Part 2 Test Under Dynamic Transmission Condition

Test Report No. 14367173H-C

Customer	**Panasonic Corporation of North America**
Description of EUT	**Radio Module** **(Tested inside of Panasonic Personal Computer FZ-G2)**
Model Number of EUT	**WW21A**
FCC ID	**ACJ9TGWW21A**
Issue Date	**February 15, 2023**
Remarks	-

Representative Test Engineer	**Approved By**
	
Tomohisa Nakagawa Engineer	Takayuki Shimada Leader

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Contents

1 Introduction

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

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

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

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

2 Customer information

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Contact Person	Ben Botros

*Remarks:
Panasonic Connect Co., Ltd. is on behalf of the applicant: Panasonic Corporation of North America (Company incorporated abroad).

The information provided from the customer is as follows;
- Applicant, Type of Equipment, Model No. FCC ID on the cover and other relevant pages
- Operating/Test Mode(s) (Mode(s)) on all the relevant pages
- SECTION 2: Customer information
- SECTION 3: Equipment under test (EUT) other than the Receipt Date
* The laboratory is exempted from liability of any test results affected from the above information in section 3.

3 Equipment under test (EUT)

3.1 Identification of EUT

Description	Radio Module
Model Number	WW21A
Serial number	2CTSA00742 (1.75 GHz and 650 MHz band) 2CTSA00747 (Above 2 GHz) 2CTSA00763 (Other than the above) 2CTSA00766 (mmW)
Rating	DC 3.0 to 3.6 V
Condition	Production prototype (Not for Sale: This sample is equivalent to mass-produced items.)
Modification	No Modification by the test lab.
Receipt Date	June 13, 2022
Test Date	November 22, 2022 to February 7, 2023

<Information of Host device>

Type	Personal Computer FZ-G2 Intel Core i7-1185G7 (1.1 GHz Max 4.9 GHz) 10.1 inch LCD (1920 x 1200)

3.2 Product description

EFS version 15.

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

Downlink CA combination is listed PART 1 report.

Wireless module (Tested inside of Panasonic Tablet PC FZ-G2)
Model: WL22A (FCC ID ACJ9TGWL22A / ISED certification number 216H-CFWL22A)

Wireless technologies	Dup.	Band		Mode
WLAN	TDD	2.4 GHz	2412 - 2472 for US 2412 - 2462 for Canada	802.11b 802.11g 802.11n(20, 40)
	TDD	5 GHz	5180 - 5240 5260 - 5320 5500 - 5720 5745 - 5825	802.11a 802.11n(20, 40) 802.11ac(20, 40, 80, 160) 802.11ax(20, 40, 80, 160)
	TDD	6 GHz	5955 - 6415 6435 - 6515 6535 - 6875 6875 - 7115	802.11ax(20, 40, 80, 160)
Bluetooth	TDD	2.4 GHz	2402 - 2480	BR/EDR/LE

Panasonic Tablet PC
Model: FZ-G2 (FCC ID ACJ9TGFZG2)

Wireless technologies	Dup.	Band		Mode
5G NR (FR2)	TDD	120 kHz	n258	Pi/2 BPSK (DFT-s-OFDM), QPSK (CP-OFDM/DFT-s-OFDM) 16QAM (CP-OFDM/DFT-s-OFDM), 64QAM (CP-OFDM/DFT-s-OFDM) MIMO Support: No
	TDD	120 kHz	n260	
	TDD	120 kHz	n261	
	-	-	-	
EN-DC(LTE-FR2 mmW) (NSA mode only)	Supported combination			*B48: not used in Canada (ISED)
	LTE Anchor Bands for NR band n258			LTE Band 2/5/7/12/66
	LTE Anchor Bands for NR band n260			LTE Band 2/5/12/13/14/48*/66
	LTE Anchor Bands for NR band n261			LTE Band 2/5/13/48*/66

4 Location

UL Japan, Inc. Ise EMC Lab.
Shielded room for SAR testings
FCC Test Firm Registration Number: 884919 / ISED SAR Lab Company Number: 2973C
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Telephone: +81 596 24 8999
Facsimile: +81 596 24 8124

5 References

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

6 Definitions, symbols, and abbreviations

6.1 Definitions

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

SAR_design_target_extremity : SAR_design_target for limbs

Tx_power_at_SAR_design_target : Transmit level that matches SAR_design_target

Δ min : housing material influence

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

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

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

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

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

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

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

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

6.2 Symbols

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

6.3 Abbreviations

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

7 Qualcomm® Smart Transmit Operation Description

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

7.1 Feature description

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

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

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

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

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

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

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

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

7.2 Basic concept of the algorithm

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

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

can maintain the radio link at a minimum reserve power level for as long as needed, and at the same time ensure the time-averaged Tx power over any defined time window is less than Plimit at all times (see Figure 2). At all times, Smart Transmit meets the below equation:

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

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

$$mmW\_time.avg.Tx\ power\ =\ \frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} mmW\_Tx\ power(t)\ dt\ \le\ input.power.limit$$

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

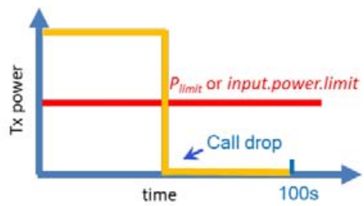
- In the case of simultaneous transmission, Smart Transmit manages all active Tx and makes sure the total exposure ratio is less than 1, i.e.,

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

or

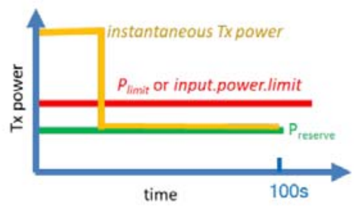
$$\sum\frac{\frac{1}{T_{SAR0}}\int_{t-T_{SAR0}}^{t} SAR0(t)dt}{Regulatory\ SAR\ limit}+\sum\frac{\frac{1}{T_{SAR1}}\int_{t-T_{SAR1}}^{t} SAR1(t)dt}{Regulatory\ SAR\ limit}\ \le\ 1$$

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



(a)

Figure 1 High Tx power when needed and permitted



(b)

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

7.3 Configurable parameters

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

- Regulatory body

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

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

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

- *Reserve_power_margin* (dB)

  The margin, in dB, below the Plimit to reserve for future transmission with a minimum Tx power (*Preserve*):
  Preserve (dBm) = Plimit (dBm) – *Reserve_power_margin* (dB)

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

- *input.power.limit* (dBm) for Tx frequency ≥ 6GHz

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

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

- *force peak for Tx transmitting frequency < 6 GHz*
  The Smart Transmit feature applies time-averaging windows when the device detects an MCC that matches Time-Averaged Exposure MCCs list. For each of the MCCs under Time-Averaged Exposure MCCs list, the Smart Transmit feature can limit either maximum peak power or maximum time-average power to Plimit per tech/band/antenna/DSI. If force peak is set to ‘1’ for a given tech/band/antenna/DSI in the EFS, then the Smart Transmit feature limits the maximum Tx power to Plimit for the selected tech/band/antenna/DSI. In other words, with force peak set to ‘1’, under static condition (i.e., fixed tech/band/antenna/DSI) and in single active Tx scenario, Smart Transmit can guarantee Tx power level of Plimit at all times.

8 Tx Varying Transmission Test Cases and Test Proposal

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

8.1 transmission scenarios

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

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

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

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

For conducted testing

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged power measurements
  - Measure conducted Tx power (for f < 6GHz) versus time, and radiated Tx power (EIRP for f > 10GHz) versus time.
  - Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
  - Perform running time-averaging over FCC defined time windows.
    Instantaneous value using Eq. 8-1, Eq. 8-4 and Eq. 8-5
  - Max 100s / 60s SAR using Eq. 8-2

- Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios (i.e., transmission scenarios 1, 2, 3, 4, 5, 6, 7, and 8) at all times.
  - Max Norm. sub6 RF Exposure Eq. 8-3 and Eq. 8-6
  - Max Norm. 4s PD using Eq. 8-7
  - Max Norm. Total RF Exposure Eq. 8-8

Mathematical expression:

– For sub-6 transmission only:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_Plimit} \times 1g\_or\_10gSAR\_P_{limit}$$

Eq. 8-1

$$\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt$$

Eq. 8-2

$$1g\_or\_10gSAR(t)\_normalized = \frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit}$$

Eq. 8-3

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_Plimit$, and $1g\_or\_10gSAR\_\ Plimit$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at Plimit, and measured 1gSAR or 10gSAR values at Plimit corresponding to sub-6 transmission. Plimit is the parameters pre-defined in Part 0 and loaded via Embedded File System (EFS) onto the EUT. T_{SAR} is the FCC defined time window for sub-6 radio.

– For sub-6+mmW transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_Plimit} \times 1g\_or\_10gSAR\_P_{limit}$$

Eq. 8-4

$$4cm^2PD(t) = \frac{\text{radiated\_Tx\_power(t)}}{radiated\_Tx\_Power\_input.power.limit} \times 4cm^2PD\_input.power.limit$$

Eq. 8-5

$$1g\_or\_10gSAR(t)\_normalized = \frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit}$$

Eq. 8-6

$$4cm^2PD(t)\_normalized = \frac{\frac{1}{TPD}\int_{t-Tpd}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ Limit}$$

Eq. 8-7

$$\frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit} + \frac{\frac{1}{TPD}\int_{t-Tpd}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ Limit} \leq 1$$

Eq. 8-8

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_Plimit$, and $1g\_or\_10gSAR\_$ Plimit correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at Plimit, and measured 1gSAR or 10gSAR values at Plimit corresponding to sub-6 transmission. Similarly, $radiated\_Tx\_power(t)$, $radiated\_Tx\_power\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit* (i.e., radiated power limit), and $4cm^2$PD value at *input.power.limit* corresponding to mmW transmission. Both Plimit and *input.power.limit* are the parameters pre-defined in Part 0 and loaded via Embedded File System (EFS) onto the EUT. T_{SAR} is the FCC defined time window for sub-6 radio; T_{PD} is the FCC defined time window for mmW radio.

For radiated testing

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged SAR and PD measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
  - For sub-6 transmission only, measure instantaneous SAR versus time; for LTE+sub6 NR transmission, request low power (or all-down bits) on LTE so that measured SAR predominantly corresponds to sub6 NR.
  - For LTE + mmW transmission, measure instantaneous E-field versus time for mmW radio and instantaneous conducted power versus time for LTE radio.
  - Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
  - Perform time averaging over FCC defined time window
    Instantaneous value using Eq. 8-9
    Max sub6 SAR using Eq. 8-10
  - Demonstrate that the total normalized time-averaged RF exposure is always less than 1 for transmission scenario 1.
    Instantaneous value Eq. 8-9, Eq. 8-12 and Eq. 8-13
    Max Norm. sub6 SAR using Eq. 8-11 and Eq. 8-14
    Max Norm. 4s PD using Eq. 8-15
    Max Norm. Total RF Exposure Eq. 8-16

Mathematical expression:
- For sub-6 transmission only:

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

Eq. 8-9

$$\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt$$

Eq. 8-10

$$1g\_or\_10gSAR(t)\_normalized = \frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit}$$

Eq. 8-11

– For LTE+mmW transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_Plimit} \times 1g\_or\_10gSAR\_P_{limit}$$

Eq. 8-12

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

Eq. 8-13

$$1g\_or\_10gSAR(t)\_normalized = \frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit}$$

Eq. 8-14

$$4cm^2PD(t)\_normalized \ = \frac{\frac{1}{TPD}\int_{t-Tpd}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ Limit}$$

Eq. 8-15

$$\frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit} + \frac{\frac{1}{TPD}\int_{t-Tpd}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ Limit} \leq 1$$

Eq. 8-16

where, $pointSAR(t)$, $pointSAR\_$ Plimit, and $1g\_or\_10gSAR\_$ Plimit correspond to the measured instantaneous point SAR, measured point SAR at Plimit, and measured 1gSAR or 10gSAR values at Plimit corresponding to sub-6 transmission. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm2PD\_input.power.limit$ correspond to the measured instantaneous E-field, E-field at *input.power.limit*, and 4cm2PD value at *input.power.limit* corresponding to mmW transmission.

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

9 SAR Time Averaging Validation Test Procedures

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

9.1 Test sequence determination for validation

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

Test sequence 1: requesting EUT to transmit at maximum power, measured Pmax for 80s, then requesting for half of the maximum power, i.e., measured Pmax /2, for the rest of the time.

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

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

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

9.2 Test configuration selection criteria for validating Smart Transmit feature

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

Used the highest *measured* 1g_or_10g SAR at Plimit (Plimit < Pmax) shown in Part 1 report and for the selected tech/band/antenna/DSI out of all radio configurations and device positions

9.2.1 Test configuration selection for time-varying Tx power transmission

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

The criteria for the selection are based on the Plimit values determined in Part 0 report. Select two bands[1] in each supported technology that correspond to least[2] and highest[3] Plimit values for validating Smart Transmit.

Note if possible, for this selection, delta (Pmax - Plimit) should be 1dB or higher.

[1] If one Plimit 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 Plimit, the radio configuration (e.g., # of RBs, channel#) and device position that correspond to the highest measured 1gSAR at Plimit shown in Part 1 report is selected.
[2] In case of multiple bands having the same least Plimit within the technology, then select the band having the highest measured 1gSAR at Plimit.
[3] The band having a higher Plimit 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 Plimit in a technology is too high (> Pmax) where the power limiting enforcement is not needed when testing with the pre-defined test sequences, then the next highest level is checked. This process is continued within the technology until the second band for validation testing is determined.

9.2.2 Test configuration selection for change in call

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

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

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

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

9.2.3 Test configuration selection for change in technology/band

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

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

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

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

9.2.4 Test configuration selection for change in antenna

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

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

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

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

9.2.5 Test configuration selection for change in DSI

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

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

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

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

9.2.6 Test configuration selection for change in time window

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

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

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

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

9.2.7 Test configuration selection for SAR exposure switching

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

1. SAR exposure switch when two active radios are in the same time window. The following radio configurations need to be covered if the device supports:

    a. LTE + sub6 NR: LTE is protected as it is anchor in NR call. However, Sub6 NR can sustain the link if LTE is at low power
    b. Interband ULCA: PCC is protected as it is primary in interband ULCA call. SCC will drop the link if SCC is requested to transmit continuously at or above Plimit regardless of PCC transmitting power level in devices with Smart Transmit EFS version 15 (or lower). SCC is expected to sustain the link when PCC is at low power in Smart Transmit EFS version 16 (or higher).

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

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

The Smart Transmit time averaging operation ensures total time-averaged RF exposure compliance independent of the source of SAR exposure (for example, LTE vs. Sub6 NR). Hence, validation of Smart Transmit in any one band combination for each simultaneous SAR transmission scenario (i.e., one band combination for LTE + Sub6 NR transmission, and one band combination for interband ULCA) is sufficient, where the SAR exposure varies among SAR_{radio1} only, SAR_{radio1} + SAR_{radio2}, and SAR_{radio2} only scenarios.

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

- Following the above two test requirements, select the required configuration(s) for the EUT supported simultaneous transmission scenario(s).

- Among all supported simultaneous transmission configurations, the selection order is

    a. select one configuration where both Plimit of radio1 and radio2 is less than their corresponding *Pmax*, preferably, with different Plimit. If this configuration is not available, then,
    b. select one configuration that has Plimit less than its *Pmax* for at least one radio. If this can not be found, then,
    c. The test for SAR exposure switch when two active radios are in the same time window is not required. For SAR exposure switch when two active radios are in the different time windows, the selection order is:
        i. Select both configurations that has Plimit of radio1 and radio2 greater than *Pmax* but having (Plimit – Pmax) < 2.2dB. If this can not be found, then,
        ii. Select at least one configuration in 60s window that has (Plimit – Pmax) < 2.2dB. If all (Plimit – Pmax) > 2.2dB, then,
        iii. Test for SAR exposure switch when two active radios are in the different time windows is not required.

