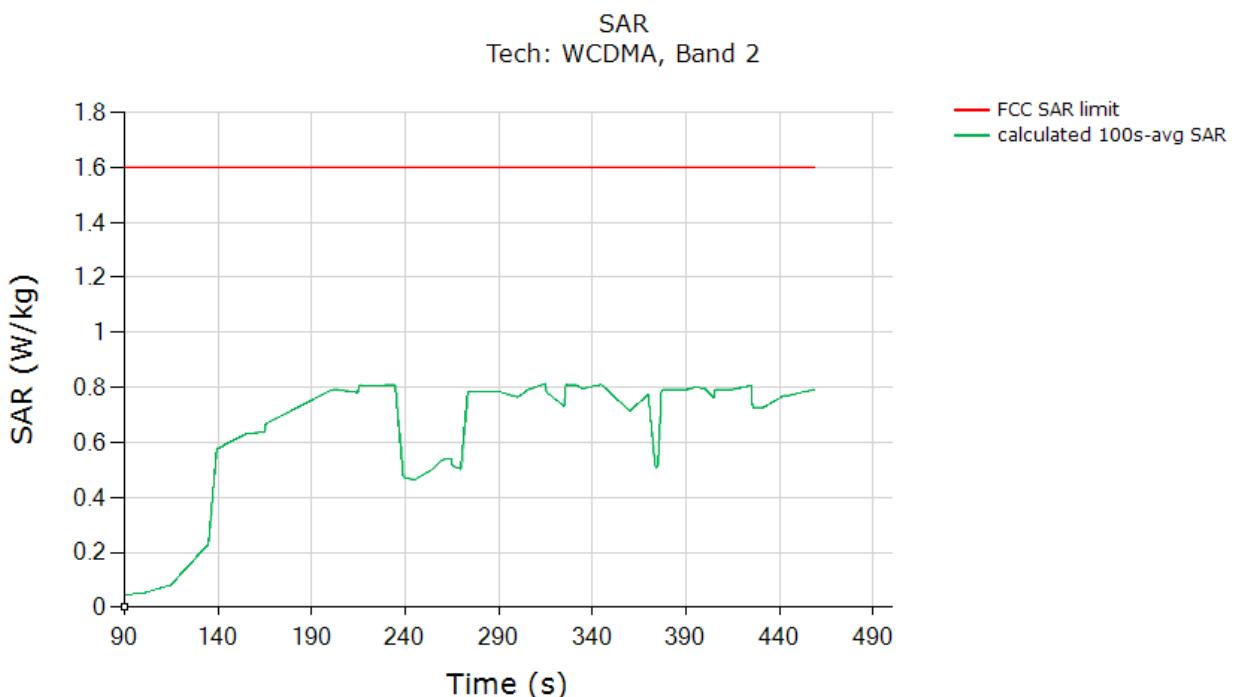


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.811
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

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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)	0.812
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

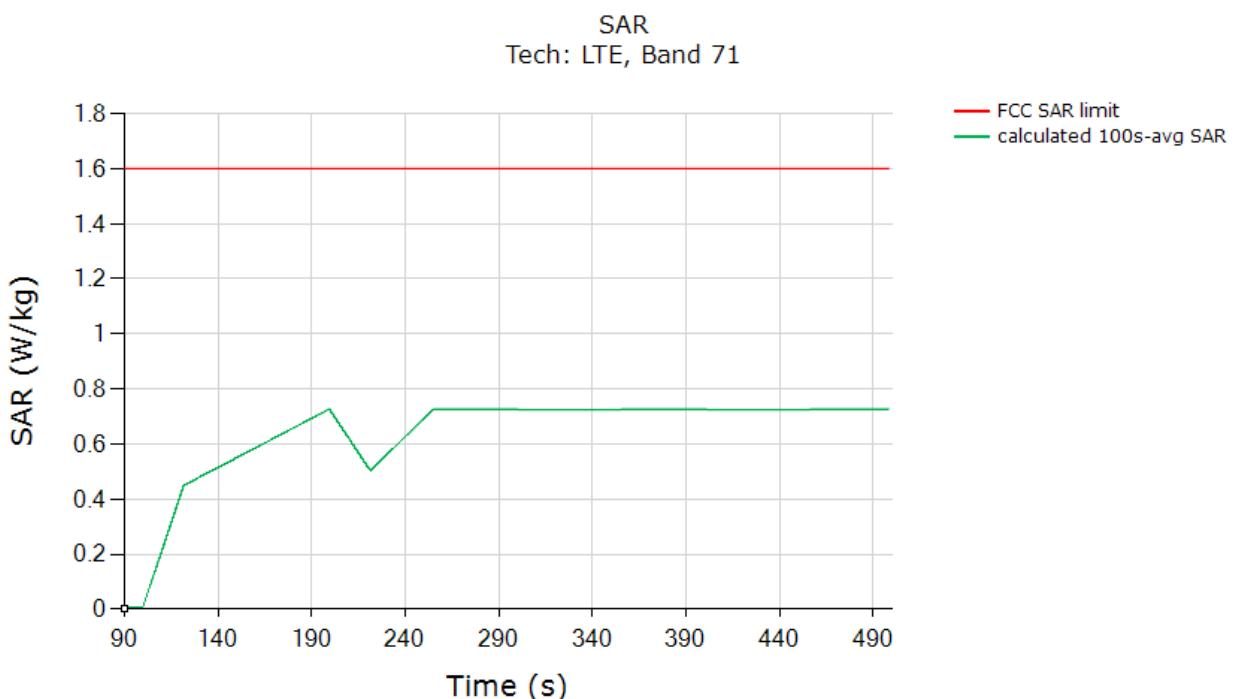
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7.1.2

LTE Band 71 Antenna 3

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:

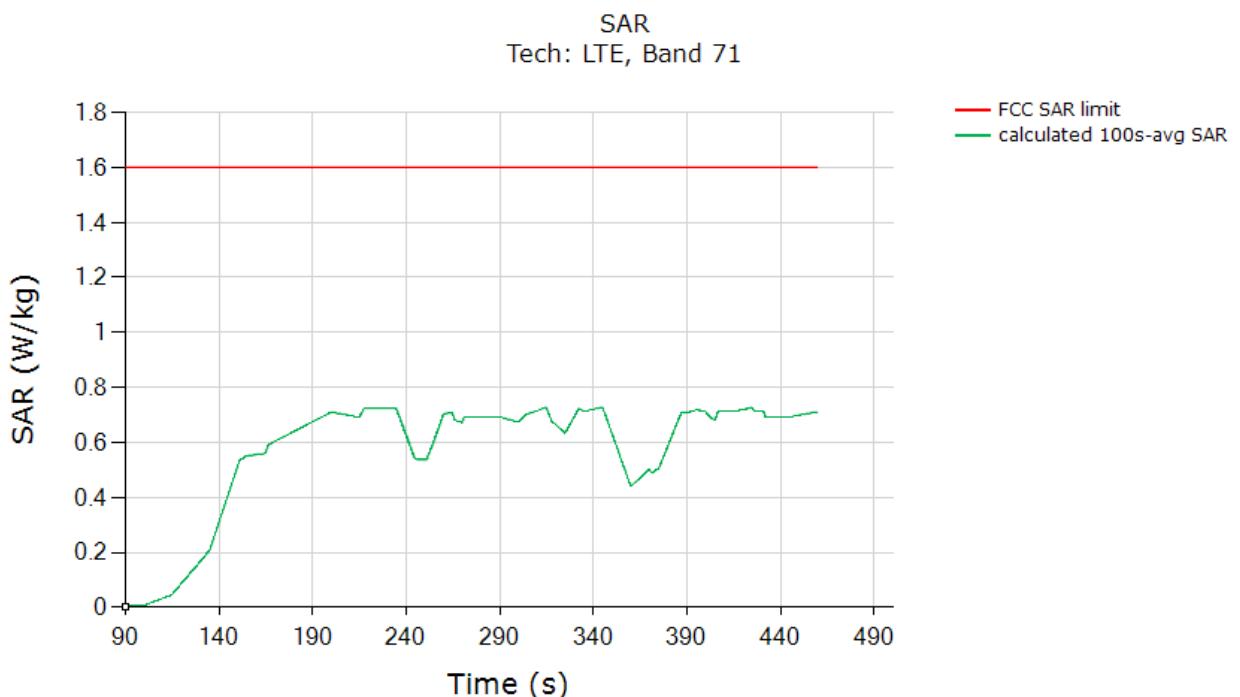


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.727
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

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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:



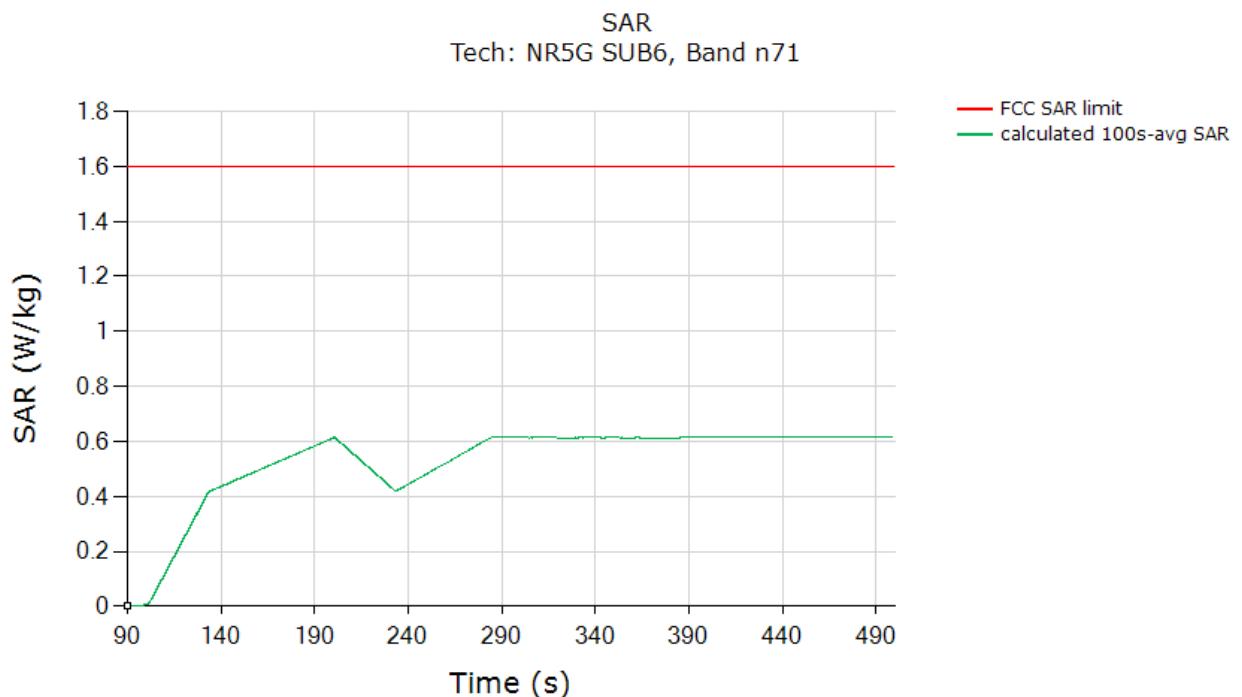
	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.727
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

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7.1.3 NR n71 SA Antenna 3

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:

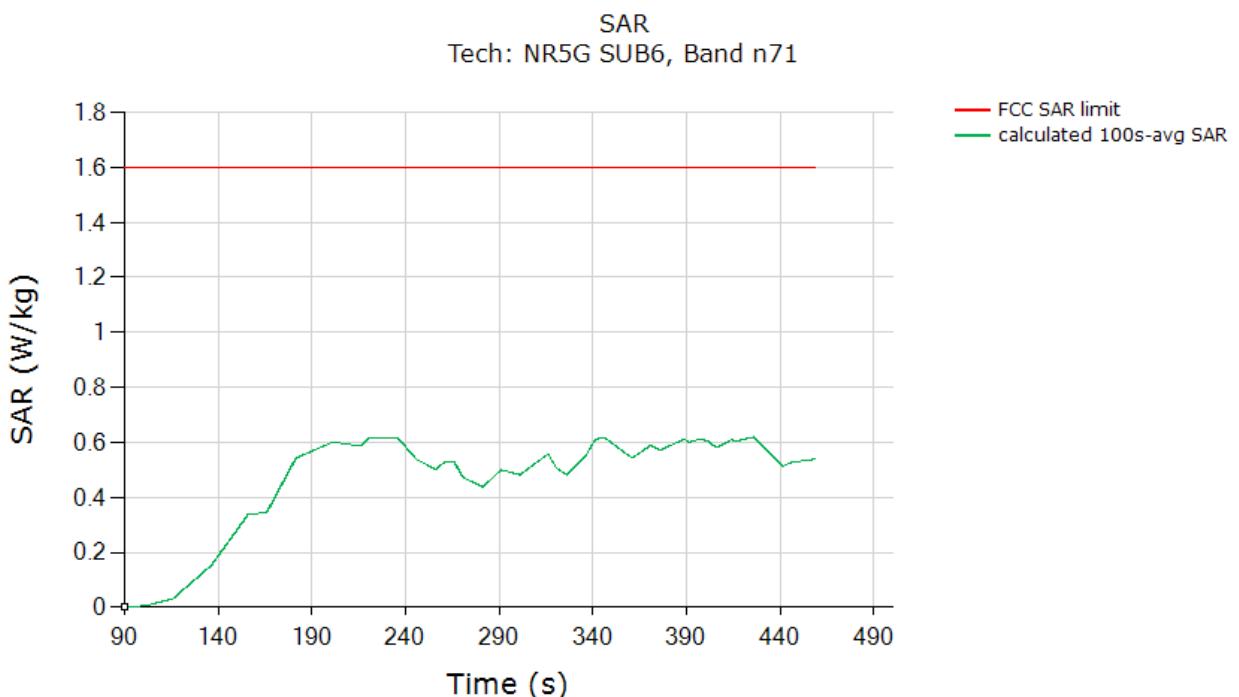


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.617
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

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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)	0.619
Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (last column in Table 6-2).	

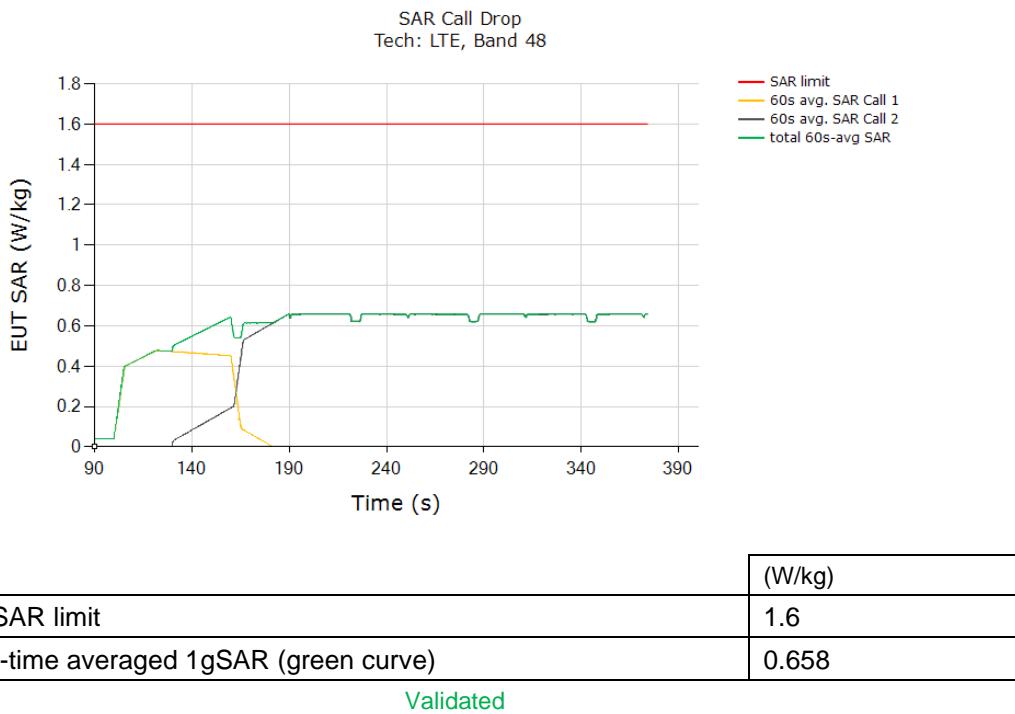
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7.2 Call Drop Test Case

This test was measured LTE Band 48, Antenna 4B, DSI = 1, 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 5-1. 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:



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

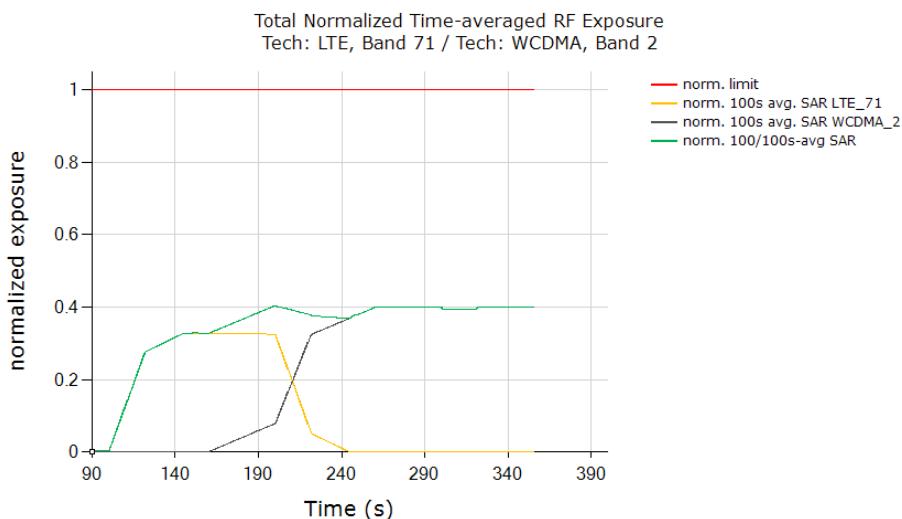
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7.3 Change in Technology/Band Test Case