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

10 PD Time Averaging Validation Test Procedures

This chapter provides the test plan and test procedures for validating Qualcomm® Smart Transmit algorithm for mmW transmission. For this EUT, millimeter wave (mmW) transmission is only in non-standalone mode, i.e., it requires an LTE link as anchor.

10.1 Test sequence for validation in mmW NR transmission

In 5G mmW NR transmission, the test sequence for validation is with the callbox requesting EUT to transmit in 5G mmW NR at maximum power all the time.

10.2 Test configuration selection criteria for validating smart transmit algorithm

10.2.1 Test configuration selection for time-varying Tx power transmission

The Smart Transmit time averaging operation is independent of bands, modes, channels, and antenna configurations (beams) for a given technology. Hence, validation of Smart Transmit in any one band/mode/channel per technology is sufficient.

10.2.2 Test configuration selection for change in antenna configuration (beam)

The Smart Transmit time averaging algorithm operation is independent of bands, modes, channels, and antenna configurations (beams) for a given technology. Hence, validation of Smart Transmit with beam switch between any two beams is sufficient.

10.2.3 Test configuration selection for SAR vs. PD exposure switch during transmission

The Smart Transmit time averaging algorithm operation is independent of the nature of exposure (SAR vs. PD) and ensures total time-averaged RF exposure compliance. Hence, validation of Smart Transmit in any one band/mode/channel/beam for mmW + sub-6 (LTE) transmission is sufficient, where the exposure varies among SAR dominant scenario, SAR+PD scenario, and PD dominant scenario.

11 Test procedures for conducted power measurements

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

11.1 Time-varying Tx power transmission scenario

Test procedure

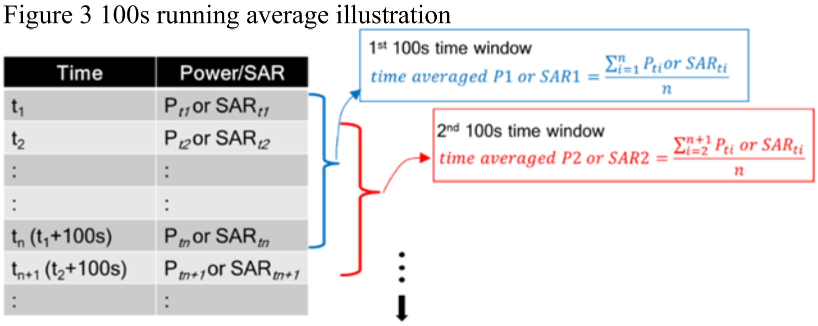
1. Measure *Pmax*, measure Plimit and calculate $P_{reserve}$ (= measured Plimit in dBm – *Reserve_power_margin* in dB) and follow Section 9.1 to generate the test sequences for all the technologies and bands selected in Section 9.2.1. Both test sequence 1 and test sequence 2 are created based on measured *Pmax* and measured Plimit of the EUT. Test condition to measure Pmax and Plimit is:

- Measure Pmax with Smart Transmit disabled and callbox set to request maximum power.
- Measure Plimit with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value (3dB for this EUT based on Part 1 report) and reset power on EUT to enable Smart Transmit, establish radio link in desired radio configuration, with callbox requesting the EUT to transmit at pre-defined test sequence1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. 8-1)) using measured Plimit from above Step 1. Perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus timeas illustrated in Figure 3.

   NOTE: In Eq. 8-1, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSARvalue by applying the measured worst-case 1gSAR or 10gSAR value at Plimit for the corresponding technology/band/antenna/DSI reported in Part 1 report.
   NOTE: For an easier computation of the 100s running average, 0 dBm for 100s can be added at the beginning of the test sequences, so the 100s running average can be directly performed starting with the first 100-seconds data using software. This technique also applies to all tests performed in this Part 2 report for easier time- averaged computation using excel software.

Figure 3 100s running average illustration



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

$$time\ average\ power\ limit\ = meas.Plimit\ + 10 \times log(\frac{FCC\ SAR\ limit}{meas.SAR\_Plimit})$$

Eq. 11-1

where *meas.* Plimit and *meas.SAR_ Plimit* correspond to measured power at Plimit and measured SAR at Plimit.

$$Time\ averaged\ mmW\ NR\ power\ limit = meas.EIRPinput.power.limit\ + 10 \times log(\frac{FCC\ PD\ limit}{meas.PD\_input.power.limit})$$

Eq. 11-2

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

4. Make another plot containing:
   a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
   b. FCC 1gSARlimit of 1.6W/kg, FCC 10gSARlimit of 4.0W/kg or PD FCC limit of 10 W/m^2.

5. Repeat Steps 2 ~ 4 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 2 with test sequence 2.

6. Repeat Steps 2 ~ 5 for all the selected technologies and bands.

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

11.2 Change in call scenario

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

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

Test procedure

1. Measure Plimit for the technology/band selected in Section 9.2.2. Measure Plimit with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximumpower.

2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit.

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

4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for about ~60 seconds, and then drop the call for ~10 seconds. Afterwards, re-establish another call in the same radio configuration (i.e., same technology/band/channel) and continue callbox requesting EUT to transmit at maximum Tx power for the remaining time of at least another 100 seconds. Measure and record Tx powerversus time. Once the measurement is done, extract instantaneous Tx power versus time, convert the measured conducted Tx power into 1gSAR or 10gSAR value using Eq. 8-1, andthen perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   NOTE: In Eq. 8-1, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSARvalue by applying the measured worst-case 1gSAR or 10gSAR value at Plimit 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 -1.

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

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

11.3 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 11.2, to validate the continuity of RF exposure limiting during the transition, the technology and band handover needs to be performed when

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

$$1g\_or\_10gSAR1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_Plimit1} \times 1g\_or\_10gSAR\_P_{limit1}$$

Eq. 11-3

$$1g\_or\_10gSAR2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_Plimit2} \times 1g\_or\_10gSAR\_P_{limit2}$$

Eq. 11-4

$$\frac{\frac{1}{Tsar}\left[\int_{t-Tsar}^{t1} 1g\_or10gSAR1(t)dt + \int_{t1}^{t} 1g\_or10gSAR2(t)dt\right]}{FCC\ SAR\ Limit}$$

Eq. 11-5

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_ Plimit _1*, and *1g_or_10gSAR_ Plimit _1*correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at Plimit, and measured *1gSAR* or *10gSAR* value at Plimit of technology1/band1; *conducted_Tx_power_2(t)*, *conducted_Tx_power_ Plimit _2(t)*, and *1g_or_10gSAR_ Plimit _2* correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at Plimit, and measured *1gSAR* or *10gSAR* value at Plimit of technology2/band2.

Test procedure

1. Measure Plimit for both the technologies and bands selected in Section 9.2.3. Measure Plimit with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit

3. Establish radio link with callbox in first technology/band selected.

4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for about ~60 seconds, and then switch to second technology/band selected. Continue with callbox requesting EUT to transmit at maximum Tx power for the remaining time of at least another 100 seconds. Measure and record Tx power versus time for the full duration of the test.

5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value using Eq. 11-3 and Eq. 11-4 and corresponding measured Plimit values from Step 1 of this section. Perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   NOTE: In Eq. 11-3 & Eq. 11-4, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at Plimit for the corresponding technology/band/antenna/DSI reported in Part 1 report.

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

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

The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 11-5).

11.4 Change in antenna

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

NOTE: If the EUT does not support antenna switch within the same technology/band, but has multiple antennas to support different frequency bands, then the antenna switch test is included as part of change in technology and band (Section11.3) test.

11.5 Change in DSI

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

11.6 Change in time window

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

$$1g\_or\_10gSAR1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_Plimit1} \times 1g\_or\_10gSAR\_P_{limit1}$$

Eq. 11-6

$$1g\_or\_10gSAR2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_Plimit2} \times 1g\_or\_10gSAR\_P_{limit2}$$

Eq. 11-7

$$\frac{\frac{1}{T1sar}\left[\int_{t-Tsar}^{t1} 1g\_or10gSAR1(t)dt\right]}{FCC\ SAR\ Limit} + \frac{\frac{1}{T2sar}\left[\int_{t1}^{t} 1g\_or10gSAR2(t)dt\right]}{FCC\ SAR\ Limit}$$

Eq. 11-8

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_Plimit_1*, and *1g_or_10gSAR_Plimit_1* correspond to the instantaneous Tx power, conducted Tx power at Plimit, and compliance *1g_or_10gSAR* values of band1 at *Plimit_1*; *conducted_Tx_power_2(t)*, *conducted_Tx_power_Plimit_2*, and *1g_or_10gSAR_Plimit_2* correspond to the instantaneous Tx power, conducted Tx power at Plimit, and compliance *1g_or_10gSAR* values of band2 at *Plimit_2*. One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window '$T1_{SAR}$' to the second band with time-averaging window '$T2_{SAR}$' happens at time-instant 't_1'.
Test procedure:

1. Measure *Plimit* for both the technologies and bands selected in Section 9.2.6. Measure *Plimit* with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value and enable Smart Transmit

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

3. Establish radio link with callbox in the technology/band having 100s time window selected in Section 9.2.6.

4. Request EUT's Tx power to be at 0 dBm for at least 100 seconds, followed by requesting EUT's Tx power to be at maximum power for about ~140 seconds, and then switch to second technology/band (having 60s time window) selected in Section 9.2.6. Continue with callbox requesting EUT's Tx power to be at maximum power for about ~60s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for at least another 100s. Measure and record Tx power versus time for the entire duration of the test.

5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 1gSAR value (see Eq. 11-6 and Eq. 11-7) using corresponding technology/band Step 1 result, and then perform 100s running average to determine time averaged 1gSAR or 1gSAR versus time. Note that in Eq. 11-6 & Eq. 11-7, instantaneous Tx power is converted into instantaneous 1gSAR or 1gSAR value by applying the worst-case 1gSAR or 1gSAR value tested in Part 1 for the selected technologies/bands at Plimit.

6. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 4.

7. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 5, (b) computed time-averaged 1gSAR versus time determined in Step 5, and (c) corresponding regulatory 1gSARlimit of 1.6W/kg or 1gSAR limit of 1.6W/kg.

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

8. Establish radio link with callbox in the technology/band having 60s time window selected in Section 9.2.6

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

10. Repeat above Step 5~7 to generate the plots

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

11.7 SAR exposure switching

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

Test procedure:

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

    a. Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 Plimit with Smart Transmit enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power.

    b. Repeat above step to measure conducted Tx power corresponding to radio2 Plimit. If radio2 is dependent on radio1 (for example, non-standalone mode of Sub6 NR requiring radio1 LTE as anchor), then establish radio1 + radio2 call with callbox, and request all down bits for radio1 LTE. In this scenario, with callbox requesting maximum power from radio2 Sub6 NR, measured conducted Tx power corresponds to radio2 Plimit (as radio1 LTE is at all-down bits)

2. Set Reserve_power_margin to actual (intended) value, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one-time window. After one-time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one-time window and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one-time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.

3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR or 1gSAR value (see Eq. 11-3 and Eq. 11-4) using corresponding technology/band Plimit measured in Step 1, and then perform the running time average to determine time-averaged 1gSAR or 1gSAR versus time.

4. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.

5. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3.

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

12 Test procedure for SAR measurements

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

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

1. "Path Loss" calibration: Place the EUT against the phantom in the worst-case position determined based on Section 9.2.1. For each band selected, prior to SAR measurement, perform "path loss" calibration between callbox antenna and EUT. Since the SAR test environment is not controlled and well calibrated for OTA (Over the Air) test, extreme care needs to be taken to avoid the influence from reflections. The test setup is described in Section 17.3 .

2. Time averaging algorithm validation:
    a. For a given radio configuration (technology/band) selected in Section 9.2.1, enable Smart Transmit and set *Reserve_power_margin* to 0 dB, with callbox to request maximum power, perform area scan, conduct pointSAR measurement at peak location of the area scan. This point SAR value, *pointSAR_Plimit*, corresponds to point SAR at the measured Plimit (i.e., measured Plimit from the EUT in Step 1 of Section 11.1).
    b. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit. Note, if *Reserve_power_margin* cannot be set wirelessly, care must be taken to re-position the EUT in the exact same position relative to the SAM or ELI phantom as in above Step 2.a. Establish radio link in desired radio configuration, with callbox requesting the EUT to transmit at power levels described by test sequence 1 generated in Step 1 of Section 11.1, conduct point SAR measurement versus time at peak location of the area scan determined in Step 2.a of this section. Once the measurement is done, extract instantaneous point SAR vs time data, pointSAR(t), and convert it into instantaneous 1gSAR or 10gSAR vs. time using Eq. 8-9.

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

    d. Make one plot containing: (a) time-averaged 1gSAR or 10gSAR versus time determined in Step 2.iii of this section, (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

    e. Repeat 2.b ~ 2.d for test sequence 2 generated in Step 1 of Section 11.1.

    f. Repeat 2.a ~ 2.e for all the technologies and bands selected in Section 9.2.1.

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

13 Test procedures for mmW radiated power measurements

Perform conducted power measurement (for f < 6GHz) and radiated power measurement (for f > 6GHz) for LTE + mmW transmission to validate Smart Transmit time averaging algorithm in the various transmission scenarios described in Section 8

Test procedure

1. Measure *P*, measure *Plimit* and calculate $P_{reserve}$ (= measured *Plimit* in dBm – *Reserve_power_margin* in dB).
   Test condition to measure *Pmax* and *Plimit* is:

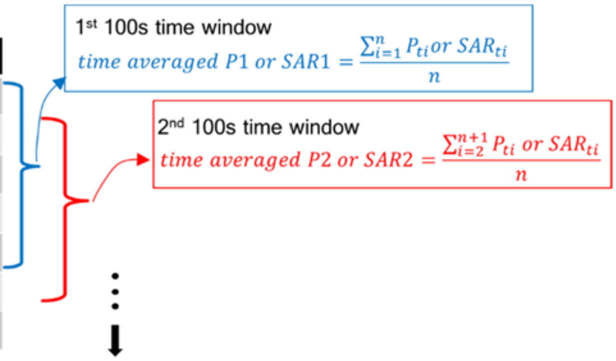
- Measure *Pmax* with Smart Transmit disabled and callbox set to request maximum power.
- Measure *Plimit* with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value (3dB for this EUT based on Part 1 report) and reset power on EUT to enable Smart Transmit, establish radio link in desired radio configuration, with callbox requesting the EUT to transmit at pre-defined test sequence1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. 8-1)) using measured *Plimit* from above Step 1. Perform 100s running average to determine time-averaged power and 1gSAR or 10gSAR versus timeas illustrated in Figure 3.

   NOTE: In Eq. 8-1, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSARvalue by applying the measured worst-case 1gSAR or 10gSAR value at *Plimit* for the corresponding technology/band/antenna/DSI reported in Part 1 report.
   NOTE: For an easier computation of the 100s running average, 0 dBm for 100s can be added at the beginning of the test sequences, so the 100s running average can be directly performed starting with the first 100-seconds data using software. This technique also applies to all tests performed in this Part 2 report for easier time- averaged computation using excel software.

Figure 4 100s running average illustration

Time	Power/SAR
t_1	P_{t1} or SAR_{t1}
t_2	P_{t2} or SAR_{t2}
:	:
:	:
t_n (t_1+100s)	P_{tn} or SAR_{tn}
t_{n+1} (t_2+100s)	P_{tn+1} or SAR_{tn+1}
:	:



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

$$time\ average\ power\ limit = meas.Plimit + 10 \times log(\frac{FCC\ SAR\ limit}{meas.SAR\_Plimit})$$

Eq. 13-1

where *meas. Plimit* and *meas.SAR_ Plimit* correspond to measured power at Plimit and measured SAR at Plimit.

$$Time\ averaged\ mmW\ NR\ power\ limit = meas.EIRPinput.power.limit + 10 \times log(\frac{FCC\ PD\ limit}{meas.PD\_input.power.limit})$$

Eq. 13-2

where $meas.EIRPinput.power.limit$ and $meas.PD\_input.power.limit$ correspond to measured EIRP at *input.power.limit* and measured power density at *input.power.limit*.

4. Make another plot containing:
    a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
    b. FCC 1gSARlimit of 1.6W/kg, FCC 10gSARlimit of 4.0W/kg or PD FCC limit of 10 W/m^2.

5. Repeat Steps 2 ~ 4 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 2 with test sequence 2.

6. Repeat Steps 2 ~ 5 for all the selected technologies and bands.

The validation criteria are, at all times, the time-averaged power versus time shown in Step 3 plot shall not exceed the time-averaged power limit (defined in Eq. 13-1), in turn, the time-averaged 1gSAR or 10gSAR versus time shown in Step 4 plot shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. 8-2).

13.1 Time-varying Tx power scenario

The purpose of the test is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged transmit power when converted into RF exposure values does not exceed the FCC limit at all times (see equation in Section 8).

Test procedure:

1. Measure conducted Tx power corresponding to *Plimit* for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:

    a. Measure radiated power corresponding to mmW *input.power.limit* by setting up the EUT to transmit in desired band/channel/beam at *input.power.limit* in Factory Test Mode (FTM). This test is performed in a calibrated anechoic chamber. Rotate the EUT to obtain maximum radiated Tx power, keep the EUT in this position and do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.

    b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE *Plimit* with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit. With EUT setup for a mmW NR call in the desired/selected LTE band and mmW NR band, perform the following steps:

    a. Establish LTE and mmW NR connection in desired band/channel/beam used in Step 1. As soon as the mmW connection is established, immediately request all-down bits on LTE link. With callbox requesting EUT to transmit at maximum mmW power to test predominantly PD exposure scenario (as SAR exposure is less when LTE transmits at low power).

b. After 120s, request LTE to go all-up bits for at least 100s. SAR exposure is dominant. There are two scenarios:

i. If $P_{limit} < P_{max}$ for LTE, then the RF exposure margin (provided to mmW NR) gradually runs out (due to high SAR exposure). This results in gradual reduction in the 5G mmW NR transmission power and eventually seized 5G mmW NR transmission when LTE goes to $P_{reserve}$ level.

ii. If $P_{limit} \geq P_{max}$ for LTE, then the 5G mmW NR transmission's averaged power should gradually reduce but the mmW NR connection can sustain all the time.

c. Record the conducted Tx power of LTE and radiated Tx power of mmW for the full duration of this test of at least 300s.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using Eq. 8-4 and *Plimit* measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1g or 10gSAR versus time.

   NOTE: In Eq. 8-4, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at Plimit for the corresponding technology/band/antenna/DSI reported in Part 1 report.

4. Similarly, convert the radiated Tx power for mmW into $4cm^2$PD value using Eq. 8-5 and the radiated Tx power limit (i.e., radiated Tx power at input.power.limit) measured in Step 1.a, then divide by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

   NOTE: In Eq. 8-5, instantaneous radiated Tx power is converted into instantaneous $4cm^2$PD by applying $4cm^2$PD value measured at *input.power.limit* for the selected band/beam.

Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as measured in Step 2, (d) computed 4s-averaged radiated Tx power for mmW versus time, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio using -1 and Eq. 11-2, respectively:

5. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged 4cm2PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (Eq. 8-8) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. 8-8).

13.2 Change in antenna configuration (beam)

This test is to demonstrate the correct power control by Smart Transmit during changes in antenna configuration (beam). Since the input.power.limit varies with beam, the Eq. 8-4, Eq. 8-5 and Eq. 8-8 in Section 8 are written as below for transmission scenario having change in beam,

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_Plimit} \times 1g\_or\_10gSAR\_P_{limit}$$

Eq. 13-3

$$4cm^2PD1(t) = \frac{\text{radiated\_Tx\_power\_1(t)}}{radiated\_Tx\_Power\_input.power.limit\_1} \times 4cm^2PD\_input.power.limit\_1$$

Eq. 13-4

$$4cm^2PD2(t) = \frac{\text{radiated\_Tx\_power\_2(t)}}{radiated\_Tx\_Power\_input.power.limit\_2} \times 4cm^2PD\_input.power.limit\_2$$

Eq. 13-5

$$\frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit} + \frac{\frac{1}{TPD}\left[\int_{t-Tpd}^{t1} 4cm^2PD1(t)dt + \int_{t1}^{t} 4cm^2PD2(t)dt\right]}{FCC\ 4cm^2PD\ Limit} \leq 1$$

Eq. 13-6

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_Plimit$, and $1g\_or\_10gSAR\_Plimit$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at *Plimit*, and measured *1gSAR or 10gSAR* values at *Plimit* corresponding to LTE transmission. Similarly, *radiated_Tx_power_1(t)*, *radiated_Tx_power_input.power.limit_1*, and *4cm2PD_input.power.limit_1* correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit*, and *4cm2PD* value at *input.power.limit* of beam 1; *radiated_Tx_power_2(t)*, *radiated_Tx_power_input.power.limit_2*, and *4cm2PD_input.power.limit_2* correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit*, and *4cm2PD* value at *input.power.limit* of beam 2 corresponding to mmW transmission.

Test procedure:

1. Measure conducted Tx power corresponding to *Plimit* for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:

    a. Measure radiated power corresponding to mmW *input.power.limit* by setting up the EUT in FTM and to transmit in desired band/channel at *input.power.limit* of beam 1. Do not disturb the position of the EUT inside the anechoic chamber for the rest of this test. Repeat this Step 1.a for beam 2.

    b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE *Plimit* 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 in EUT, With EUT setup for LTE + mmW connection, perform the following steps:

    a. Establish LTE (sub-6) and mmW NR connection in beam 1. As soon as the mmW connection is established, immediately request all-down bits on LTE link with the callbox requesting EUT to transmit at maximum mmW power.

    b. After beam 1 transmits for at least 20s, request the EUT to change from beam 1 to beam 2, and continue transmitting with beam 2 for at least 20s.

c. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using the similar approach described in Step 3 of Section 4.3.2. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time.

4. Similarly, convert the radiated Tx power for mmW NR into $4cm^2$PD value using Eq. 13-4, Eq. 13-5 and the radiated Tx power limits (i.e., radiated Tx power at *input.power.limit*) measured in Step 1.a for beam 1 and beam 2, respectively, and then divide the resulted PD values by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time for beam 1 and beam 2. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

   NOTE: In Eq. 13-4 and Eq. 13-5, instantaneous radiated Tx power of beam 1 and beam 2 is converted into instantaneous $4cm^2$PD by applying the worst-case $4cm^2$PD value measured at the *input.power.limit* of beam 1 and beam 2 in Part 1 report, respectively.

5. Since the measured radiated powers for beam 1 and beam 2 in Step 1.a were performed at an arbitrary rotation of EUT in anechoic chamber, repeat Step 1.a of this procedure by rotating the EUT to determine maximum radiated power at *input.power.limit* in FTM mode for both beams separately. Re-scale the measured instantaneous radiated power in Step 2.c by the delta in radiated power measured in Step 5 and the radiated power measured in Step 1.a for plotting purposes in next Step. In other words, this step essentially converts measured instantaneous radiated power during the measurement in Step 2 into maximum instantaneous radiated power for both beams. Perform 4s running average to compute 4s-avearged radiated Tx power. Additionally, use these EIRP values measured at *input.power.limit* at respective peak locations to determine the EIRP limits both these beams.

6. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as obtained in Step 5, (d) computed 4s-averaged radiated Tx power for mmW versus time, as obtained in Step 5, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio, respectively.

7. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged $4cm^2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (Eq. 13-6) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. 13-6).

13.3 Switch in SAR vs. PD exposure during transmission

This test is to demonstrate that Smart Transmit algorithm is independent of the nature of exposure (SAR vs. PD), accurately accounts for switching in exposures among SAR dominant, SAR+PD, and PD dominant scenarios, and ensures total time-averaged RF exposure compliance.

Test procedure:

1. Measure conducted Tx power corresponding to *Plimit* for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:
   a. Measure radiated power corresponding to *input.power.limit* by setting up the EUT to transmit in desired band/channel/beam at *input.power.limit* in FTM. This test is performed in a calibrated anechoic chamber. Rotate the EUT to obtain maximum radiated Tx power, keep the EUT in this position and do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.

b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE *Plimit* 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 in EUT, with EUT setup for LTE + mmW call, perform the following steps:
   a. Establish LTE (sub-6) and mmW NR connection with callbox.

   b. As soon as the mmW connection is established, immediately request all-down bits on LTE link. Continue LTE (all-down bits) + mmW transmission for more than 100s duration to test predominantly PD exposure scenario (as SAR exposure is negligible from all-down bits in LTE).

   c. After 120s, request LTE to go all-up bits, mmW transmission should gradually run out of RF exposure margin if LTE's $P_{limit} < P_{max}$ and seize mmW transmission (SAR only scenario); or mmW transmission should gradually reduce in Tx power and will sustain the connection if LTE's $Plimit > Pmax$.

   d. After 75s, request LTE to go all-down bits, mmW transmission should start getting back RF exposure margin and transmit again.

   e. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of at least 300s.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using Eq. 8-4 and *Plimit* measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time.

   NOTE: In Eq. 8-4, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at *Plimit* for the corresponding technology/band/antenna/DSI reported in Part 1 report.

4. Similarly, convert the radiated Tx power for mmW into 4cm2PD value using Eq. 8-5 and the radiated Tx power limit (i.e., radiated Tx power at *input.power.limit*) measured in Step 1.a, then divide this by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized 4cm2PD versus time. Perform 4s running average to determine normalized 4s-averaged 4cm2PD versus time.

   NOTE: In Eq. 8-5, instantaneous radiated Tx power is converted into instantaneous $4cm^2$PD by applying the worst-case $4cm^2$PD value measured at input.power.limit for the selected band/beam in Part 1 report.

5. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as measured in Step 2, (d) computed 4s-averaged radiated Tx power for mmW versus time, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio using -1 &Eq. 11-2, respectively.

6. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged 4cm2PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (Eq. 8-8) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. 8-8).

14 Test procedure for PD measurements

The following steps are used to perform the validation through PD measurement for transmission scenario 1 described in Section 2:

1. Place the EUT on the cDASY6 platform to perform PD measurement in the worst-case position/surface for the selected mmW band/beam. In PD measurement, the callbox is set to request maximum Tx power from EUT all the time. Hence, "path loss" calibration between callbox antenna and EUT is not needed in this test.

2. Time averaging algorithm validation:

   a. Measure conducted Tx power corresponding to *Plimit* for LTE in selected band, and measure point E-field corresponding to *input.power.limit* in desired mmW band/channel/beam by following the below steps:

      i. Measure conducted Tx power corresponding to LTE *Plimit* with Smart Transmit enabled and Reserve_power_margin set to 0 dB, with callbox set to request maximum power.

      ii. Measure point E-field at peak location of fast area scan corresponding to input.power.limit by setting up the EUT to transmit in desired mmW band/channel/beam at input.power.limit in FTM Mode. Do not disturb the position of EUT and mmW cDASY6 probe.

   b. Set Reserve_power_margin to actual value (i.e., intended value) and reset power on EUT, place EUT in online mode. With EUT setup for LTE (sub-6) + mmW NR call, as soon as the mmW NR connection is established, request all-down bits on LTE link. Continue LTE (all-down bits) + mmW transmission for more than 100s duration to test predominantly PD exposure scenario. After 120s, request LTE to go all-up bits, mmW transmission should gradually reduce. Simultaneously, record the conducted Tx Simultaneously, record the conducted Tx power of LTE transmission using power meter and point E-field (in terms of ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ of mmW transmission using cDASY6 E-field probe at peak location identified in Step 2.a.ii for the entire duration of this test of at least 300s.

   c. Once the measurement is done, extract instantaneous conducted Tx power versus time for LTE transmission and $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ Once the measurement is done, extract instantaneous conducted Tx power versus time for 1gSAR value using Eq. 8-12 and *Plimit* measured in Step 2.a.i, and then divide this by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time
   NOTE: In Eq. 8-12, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at *Plimit* for the corresponding technology/band reported in Part 1 report.

   d. 1gSAR value using Eq. 8-12 and *Plimit* measured in Step 2.a.i, and then divide this by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time

      NOTE: In Eq. 8-12, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at *Plimit* for the corresponding technology/band reported in Part 1 report.

e. Make one plot containing: (i) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 2.c, (ii) computed normalized 4s-averaged $4cm^2$PD versus time determined in Step 2.d, and (iii) corresponding total normalized time-averaged RF exposure versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 2.e.iii shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. 8-16).

15 Validation criteria

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

15.1 Conducted power measurement

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

nominal Pmax - device uncertainty ≤ measured Pmax ≤ min{nominal Pmax + device uncertainty, rated Pmax}
nominal Plimit - device uncertainty ≤ measured Plimit ≤ min{nominal Plimit + device uncertainty, rated Pmax}

Express with another way, all measure power should be within the nominal power (Pmax/Plimit) +/- device uncertainty.

15.2 Time-varying Tx power

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

Sample calculation other than NR:
maximum of time-avg SAR = 0.8 W/kg
measured SAR@Plimit = 0.7 W/kg
device(sub6) uncert = 1.0 dB
10 log (0.8 / 0.7) = 0.580 dB then validated

Sample calculation for NR:
maximum of time-avg SAR = 0.65 W/kg
measured SAR@Plimit = 0.7 W/kg
device(sub6) uncert = 1.0 dB
reserved factor = 0.75
10 log (0.65 / 0.7 / 0.75) = 0.928 dB then validated

15.3 Call drop Tx power

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

Sample calculation is same as section 15.2

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

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

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

Sample calculation:
measured SAR1@Plimit1 = 0.7 W/kg
normalized measured SAR1@Plimit1 = 0.7 / 1.6 = 0.438

measured SAR2@Plimit2 = 0.6 W/kg
normalized measured SAR2@Plimit2 = 0.6 / 1.6 = 0.375

device(sub6) uncert = 1.0 dB

Lower criteria: min{0.438,0.375} - 1.0 dB =0.375 * $10^{(-1.0/10)}$ = 0.297
Higher criteria: max{0.438,0.375} + 1.0 dB =0.438 * $10^{(+1.0/10)}$ = 0.550

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

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

15.5 FR2 Time-varying Tx power

Maximum of time-avg normalized SAR (black curve) = normalized measured SAR@Plimit ± device(sub6 radio) uncertainty

Maximum of time-avg normalized PD (yellow curve) = normalized measured PD@input.power.limit ± device(mmW NR) uncertainty

The max combined exposure, i.e., max total.norm.time-avg.RF.exposure (green curve) < 1.0.

Sample calculation for sub 6 is same as section 15.2.