This test was conducted with callbox requesting maximum power, and with a technology switch from LTE Band 71, Antenna 3, DSI = 1 to WCDMA Band 2, Antenna 4B, DSI = 1. 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:

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)	0.404
Validated	

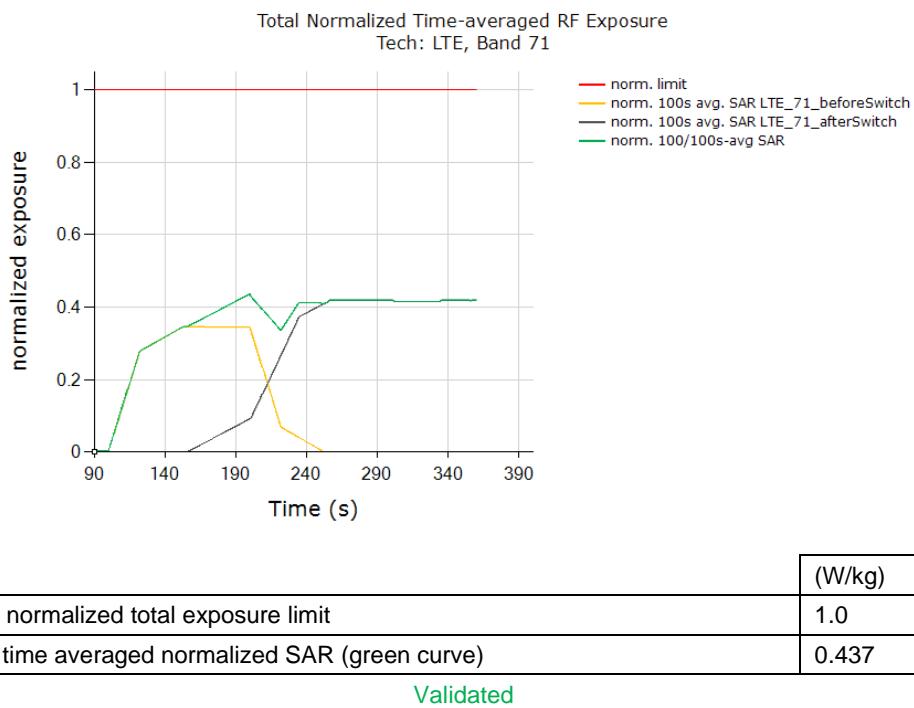
The test result validated the continuity of power limiting in technology/band switch scenario.

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7.4 Change in Antenna test Results

This test was conducted with callbox requesting maximum power, and with an antenna switch from LTE B71, Antenna 3, DSI = 1 to LTE B71, Antenna 1, DSI = 1. Following procedure detailed in Section 4.3.4, and using the measurement setup shown in Figure 5-1b, the technology/band switch was performed when the DUT is transmitting at P_{reserve} level as shown in the plot below (dotted black region).

All the time-averaged conducted Tx power measurement results were converted into timeaveraged 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:



The test result validated the continuity of power limiting in antenna switch scenario.

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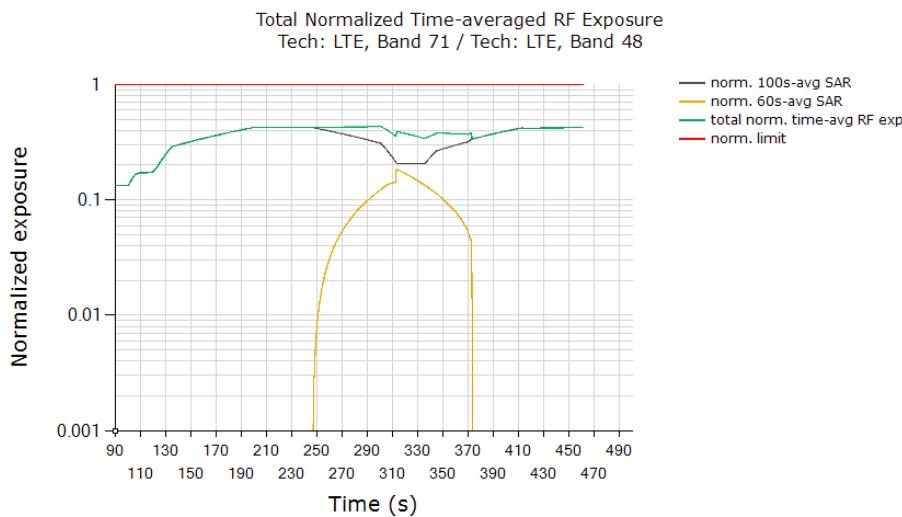
7.5 Change in Time window test results

This test was conducted with callbox requesting maximum power, and with time-window/antenna switch between LTE B71, Antenna 3, DSI = 1 (100s window) and LTE B48, Antenna 1, DSI = 1 (60s window). Following procedure detailed in Section 4.3.6, and using the measurement setup shown in Figure 5-1(b), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at P_{reserve} level.

7.5.1 Test case 1: transition from LTE B71 to LTE B48 (i.e., 100s to 60s), then back to LTE B71

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

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 100s-averaged normalized SAR in LTE B71 as shown in black curve. Similarly, equation (7b) is used to obtain 60s-averaged normalized SAR in LTE B48 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)	0.431
Validated	