Sample calculation for NR:
measured PD@input.power.limit = 0.7 mW/cm^2
maximum of time-avg PD = 0.6 mW/cm^2
normalized measured SAR@Plimit = 0.7 / 1.0 = 0.7
device(mmW) uncert = 2.1 dB
reserved factor = 0.75
10 log (0.6 / 0.7 / 0.75) = 0.579 dB then validated

15.6 FR2 beam switch

The maximum of time-avg normalized PD of the 1st beam = measured normalized PD@corresponding input.power.limit ± device(mmW NR) uncertainty

The maximum of time-avg normalized PD of the 2nd beam = measured normalized PD@corresponding input.power.limit ± device(mmW NR) uncertainty

15.7 SAR vs PD exposure switch

norm.4s.4cm^{2}PD vs. time (yellow curve): the maximum of time-avg normalized PD = normalized measured PD@input.power.limit ± device(mmW NR) uncertainty

total.norm.time-avg.RF.exposure vs time: the maximum value of the combined exposure (green curve) < 1.0

Sample calculation for sub 6 is same as section15.5.

*For NR, reserved factor might be needed to calculation for RF exposure value per EFS version, such as 0.75 for EFS version 15 or lower and 1.00 for equal or 16 or higher.

EUT has the uncertainties 2.1 dB for mmW range, these values are used for validation criteria.

16 Test Configurations for Sub-6

16.1 Pmax Plimit

The Plimit values, corresponding to each DSI *SAR_design_target*, for technologies and bands supported by EUT are derived in Part 0 report and summarized in Table 16-1 *Plimit* for supported technologies and bands

Note all Plimit power levels entered in Table 16-1 *Plimit* for supported technologies and bands correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes (for e.g., GSM & LTE TDD).

DSI	State
0	Full power operation
1	Reduction power operation

The Plimit used in this report are determined and listed in Part 0 report.

If Pmax < Plimit then
Pmax is used for test
Else Plimit is used for test

Considering uncertainty and power tolerance, upper limit is specified as Plimit + 1 dB, Pmax + 1 dB.

Table 16-1 *Plimit* for supported technologies and bands

RAT	Force Peak	Band	Pmax	Plimit(DSI 0)	Plimit (DSI 1)
WCDMA		2	23.5	22.2	16.7
		4	22.7	21.8	17.6
		5	23.5	22.1	16.2
LTE		2	23.0	22.5	16.5
		4	23.0	21.5	17.0
		5	23.0	23.5	16.6
		7	23.0	22.1	16.8
		12	23.0	26.0	17.9
		13	23.0	23.7	17.1
		14	23.0	23.5	17.1
		17	23.0	26.1	18.2
		25	23.0	22.6	16.6
		26	23.0	22.3	16.6
		38	23.0	24.6	20.5
		41	23.0	25.5	19.1
	Y	42*	10.8	20.6	10.9
	Y	48*	9.9	21.1	11.3
		66	23.0	21.5	17.0
		71	23.0	24.4	18.1
NR		n2	23.5	22.4	17.4
		n5	23.5	23.2	17.0
		n41	20.5	20.8	11.2
		n66	22.5	20.8	17.0
		n71	23.5	25.3	18.4
		n77(FCC Block A)	23.5	19.1	8.0
		n77(FCC Block C)	23.5	19.1	8.0
	Y	n77(ISED)*	8.2	18.4	8.6
	Y	n78(ISED)*	8.2	18.4	8.6

If $P_{max} < P_{limit}$ then,
The EUT operates at P_{max} for static SAR measurement
else EUT transmit at P_{limit} for static SAR measurement
Below bands Plimit is converted to Pmax by applying above condition.

RAT	Force Peak	Band	Pmax	Plimit(DSI 0)	Plimit (DSI 1)
LTE		5	23.0	**23.0**	16.6
		12	23.0	**23.0**	17.9
		13	23.0	**23.0**	17.1
		14	23.0	**23.0**	17.1
		17	23.0	**23.0**	18.2
		38	23.0	**23.0**	20.5
		41	23.0	**23.0**	19.1
	Y	42*	10.8	**10.8**	**10.8**
	Y	48*	9.9	**9.9**	**9.9**
		71	23.0	**23.0**	18.1
NR		n41	20.5	**20.5**	11.2
		n71	23.5	**23.5**	18.4
	Y	n77(ISED)*	8.2	**8.2**	**8.2**
	Y	n78(ISED)*	8.2	**8.2**	**8.2**

Note(s):
- LTE band 42 is only for ISED, LTE band 48 is only for FCC.
- FCC support only n77, ISED supports both n77/n78
- Plimit(DSI 0 / 1) has a tolerance (±1 dB).
- Tune up limit = Plimit

Additional information

For LTE B48 (FCC)

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

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

For LTE B42(ISED)

Uplink Downlink config (UDC)	Special sub frame (SSF)	Burst ave tune up DSI=0/1 [dBm]	Pmax burst ave [dBm]	Time ave DSI=0/1 [dBm]
0	0 to 7	10.8	10.8	8.5
1	0 to 7	12.0	12.0	8.5
2	0 to 7	14.9	14.9	8.5
3	0 to 7	13.4	13.4	8.5
4	0 to 7	15.1	15.1	8.5
5	0 to 7	18.0	18.0	8.5
6	0 to 7	11.2	11.2	8.5

LTE band 42 doesn't have a same burst tune up for UDC/SSF but has same time average tune up limit.

* Maximum tune up output power, *Pmax*, is used to configure EUT during RF tune up procedure. The maximum allowed output power is equal to maximum tune up output power (+/- 1 dB power tolerance) + 1dB device uncertainty.

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

16.2 WWAN (sub-6) transmission configuration

Table 16-2 Radio configurations selected for part2 test.

Secnario	Test method	RAT	TA mode	Ant#	DSI	Dup.	Band	Mode	Freq [MHz]	Rbnum	RBp	Pmax [dBm]	MPR [dB]	meas. Pmax [dBm]	Plim [dBm]	meas Plimi [dBm]	meas. SAR [W/kg]
Time-varying	Cond. Power meas	WCDMA	TAE	1	0	FDD	2	RMC	1880.0	NA	NA	23.5	0.0	23.34	22.2	22.04	0.779
Tx power transmission	SAR meas.	WCDMA	TAE	1	0												
Time-varying	Cond. Power meas	WCDMA	TAE	1	1	FDD	5	RMC	836.6	NA	NA	23.5	0.0	23.31	16.2	15.98	0.626
Tx power transmission	SAR meas.	WCDMA	TAE	1	1												
Time-varying	Cond. Power meas	LTE	TAE	1	0	FDD	4	QPSK	1732.5	100	0	23.0	1.0	21.55	21.5	21.08	0.696
Tx power transmission	SAR meas.	LTE	TAE	1	0												
Time-varying	Cond. Power meas	LTE	TAE	1	1	FDD	2	QPSK	1860.0	100	0	23.0	1.0	21.89	16.5	16.41	0.672
Tx power transmission	SAR meas.	LTE	TAE	1	1												
Time-varying	Cond. Power meas	NR	TAE	1	0	FDD	n2	BPSK	1860.0	1	1	23.5	0.0	22.71	22.4	22.70	0.652
Tx power transmission	SAR meas.	NR	TAE	1	0												
Time-varying	Cond. Power meas	NR	TAE	1	1	TDD	n77	BPSK	3840.0	1	271	23.5	0.0	22.59	8.0	7.41	0.688
Tx power transmission	SAR meas.	NR	TAE	1	1												
Change in call	Cond. Power meas	NR	TAE	1	1	TDD	n77	BPSK	3840.0	1	271	23.5	0.0	22.59	8.0	7.41	0.688
Change in technology	Cond. Power meas	LTE	TAE	1	0	FDD	25	QPSK	1860.0	1	0	23.0	0.0	22.72	22.6	22.30	0.730
and band		WCDMA	TAE	1	1	FDD	5	RMC	836.6	NA	NA	23.5	0.0	23.31	16.2	15.98	0.626
Change in DSI	Cond. Power meas	LTE	TAE	1	1	FDD	66	QPSK	1770.0	50	24	23.0	1.0	22.07	17.0	17.08	0.782
				1	0	FDD	66	QPSK	1720.0	50	24	23.0	1.0	22.07	21.5	22.07	0.731
Change in time window	Cond. Power meas	LTE	TAE	1	1	FDD	5	QPSK	836.5	50	0	23.5	1.0	21.78	16.6	16.33	0.621
		LTE	FP	1	1	TDD	48	QPSK	3560.0	50	50	9.9	0.0	9.83	9.9	9.83	0.415
SAR exposure switching	Cond. Power meas	LTE	TAE	1	1	FDD	2	QPSK	1860.0	100	0	23.0	1.0	21.89	16.5	16.41	0.672
(ENDC)		NR	TAE	1	1	FDD	n5	BPSK	836.5	1	1	23.5	0.0	23.21	17.0	16.87	0.698

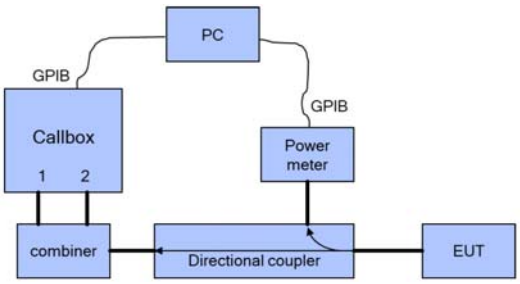
Notes

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

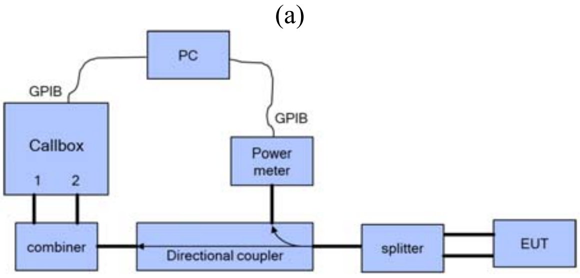
17 Conducted Power / SAR Test Results for Sub-6 Smart Transmit Algorithm Validation

17.1 Measurement setup for conducted power measurement.

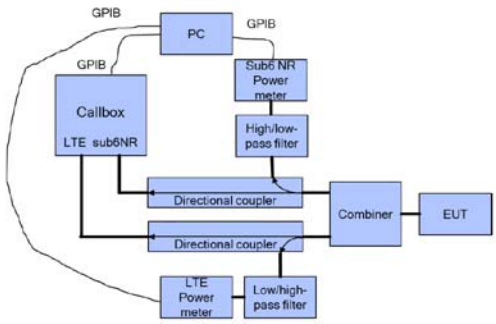
The Rohde & Schwarz CMW500 callbox is used in this test. The test setup picture and schematic are shown in below for measurements with a single antenna of EUT, and for measurements involving antenna switch. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port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



(a)



(b)



(c)

Figure 5 Example conducted power measurement setup

Both the callbox and power meter are connected to the PC using GPIB cables. Two test scriptsare custom made for automation, and the test duration set in the test scripts is 500 seconds.
For time-varying transmit power measurement, the PC runs the 1st test script to send GPIB commands to control the callbox's requested power versus time, while at the same time to record the conducted power measured at EUT RF port using the power meter. The commands sent to thecallbox to request power are:

1. 0dBm for 100 seconds
2. test sequence 1 or test sequence 2, for360 seconds
3. stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

Power meter readings are periodically recorded every 100ms. A running average of this measuredTx power over 100 seconds is performed in the post-data processing to determine the 100s-time averaged power.
For call drop, technology/band/antenna switch, and DSI switch tests, after the call is established,the callbox is set to request the EUT to transmit at 0dBm for 100 seconds while simultaneously starting the 2nd test script runs at the same time to start recording the Tx power measured at EUTRF port using the power meter. After the initial 100 seconds since starting the Tx power recording, the callbox is set to request maximum power from the EUT for the rest of the test.

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

17.2 Plimit and Pmax measurement results

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

Table 16-2 Radio configurations selected for part2 test.

Within the tune up limit , +/- 1dB

Validated

17.3 Measurement setup for SAR measurement.

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

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

Probe integration times depend on the communication signal being tested. Integration times used by SPEAG for their probe calibrations can be downloaded from here (integration time is listed on the bottom of the first page for each tech):
https://www.speag.com/assets/downloads/services/cs/UIDSummary171205.pdf

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

1. With *Reserve_power_margin* set to 0 dB, area scan is performed at *Plimit*, and time-averaged pointSAR measurements are conducted to determine the pointSAR at *Plimit*, denoted as *point*SAR*Plimit*.

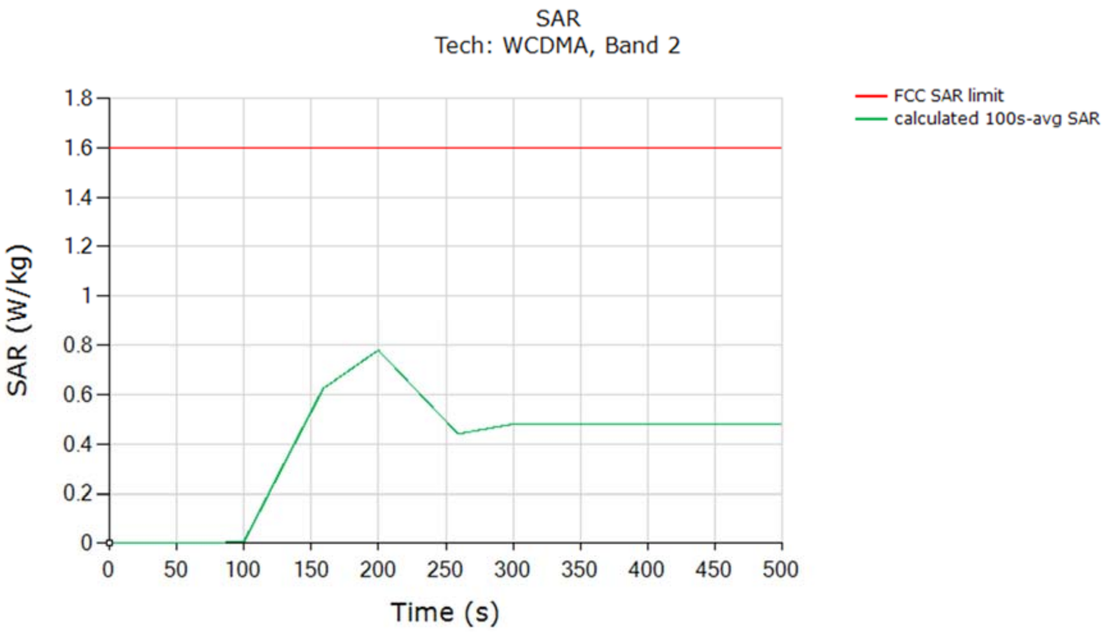
2. With *Reserve_power_margin* to actual (intended) value (see Table 3-1), two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

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

17.4 Time-varying Tx power measurement results

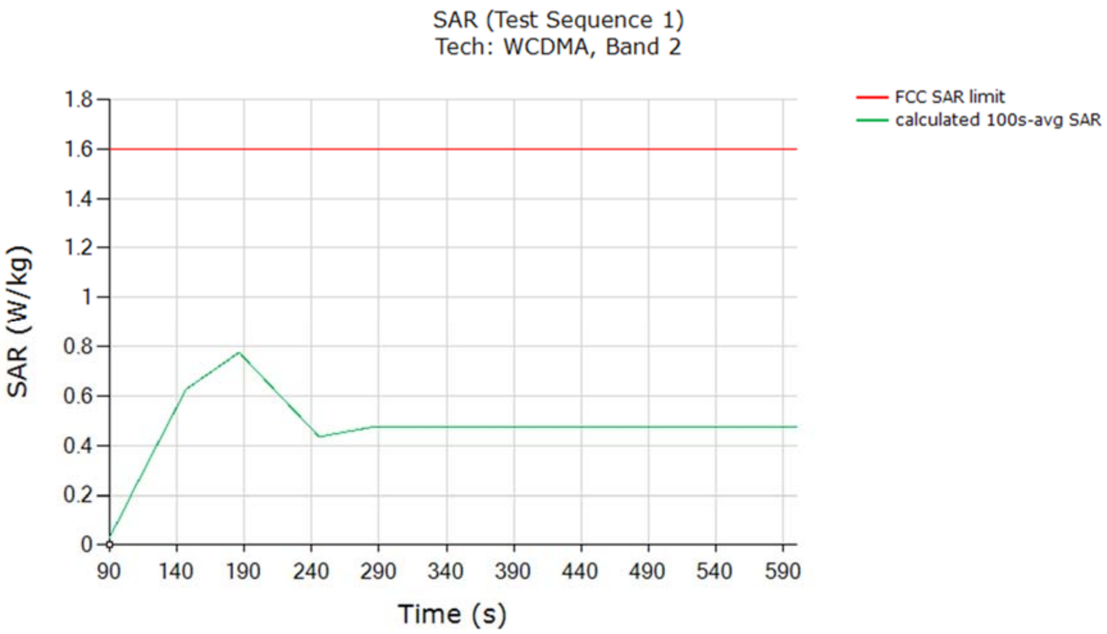
17.4.1 WCDMA band 2

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



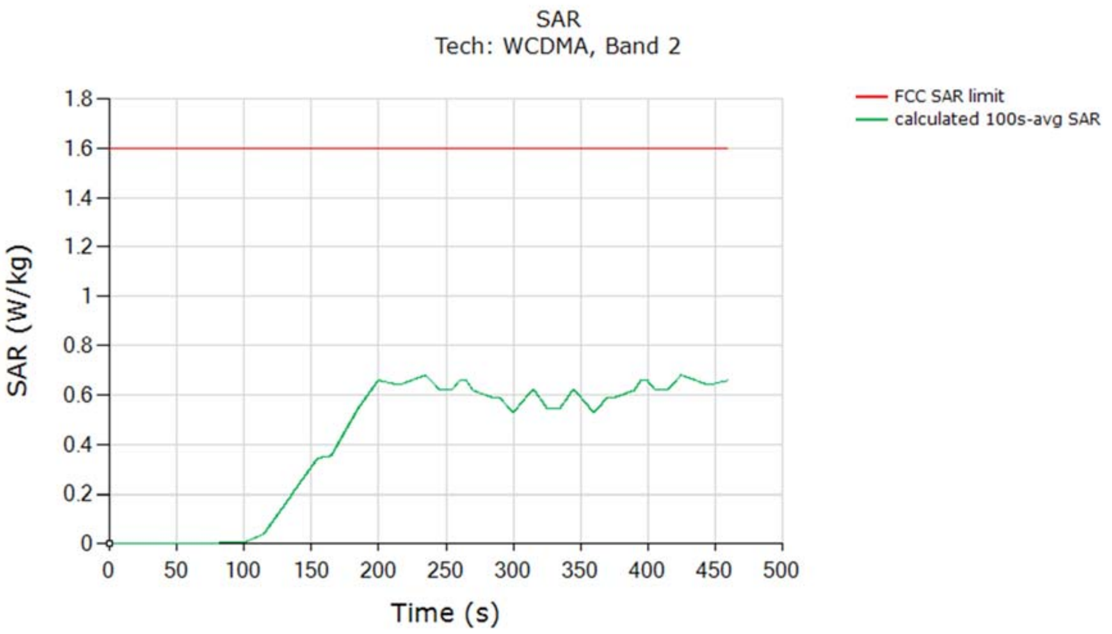
Max 100s SAR = 0.779
Max 100s SAR / Meas.SAR @ Plimit = -0.001 dB
Validated

Test result for test sequence 1 (SAR):



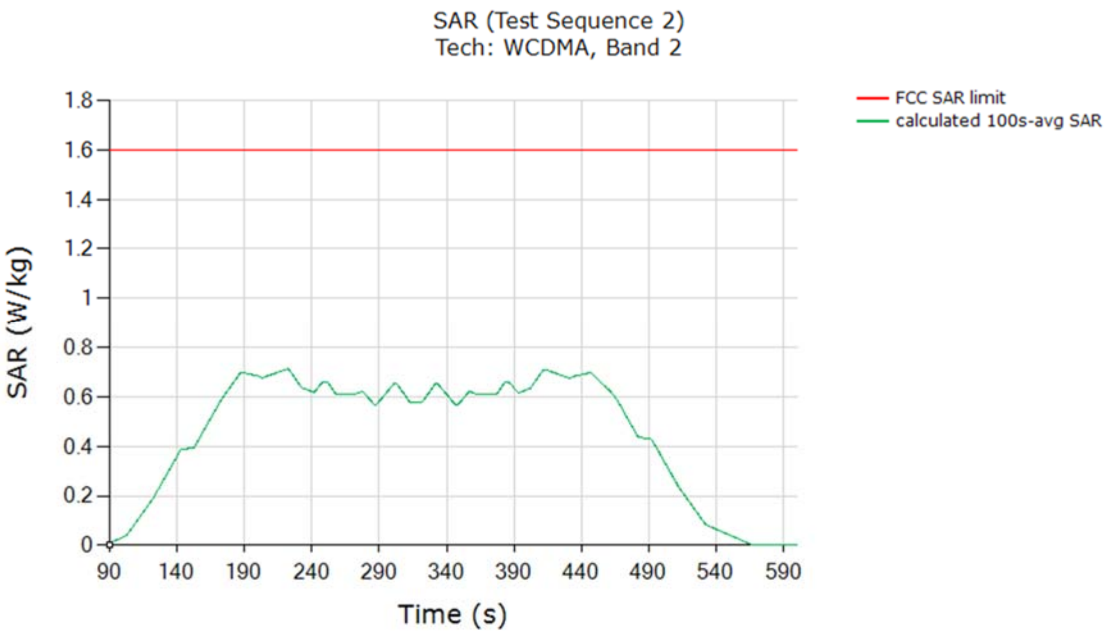
Max 100s SAR = 0.775 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.025 dB
Validated

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



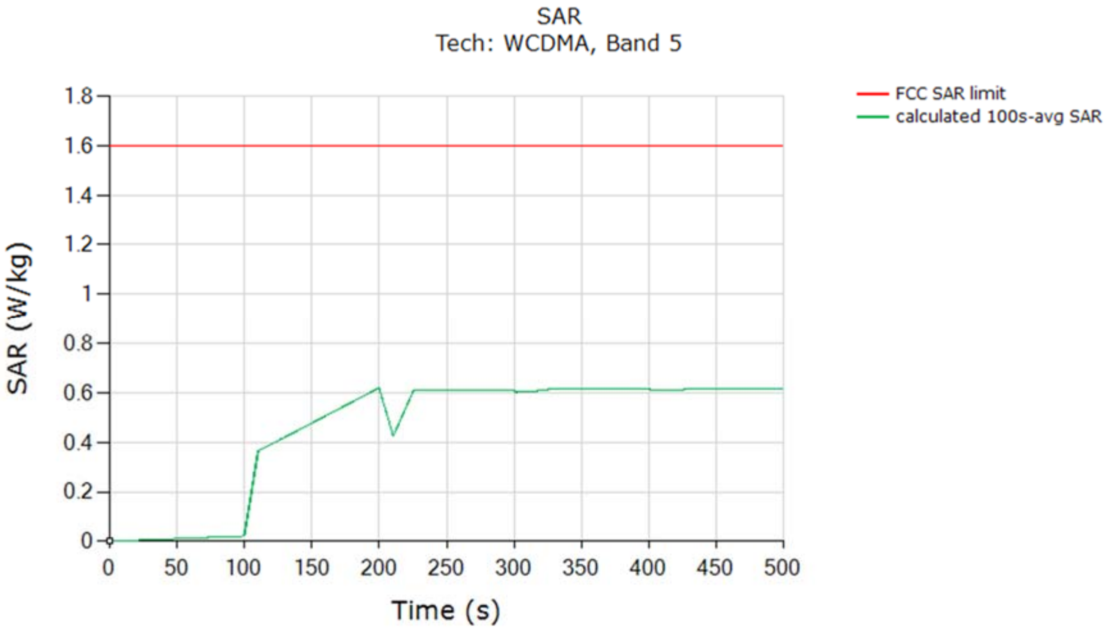
Max 100s SAR = 0.680
Max 100s SAR / Meas.SAR @ Plimit = -0.593 dB
Validated

Test result for test sequence 2 (SAR):



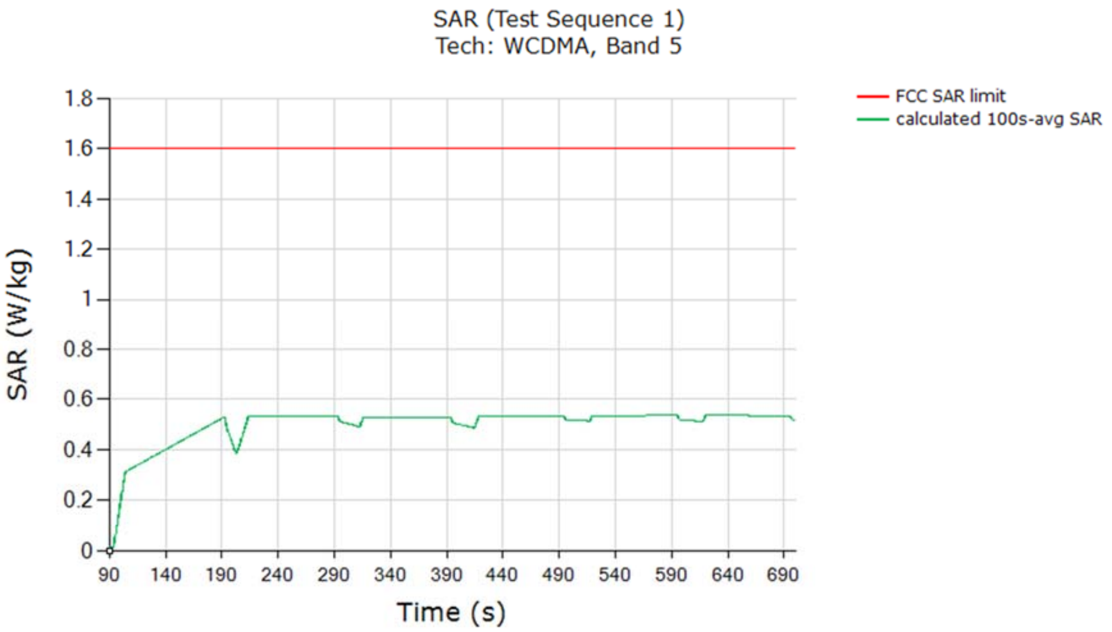
Max 100s SAR = 0.712 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.391 dB
Validated

17.4.2 WCDMA band 5
Test result for test sequence 1 (Conducted RF exposure):



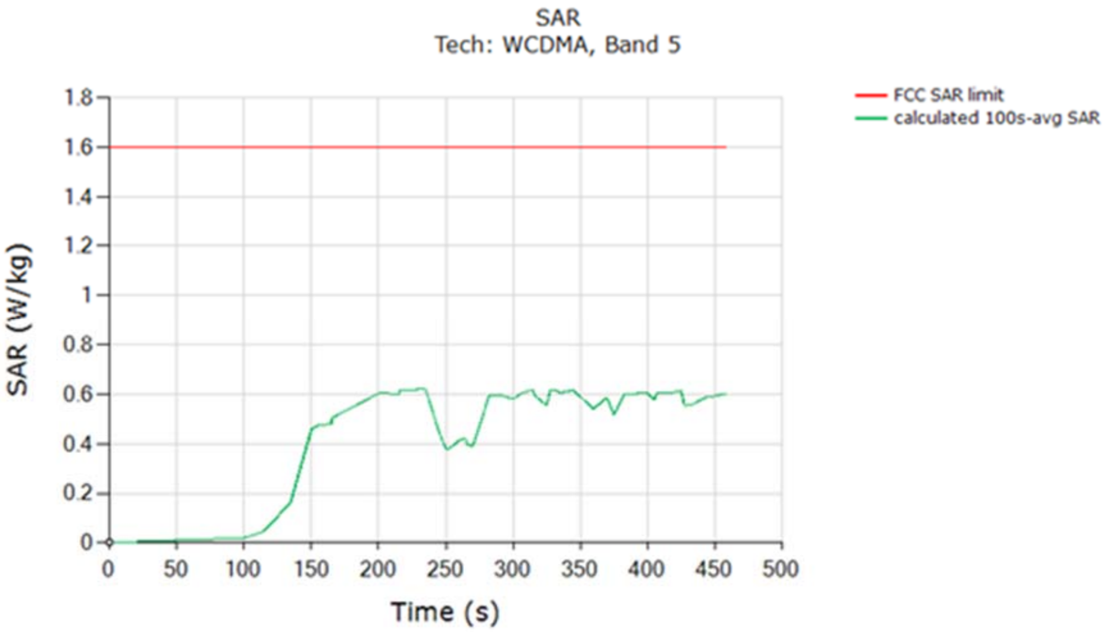
Max 100s SAR = 0.619 W/kg
Max 100s SAR / Meas.SAR @ Plimit = -0.046 dB
Validated

Test result for test sequence 1 (SAR):



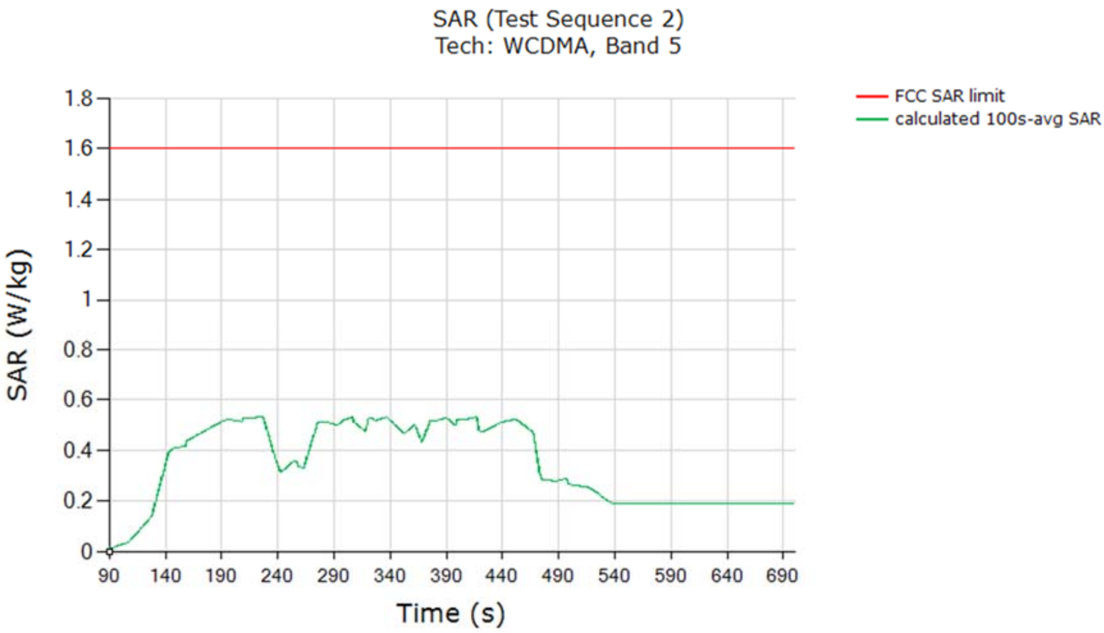
Max 100s SAR = 0.537 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.662 dB
Validated