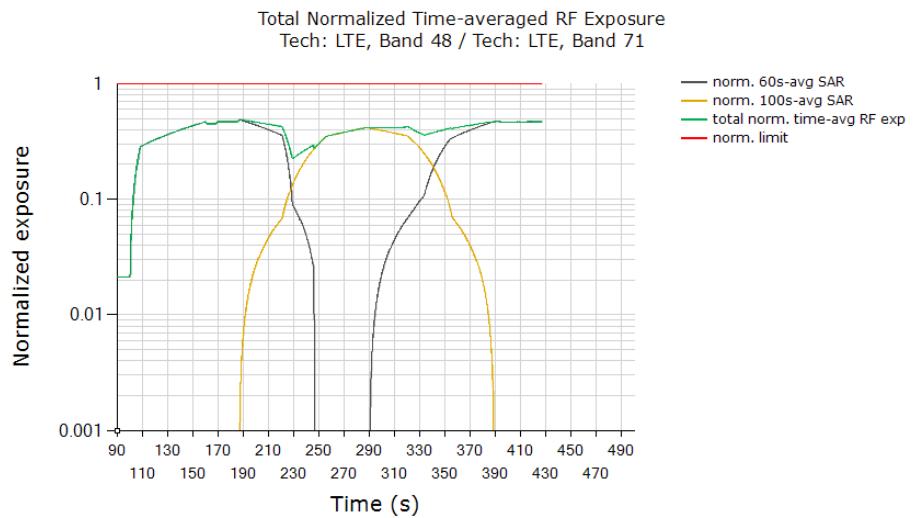
Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 100s-to-60s window at ~250s time stamp, and from 60s-to-100s window at ~310s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged 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 0.431 being ≤ 0.63 ($= 0.8/1.6 + 1\text{dB}$ device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

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7.5.2 Test case 2: transition from LTE B48 to LTE B71 (i.e., 60s to 100s), then back to LTE B48

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 B48 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in LTE B71 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)	0.490
Validated	

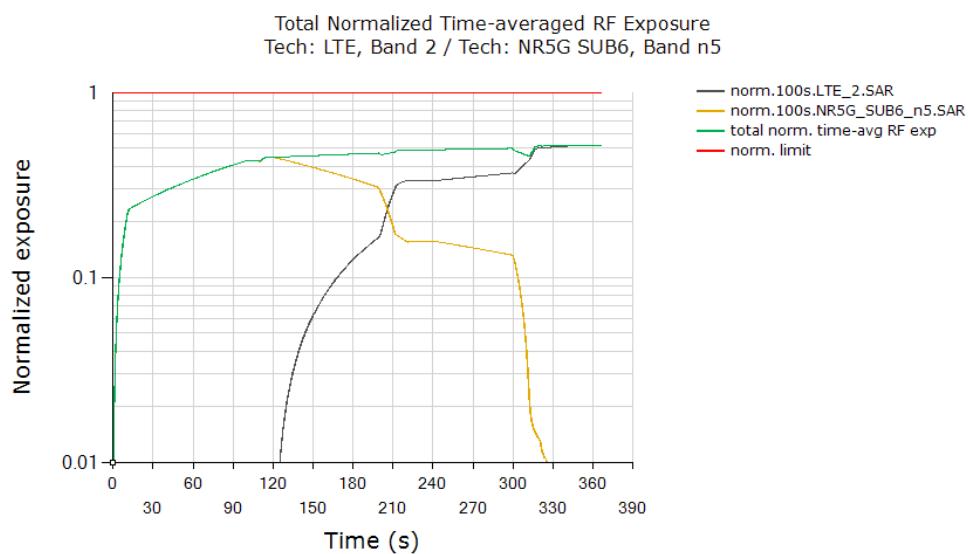
Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 60s-to-100s window at ~185s time stamp, and from 100s-to-60s window at ~290s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged 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 0.490 being ≤ 0.63 ($= 0.8/1.6 + 1\text{dB}$ device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

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7.6 Switch in SAR exposure test results (ENDC Same Time Window SSR = 0.2)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 2 + Sub6 NR Band n5 call. Following procedure detailed in Section 4.3.7 and Appendix C.2, and using the measurement setup shown in Figure 5-1(c) since LTE and Sub6 NR are on different antenna ports, 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_{sub6NR} + 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 2 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in Sub6 NR n5 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)	0.519
Validated	

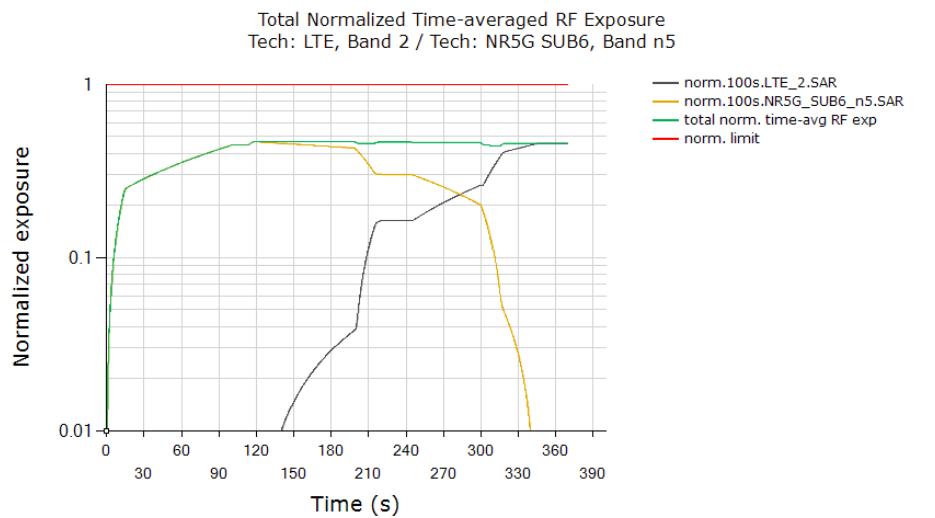
Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and in LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. Here, Smart Transmit allocates a maximum of 100% of exposure margin (based on 3dB reserve margin setting) for Sub6 NR. This corresponds to a normalized 1gSAR exposure value = 100% * 0.714W/kg measured SAR at Sub6 NR P_{limit} / 1.6W/kg limit = 0.446 ± 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 = 0.736 W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.460 ± 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 0.519 being ≤ 0.63 (= 0.8/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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7.7 Switch in SAR exposure test results (ENDC Same Time Window SSR = 0.8)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 2 + Sub6 NR Band n5 call. Following procedure detailed in Section 4.3.7 and Appendix C.2, and using the measurement setup shown in Figure 5-1(c) since LTE and Sub6 NR are on different antenna ports, 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_{sub6NR} + 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 2 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in Sub6 NR n5 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).