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



Max 100s SAR = 0.619 W/kg
Max 100s SAR / Meas.SAR @ Plimit = -0.048 dB
Validated

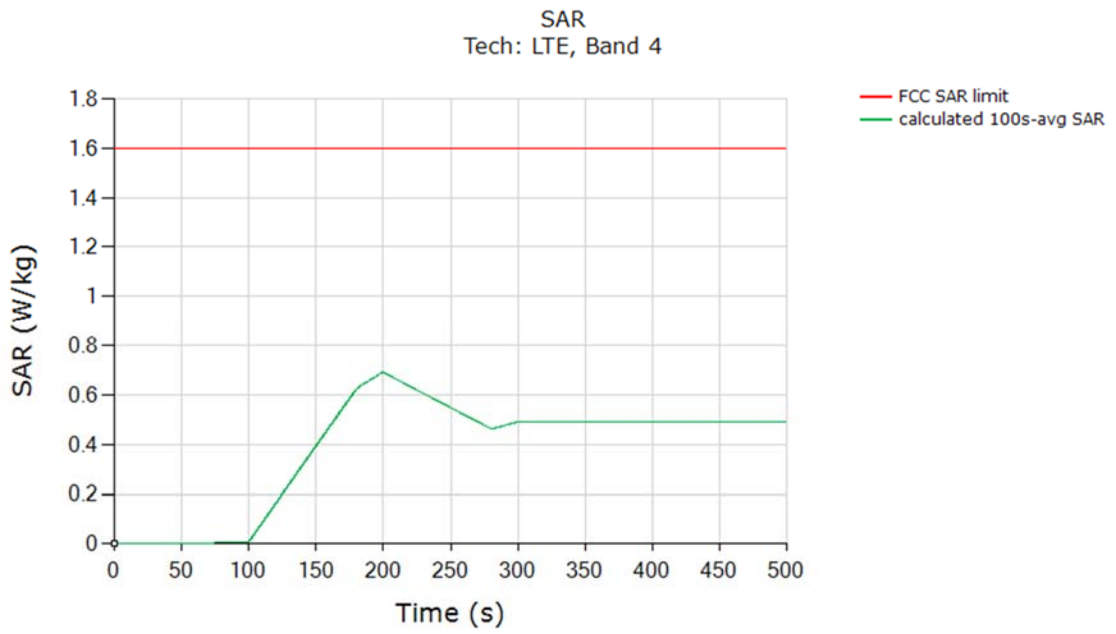
Test result for test sequence 2 (SAR):



Max 100s SAR = 0.532 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.710 dB
Validated

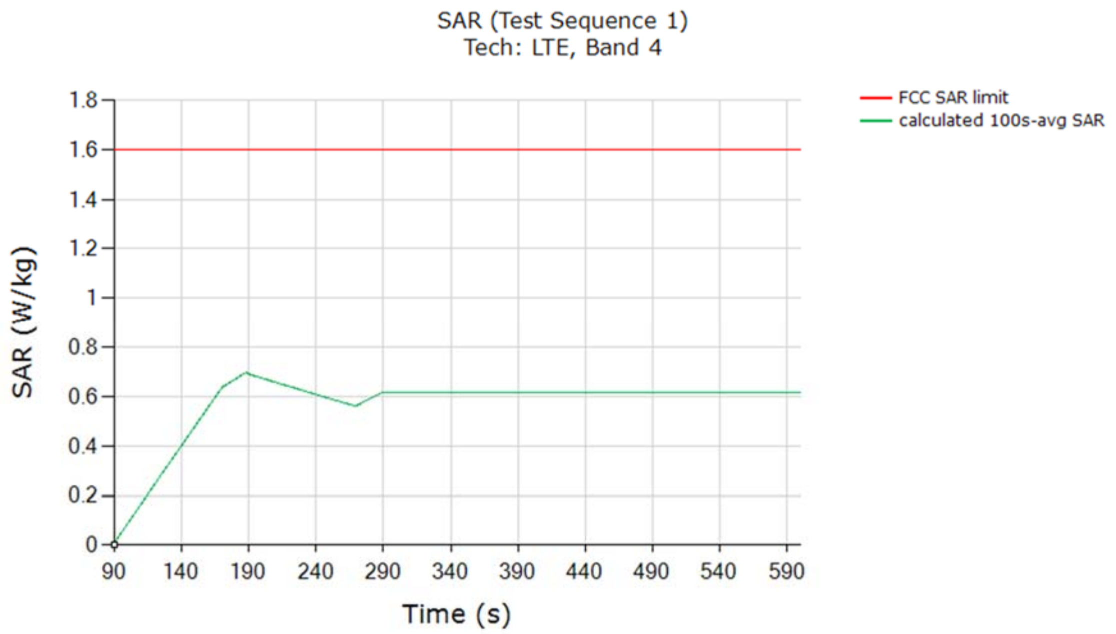
17.4.3 LTE band 4

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



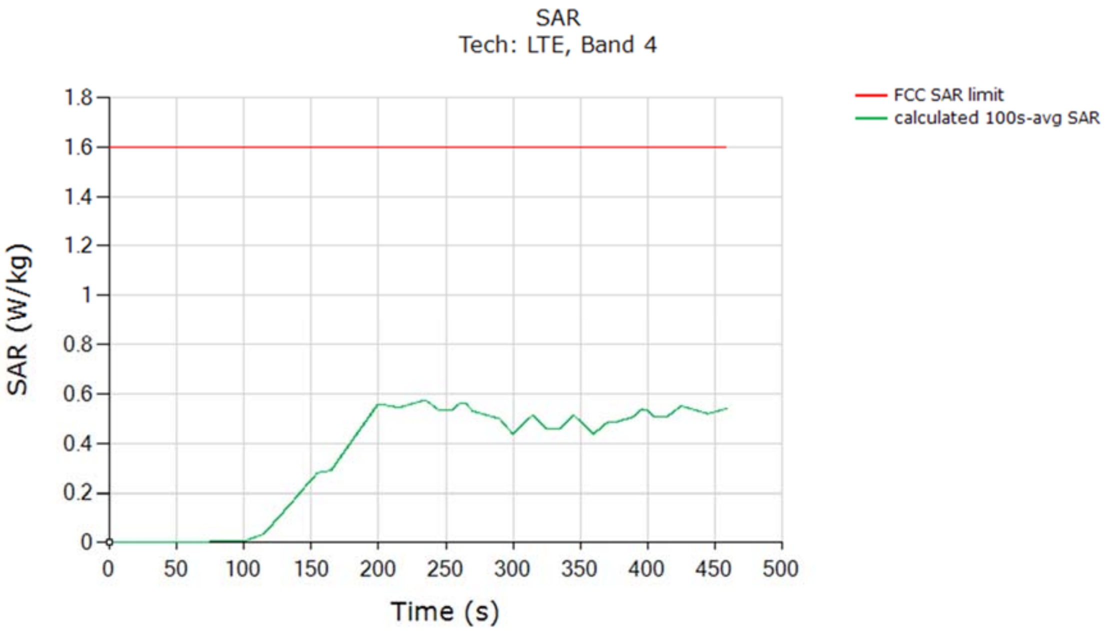
Max 100s SAR = 0.692
Max 100s SAR / Meas.SAR @ Plimit = -0.027 dB
Validated

Test result for test sequence 1 (SAR):



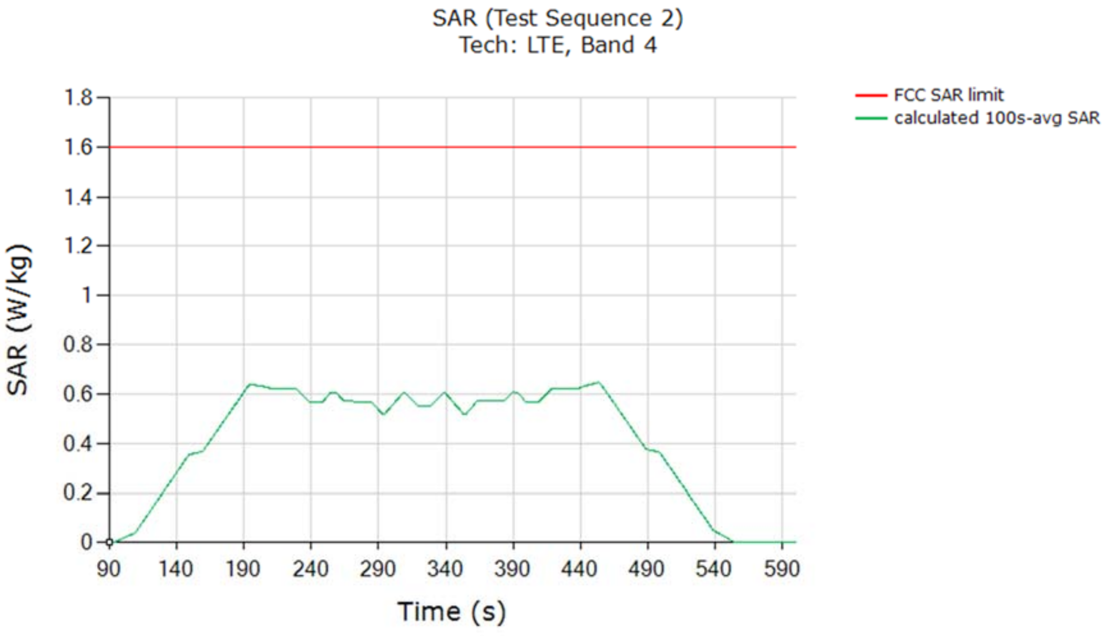
Max 100s SAR = 0.697 W/kg
Max 100s SAR / Meas. SAR @ Plimit = 0.007 dB
Validated

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



Max 100s SAR = 0.575
Max 100s SAR / Meas.SAR @ Plimit = -0.831 dB
Validated

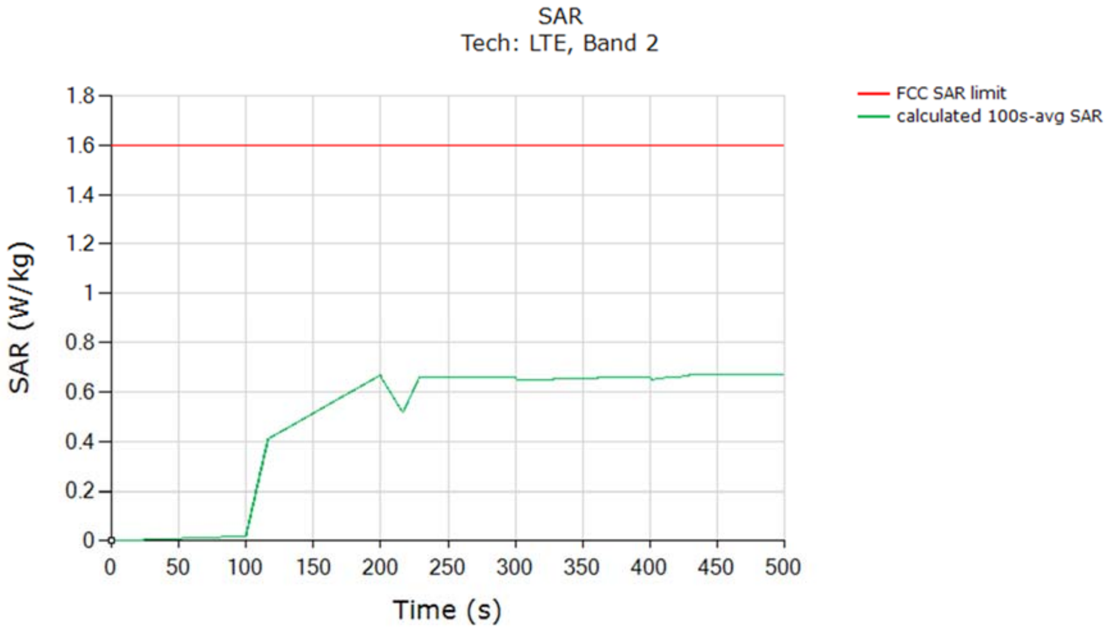
Test result for test sequence 2 (SAR):



Max 100s SAR = 0.646 W/kg
Max 100s SAR / Meas. SAR @ Plimit = -0.320 dB
Validated

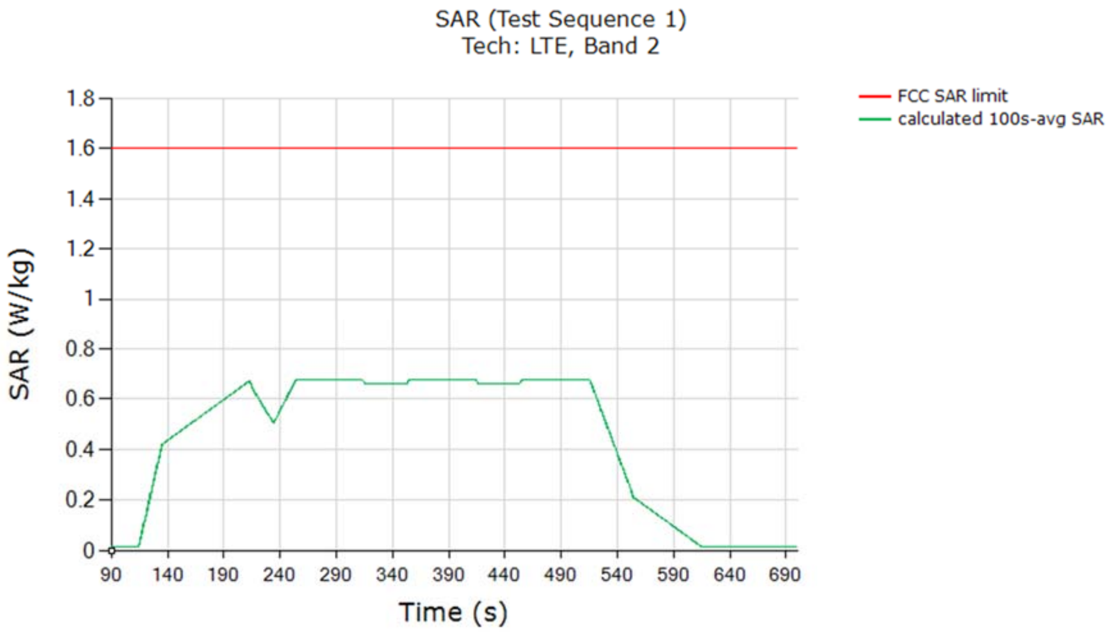
17.4.4 LTE band 2

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



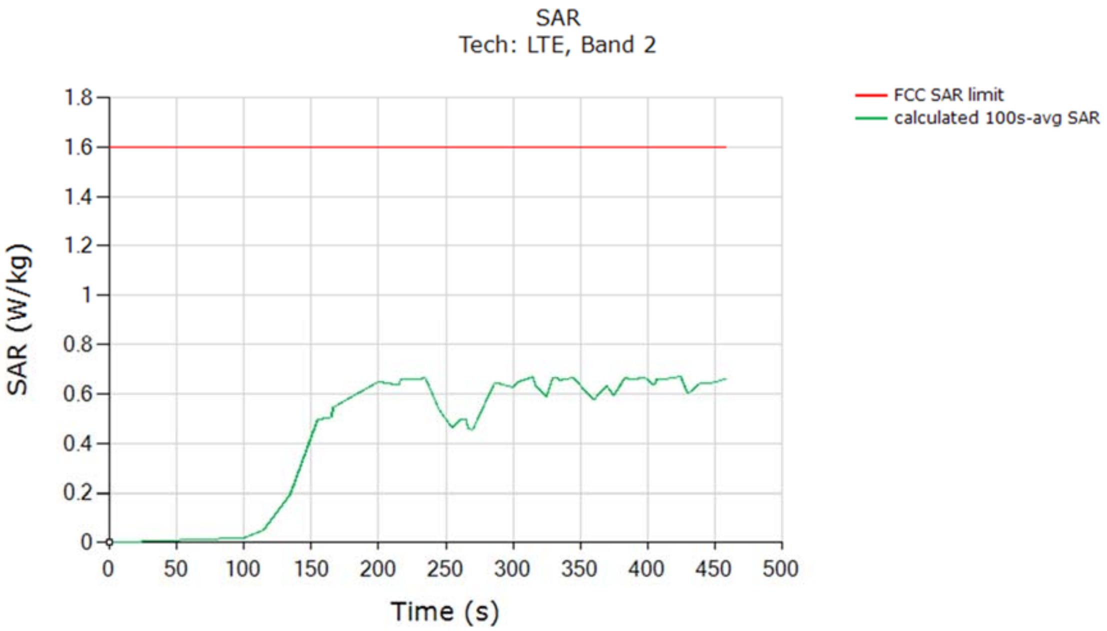
Max 100s SAR = 0.672
Max 100s SAR / Meas.SAR @ Plimit = -0.003 dB
Validated