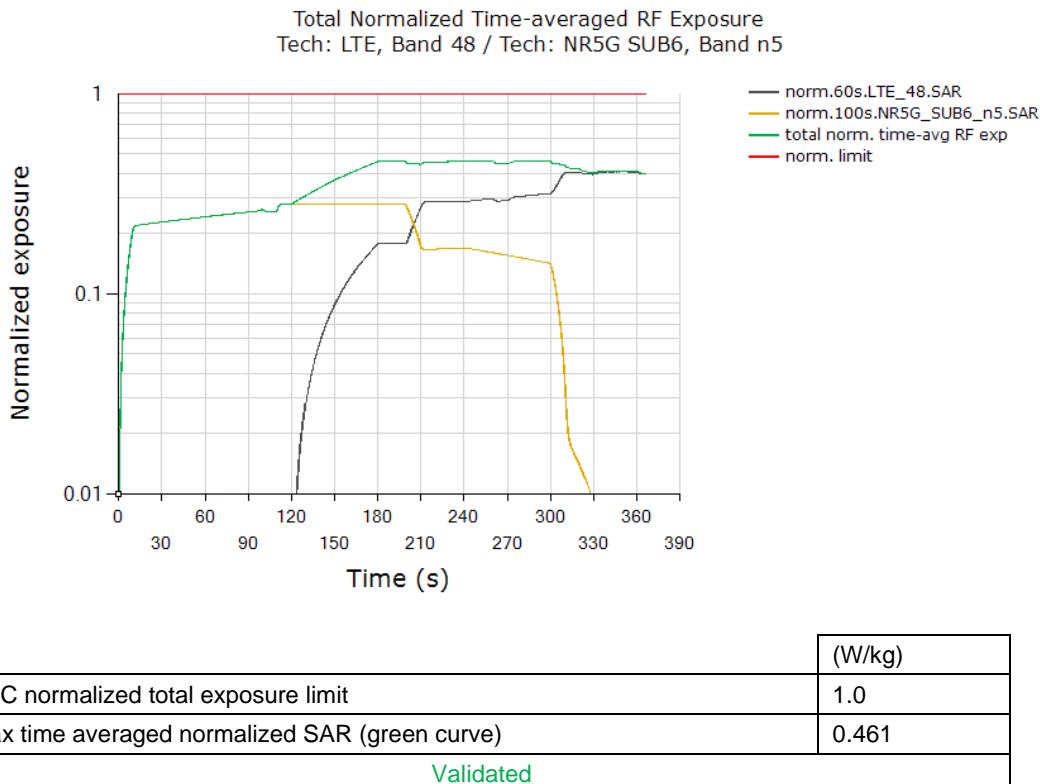
		(W/kg)
FCC normalized total exposure limit		1.0
Max time averaged normalized SAR (green curve)		0.467
Validated		

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% * 0.714W/kg measured SAR at Sub6 NR P_{limit} / 1.6W/kg limit = 0.446 ± 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 = 0.736 W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.460 ± 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 0.467 being ≤ 0.63 (= 0.8/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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7.8 Switch in SAR exposure test results (ENDC; Different Time Window SSR 0.2)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 48, Antenna 1 + Sub6 NR Band n5, Antenna 3 call. Following procedure detailed in Section 4.3.7 and Appendix C.2, and using the measurement setup shown in Figure 5-1(c) since LTE and Sub6 NR do not share the same 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_{sub6NR} + SAR_{LTE} scenario (t = 120s ~ 240s) and SAR_{LTE} only scenario (t > 240s).

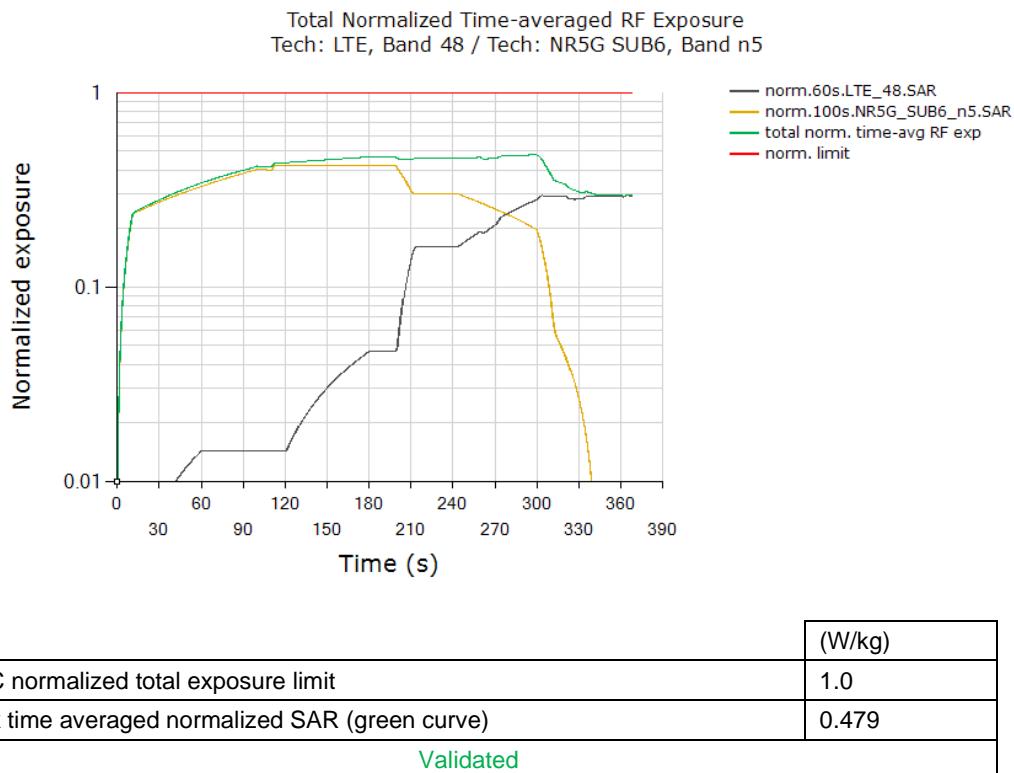


Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and in LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. For predominantly NR SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.767W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.479 ± 1 dB device related uncertainty (see orange curve between 0s~120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.714 W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.446 ± 1 dB 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} + 1 dB device uncertainty. In this test, with a maximum normalized SAR of 0.461 being ≤ 0.63 ($= 0.8/1.6 + 1$ dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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7.9 Switch in SAR exposure test results (ENDC; Different Time Window SSR 0.8)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 48, Antenna 1 + Sub6 NR Band n5, Antenna 3 call. Following procedure detailed in Section 4.3.7 and Appendix C.2, and using the measurement setup shown in Figure 5-1(c) since LTE and Sub6 NR do not share the same 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_{sub6NR} + SAR_{LTE} scenario (t = 120s ~ 240s) and SAR_{LTE} only scenario (t > 240s).