Test result for test sequence 1 (SAR):



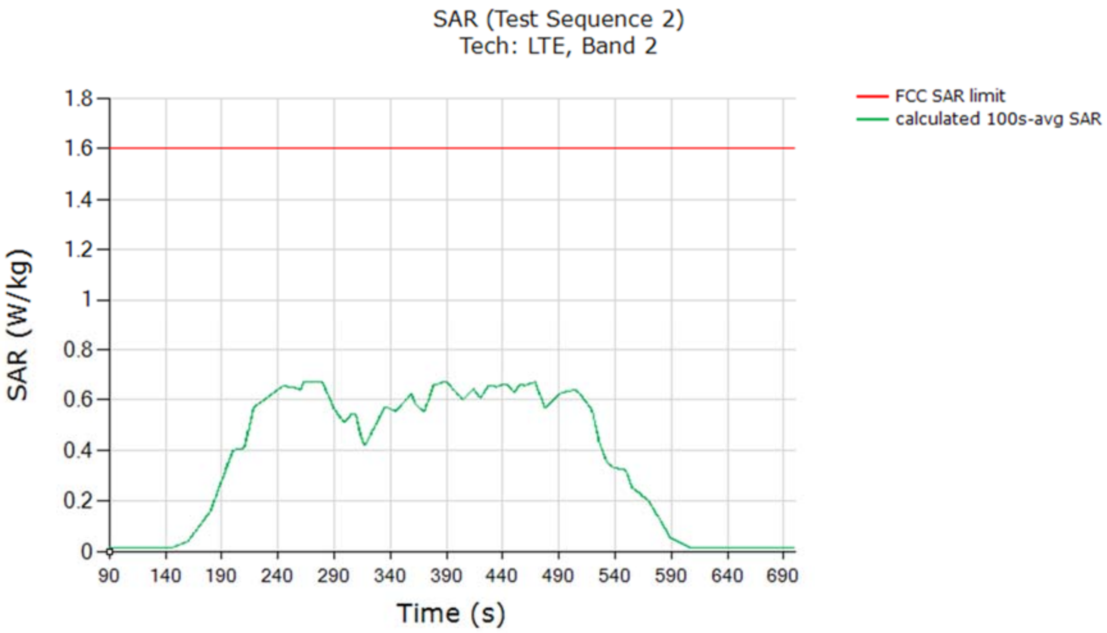
Max 100s SAR = 0.678 W/kg
Max 100s SAR / Meas. SAR @ Plimit = 0.039 dB
Validated

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



Max 100s SAR = 0.670
Max 100s SAR / Meas.SAR @ Plimit = -0.010 dB
Validated

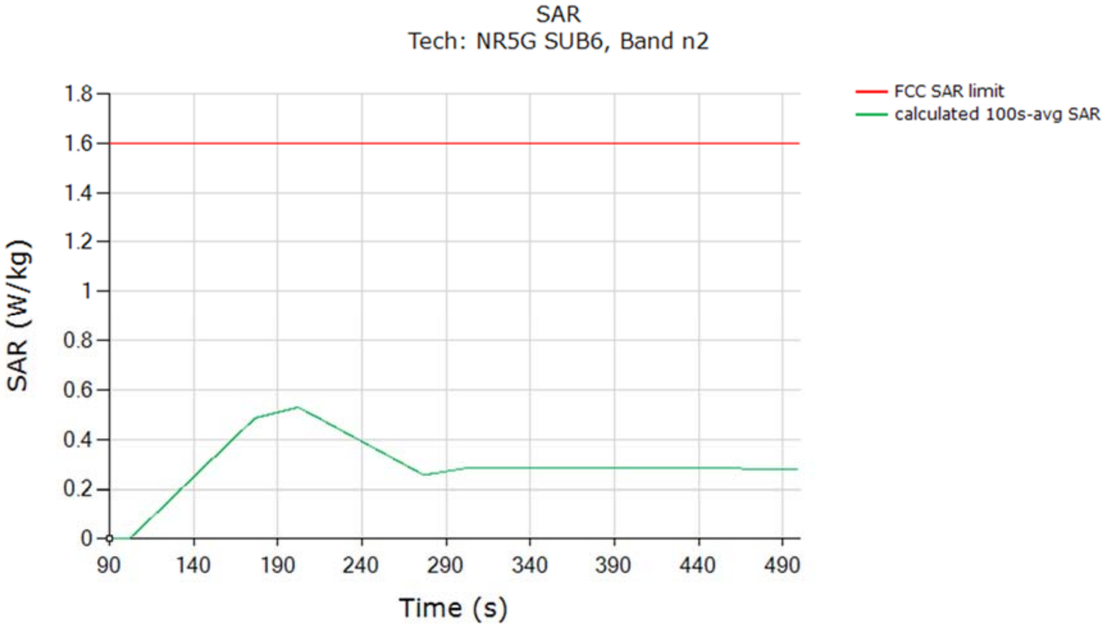
Test result for test sequence 2 (SAR):



Max 100s SAR = 0.673 W/kg
Max 100s SAR / Meas. SAR @ Plimit = 0.008 dB
Validated

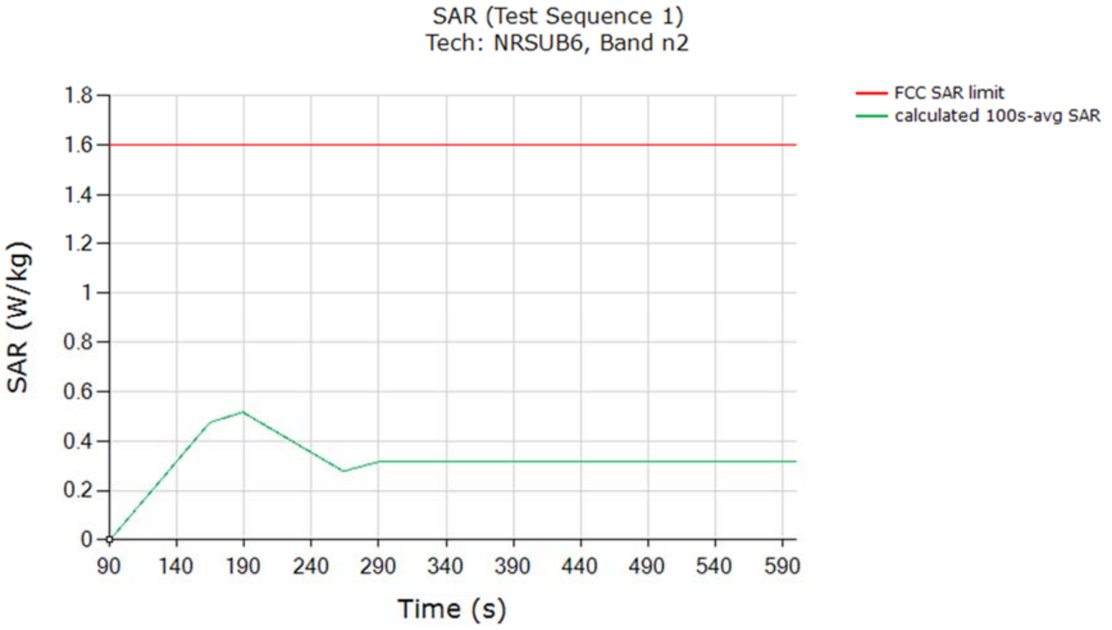
17.4.5 NR n2

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



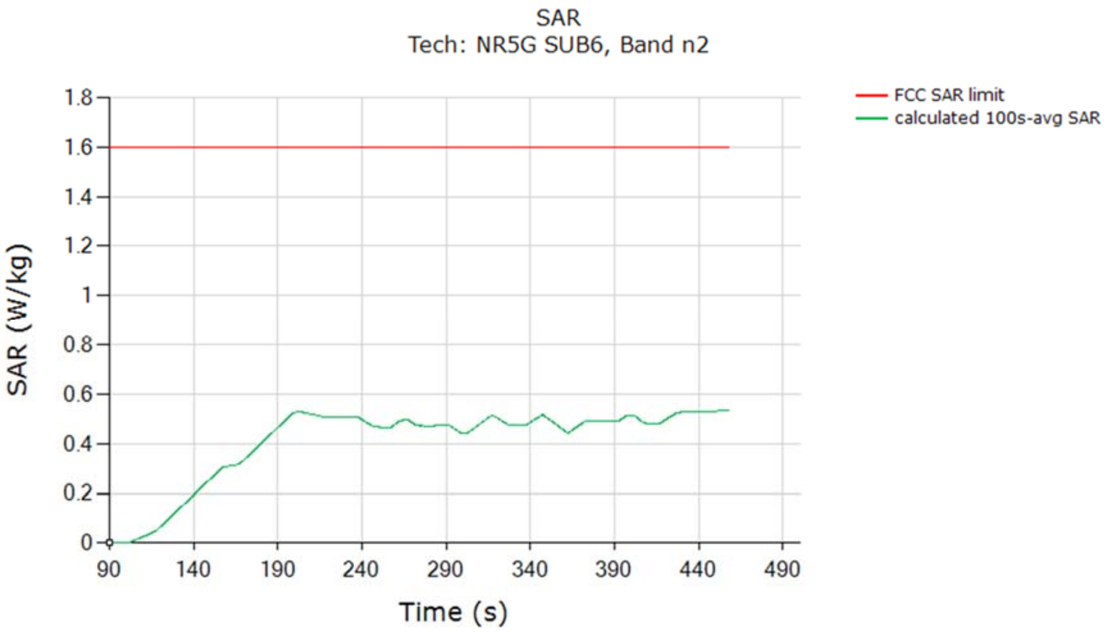
Max 100s SAR = 0.530
Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.347 dB
Validated

Test result for test sequence 1 (SAR):



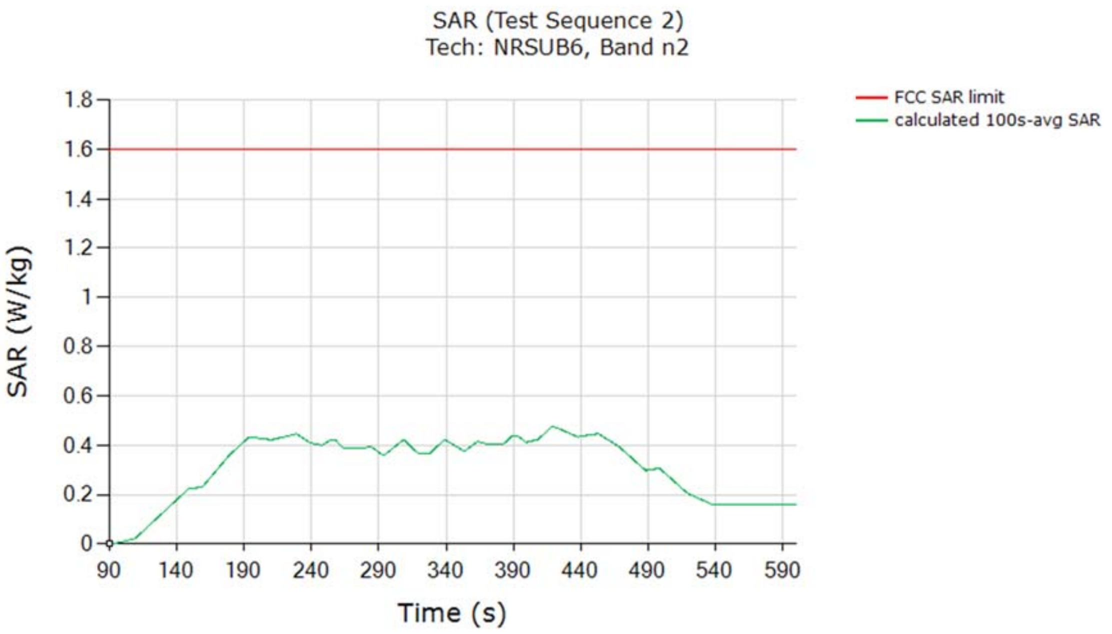
Max 100s SAR = 0.516 W / kg
Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.234 dB
Validated

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



Max 100s SAR = 0.534
Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.380 dB
Validated

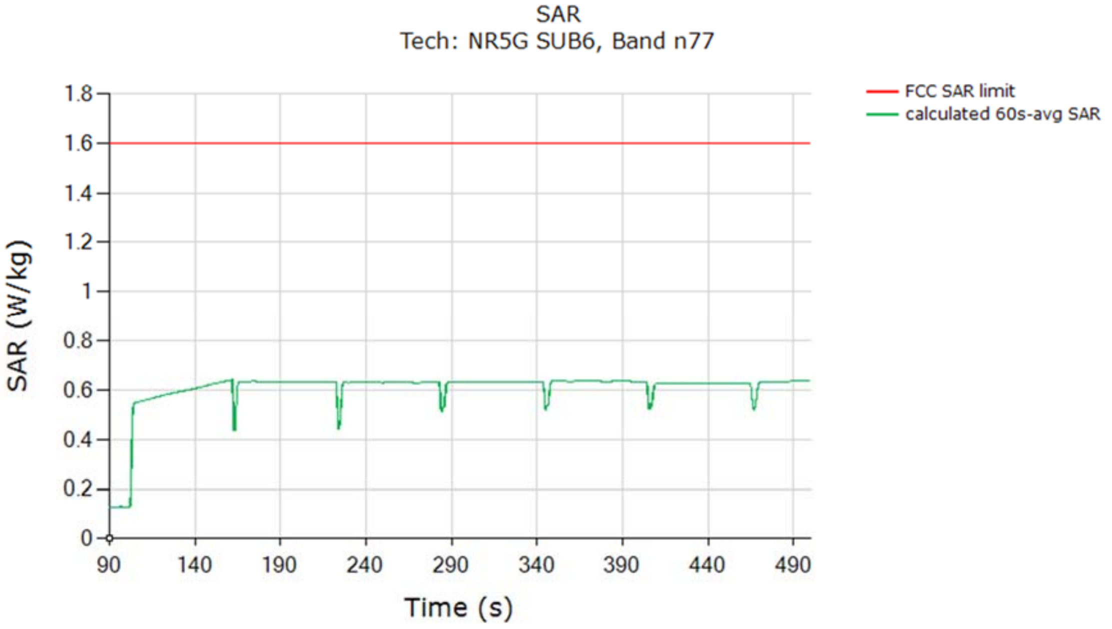
Test result for test sequence 2 (SAR):