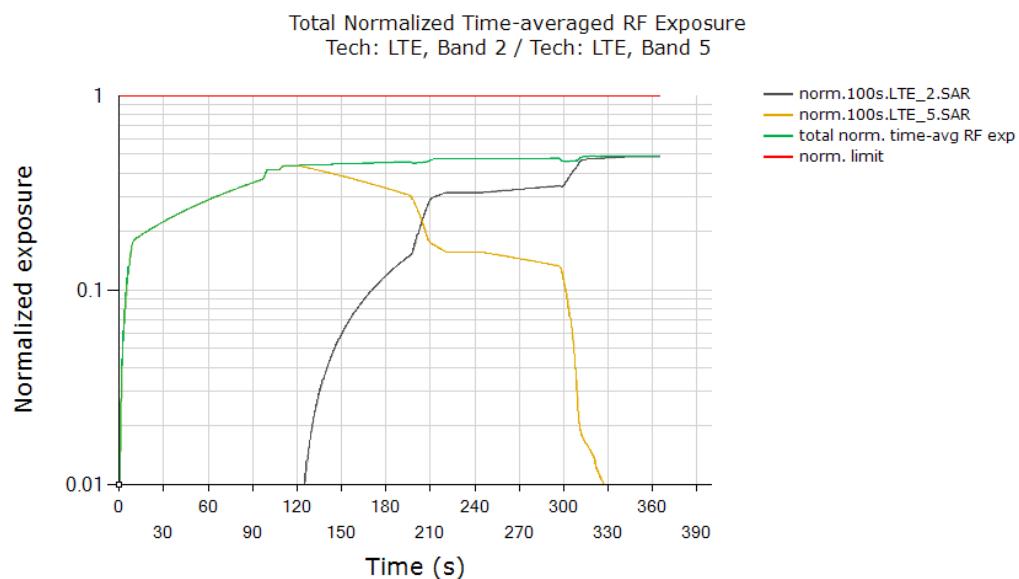
Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and in LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. For predominantly NR SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.767W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.479 ± 1 dB device related uncertainty (see orange curve between 0s~120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.714 W/kg measured SAR at LTE P_{limit} / 1.6W/kg limit = 0.446 ± 1 dB 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} + 1 dB device uncertainty. In this test, with a maximum normalized SAR of 0.479 being ≤ 0.63 ($= 0.8/1.6 + 1$ dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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7.10 Switch in SAR exposure test results (Inter-band ULCA SSR 0.2)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 2 (PCC), Antenna 4B + LTE Band 5 (SCC), Antenna 3 call. The measurement setup shown in Figure 5-1(c) was used because each LTE do not share the same antenna port. The SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, i.e., in SAR_{SCC} max scenario ($t = 0\text{s} \sim 120\text{s}$), $\text{SAR}_{\text{PCC}} + \text{SAR}_{\text{SCC}}$ max scenario ($t = 120\text{s} \sim 240\text{s}$) and SAR_{PCC} max scenario ($t > 240\text{s}$).

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (5a), (5b) and (5c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (5a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE B2 (PCC) as shown in black curve. Similarly, equation (5b) is used to obtain 100s-averaged normalized SAR in LTE B5 (SCC) as shown in orange curve. Equation (5c) 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)		0.489
Validated		

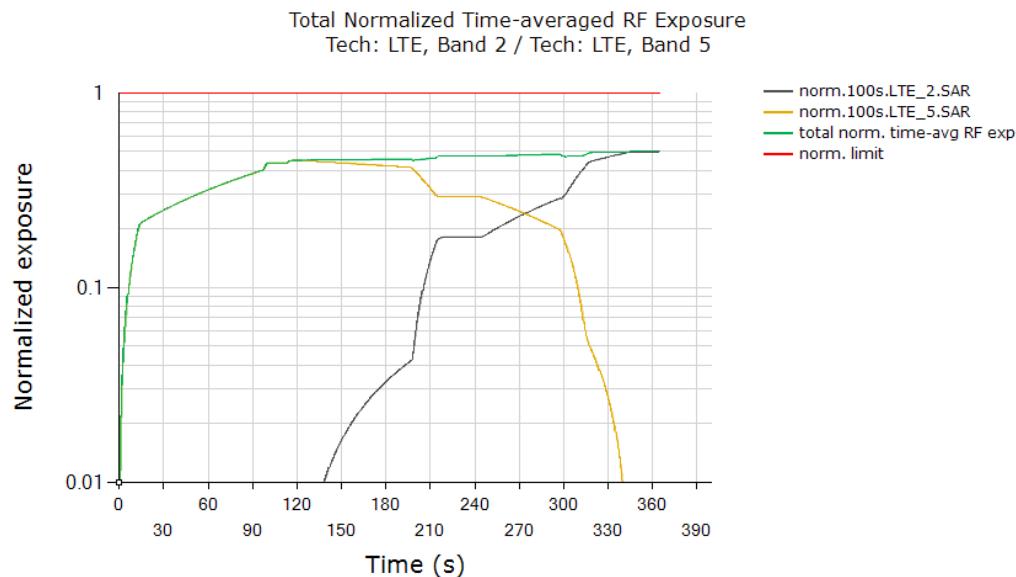
Plot Notes: Device starts predominantly in LTE B2 (PCC) SAR exposure scenario between 0s and 120s, and in LTE B2 (PCC) SAR + LTE B5 (SCC) SAR exposure scenario between 120s and 240s, and in predominantly in LTE B5 (SCC) SAR exposure scenario after $t=240\text{s}$. In SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized $\text{SAR}_{\text{design_target}} + 1 \text{ dB}$ device uncertainty. In this test, with a maximum normalized SAR of 0.489 being ≤ 0.63 ($= 0.8/1.6 + 1 \text{ dB}$ device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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7.11 Switch in SAR exposure test results (Inter-band ULCA SSR 0.8)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 2 (PCC), Antenna 4B + LTE Band 5 (SCC), Antenna 3 call. The measurement setup shown in Figure 5-1(c) was used because each LTE do not share the same antenna port. The SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, i.e., in SAR_{SCC} max scenario (t = 0s ~ 120s), SAR_{PCC} + SAR_{SCC} max scenario (t = 120s ~ 240s) and SAR_{PCC} max scenario (t > 240s).

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (5a), (5b) and (5c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (5a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE B2 (PCC) as shown in black curve. Similarly, equation (5b) is used to obtain 100s-averaged normalized SAR in LTE B5 (SCC) as shown in orange curve. Equation (5c) 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)	0.501
Validated	

Plot Notes: Device starts predominantly in LTE B2 (PCC) SAR exposure scenario between 0s and 120s, and in LTE B2 (PCC) SAR + LTE B5 (SCC) SAR exposure scenario between 120s and 240s, and in predominantly in LTE B5 (SCC) SAR exposure scenario after t=240s. In SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target + 1 dB device uncertainty. In this test, with a maximum normalized SAR of 0.501 being ≤ 0.63 ($= 0.8/1.6 + 1$ dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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8 EQUIPMENT LIST

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	5/10/2022	Annual	5/10/2023	MY42082659
Agilent	E4438C	ESG Vector Signal Generator	2/14/2022	Annual	2/14/2023	MY42082385
Agilent	N5182A	MXG Vector Signal Generator	7/20/2022	Annual	7/20/2023	MY47420800
Agilent	N5182A	MXG Vector Signal Generator	6/21/2022	Annual	6/21/2023	MY47420651
Agilent	8753ES	S-Parameter Vector Network Analyzer	2/11/2022	Annual	2/11/2023	MY40003841
Agilent	8753ES	S-Parameter Vector Network Analyzer	12/17/2021	Annual	12/17/2022	MY40000670
Agilent	E5515C	Wireless Communications Test Set	5/12/2022	Annual	5/12/2023	GB43304278
Agilent	E5515C	Wireless Communications Test Set	1/14/2020	Triennial	1/14/2023	GB43304447
Agilent	N4010A	Wireless Connectivity Test Set	N/A	N/A	N/A	GB46170464
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433972
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433974
Anritsu	ML2495A	Power Meter	3/17/2022	Annual	3/17/2023	941001
Anritsu	ML2496A	Power Meter	3/31/2022	Annual	3/31/2023	1138001
Anritsu	MA2411B	Pulse Power Sensor	4/29/2022	Annual	4/29/2023	1207470
Anritsu	MA2411B	Pulse Power Sensor	9/21/2021	Annual	9/21/2022	1315051
Anritsu	MT8821C	Radio Communication Analyzer MT8821C	6/27/2022	Annual	6/27/2023	6261895213
Anritsu	MT8821C	Radio Communication Analyzer MT8821C	5/24/2022	Annual	5/24/2023	6201144418
Anritsu	MT8821C	Radio Communication Analyzer MT8821C	3/31/2022	Annual	3/31/2023	6201664756
Anritsu	MT8821C	Radio Communication Analyzer MT8821C	9/26/2021	Annual	9/26/2022	6201524637
Anritsu	MT8000A	Radio Communication Test Station	4/15/2022	Annual	4/15/2023	6272337439
Anritsu	MA24106A	USB Power Sensor	8/12/2022	Annual	8/12/2023	1349513
Anritsu	MA24106A	USB Power Sensor	8/5/2022	Annual	8/5/2023	1344555
Control Company	4352	Long Stem Thermometer	9/10/2021	Biennial	9/10/2023	210774678
Control Company	4352	Long Stem Thermometer	9/10/2021	Biennial	9/10/2023	210774685
Control Company	4353	Long Stem Thermometer	10/28/2020	Biennial	10/28/2022	200670623
Control Company	4040	Therm./ Clock/ Humidity Monitor	1/21/2022	Annual	1/21/2023	160574418
Mitutoyo	500-196-30	CD-6"ASX 6Inch Digital Caliper	2/16/2022	Triennial	2/16/2025	A20238413
Keysight Technologies	N6705B	DC Power Analyzer	5/5/2021	Triennial	5/5/2024	MY53004059
Keysight Technologies	N9020A	MXA Signal Analyzer	4/14/2022	Annual	4/14/2023	MY48010233
Keysight Technologies	E7515B	UXM 5G WIRELESS TEST PLATFORM	3/16/2022	Annual	3/16/2023	MY60192562
MCL	BW-N6W5+	6dB Attenuator	CBT	N/A	CBT	1139
Mini-Circuits	BW-N20W5	Power Attenuator	CBT	N/A	CBT	1226
Mini-Circuits	ZUDC10-83-S+	Directional Coupler	CBT	N/A	CBT	2050
Narda	4772-3	Attenuator (3dB)	CBT	N/A	CBT	9406
Narda	BW-S3W2	Attenuator (3dB)	CBT	N/A	CBT	120
Pasternack	PE5011-1	Torque Wrench	12/21/2021	Biennial	12/21/2023	82475
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	5/3/2022	Annual	5/3/2023	128635
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	4/8/2022	Annual	4/8/2023	162125
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	4/7/2022	Annual	4/7/2023	167283
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	2/21/2022	Annual	2/21/2023	164948
Rohde & Schwarz	NRP8S	3-Path Dipole Power Sensor	11/27/2021	Annual	11/27/2022	109961
Rohde & Schwarz	NRP8S	3-Path Dipole Power Sensor	5/19/2022	Annual	5/19/2023	109957
Rohde & Schwarz	NRP50S	3-Path Dipole Power Sensor	11/19/2021	Annual	11/29/2022	101350

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.

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9 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	∞
Hemispherical 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 Uncertainty	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)						11.5	11.3	60
Expanded Uncertainty (95% CONFIDENCE LEVEL)						23.0	22.6	

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10 CONCLUSION

10.1 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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