Max 100s SAR = 0.474 W / kg
Max 100s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = -0.136 dB
Validated

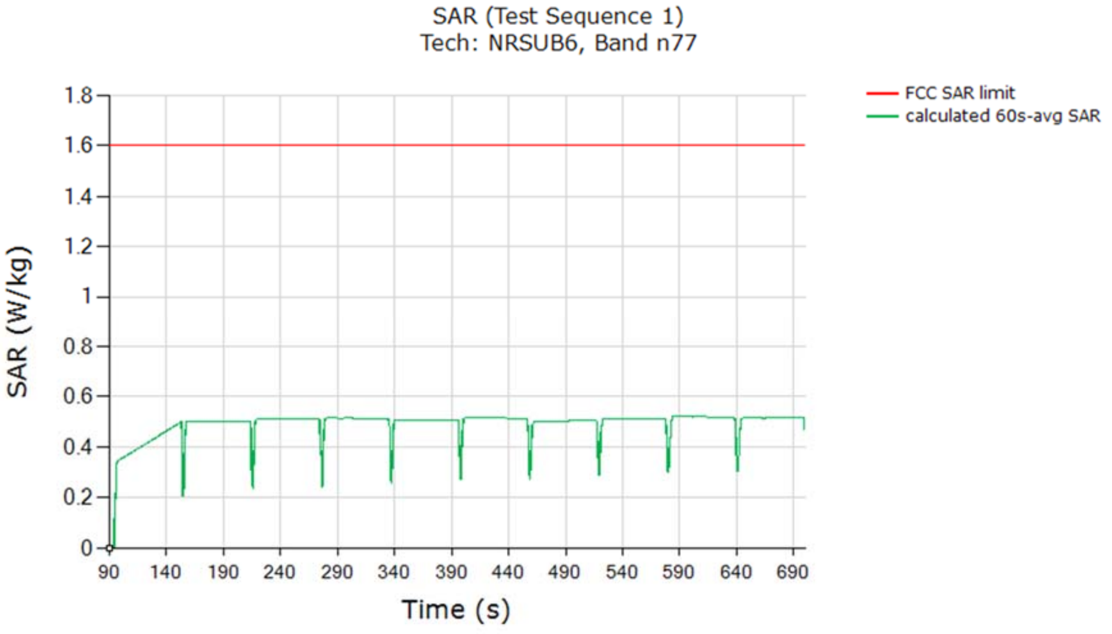
17.4.6 NR n77

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



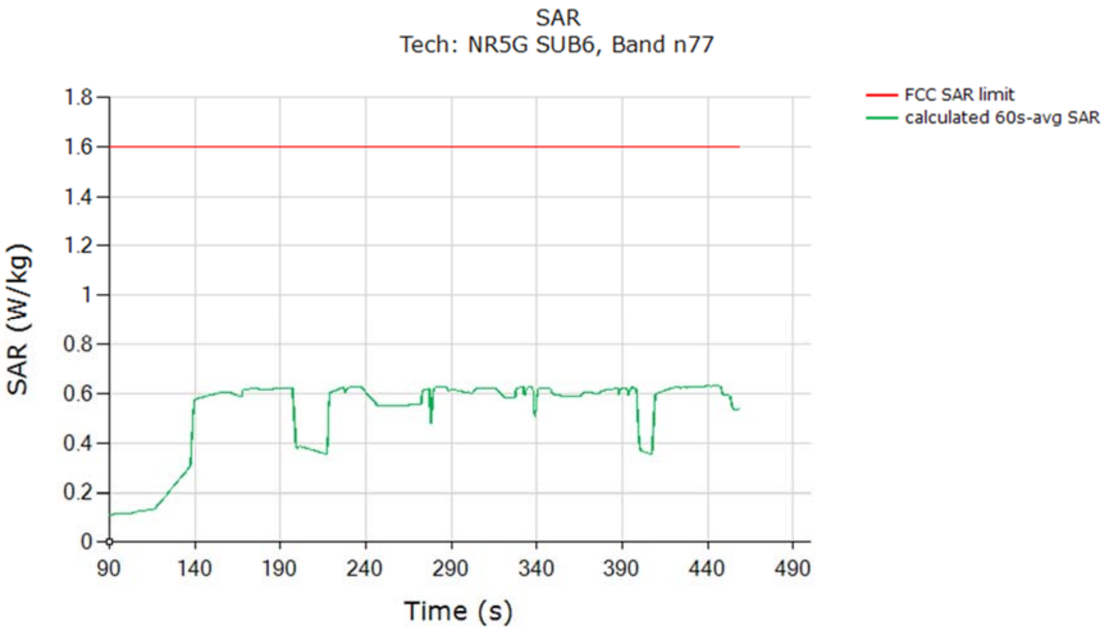
Max 60s SAR = 0.642
Max 60s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.947 dB
Validated

Test result for test sequence 1 (SAR):



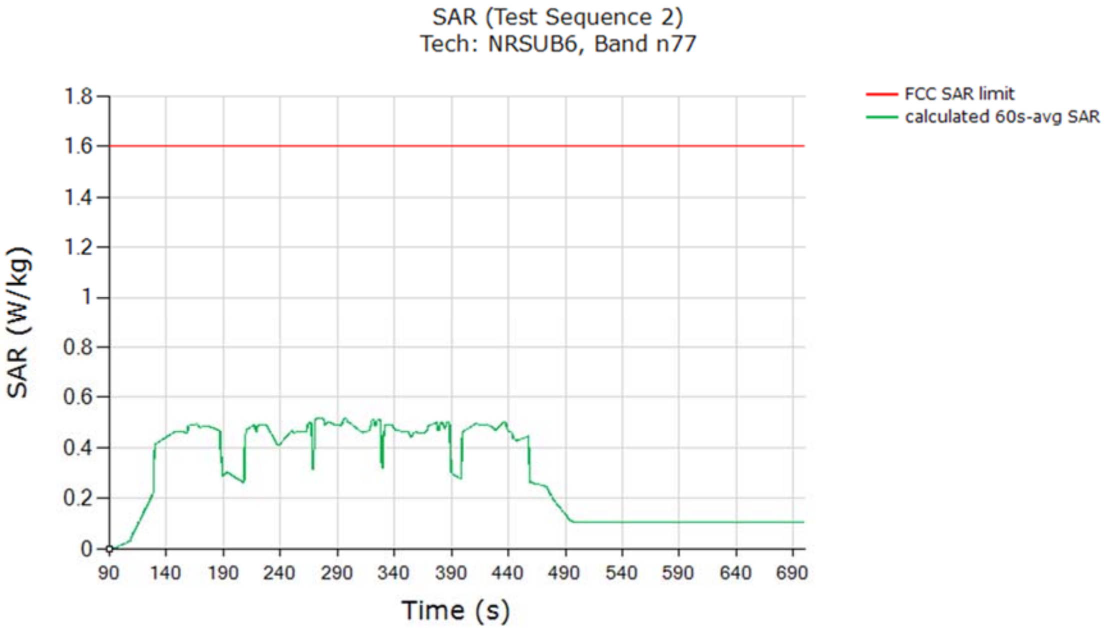
Max 60s SAR = 0.520 W/kg
Max 60s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.034 dB
Validated

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



Max 60s SAR = 0.629
Max 60s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.863 dB
Validated

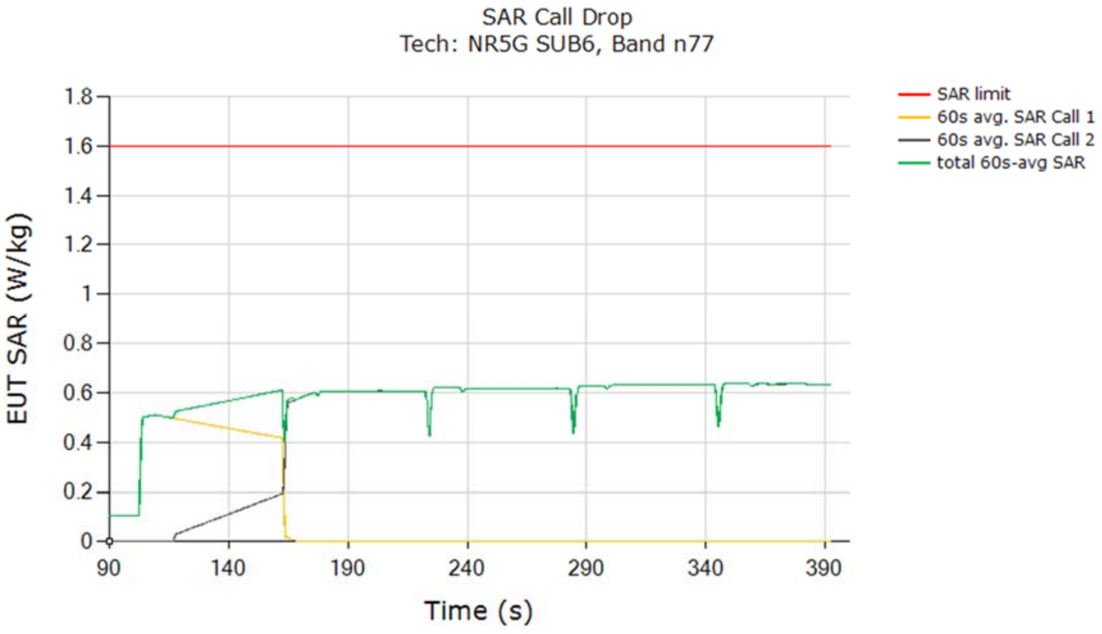
Test result for test sequence 2 (SAR):



Max 60s SAR = 0.517 W/kg
Max 60s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.006 dB
Validated

17.5 Change in Call Test Results

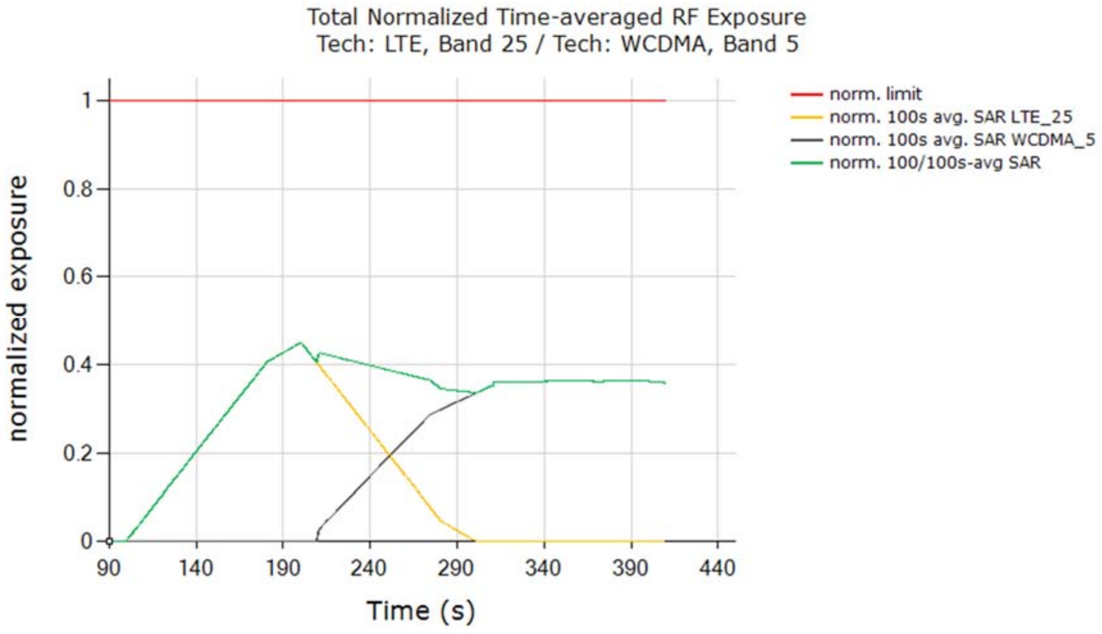
17.5.1 NR band n77 20230113 hyg OK



Call Drop Time = 110.000 seconds
Max 60s SAR = 0.636 W/kg
Max 60s SAR / Meas. SAR @ Plimit / reserve factor for sub6NR = 0.911 dB
Validated

17.6 Change in technology/band test results

17.6.1 LTE band 25 to WCDMA band 5



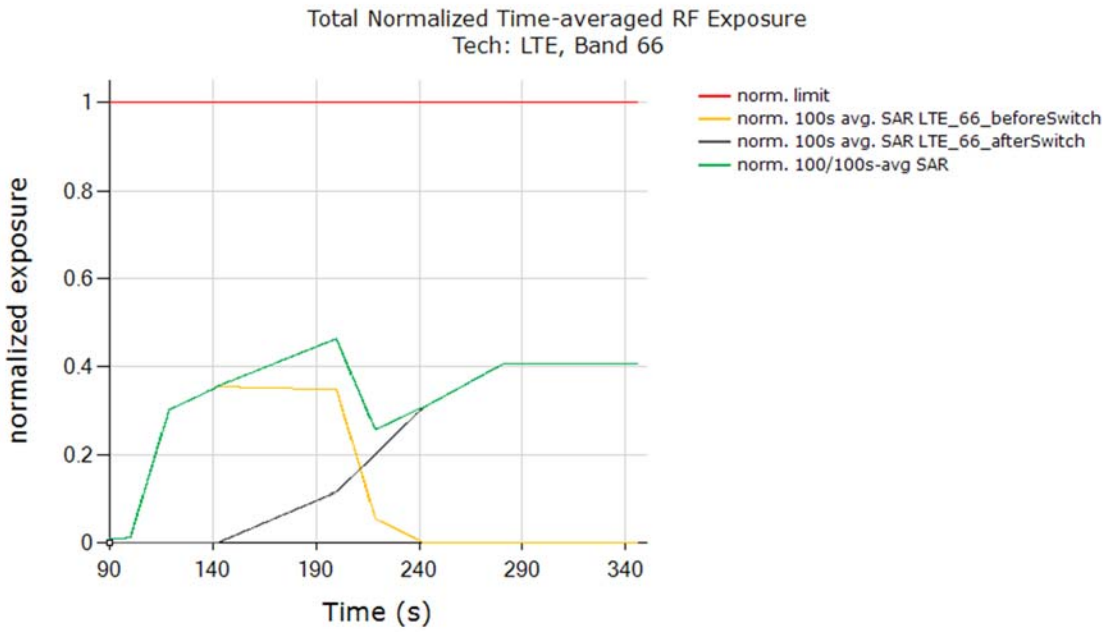
Switch time = 205.000
Max norm. 100s SAR for Tech/Band/Ant/DSI 1 = 0.450
Max norm. 100s SAR for Tech/Band/Ant/DSI 2 = 0.363
Maximum norm. Total time-avg. SAR = 0.450

Band (Direction)	meas.SAR [W/kg]	norm SAR	Criteria
From LTE Band 25	0.730	0.456	Lower limit = 0.391 - 1 dB = 0.311
To WCDMA Band 5	0.626	0.391	Higher limit = 0.456 + 1 dB = 0.574

Validated

17.7 Change in DSI test results

17.7.1 LTE band 66 DSI1 to DSI0



Switch time = 142.200 sec
Max norm. 100s SAR for DSI 1 = 0.354
Max norm. 100s SAR for DSI 0 = 0.407
Maximum norm. Total time-avg. SAR = 0.463

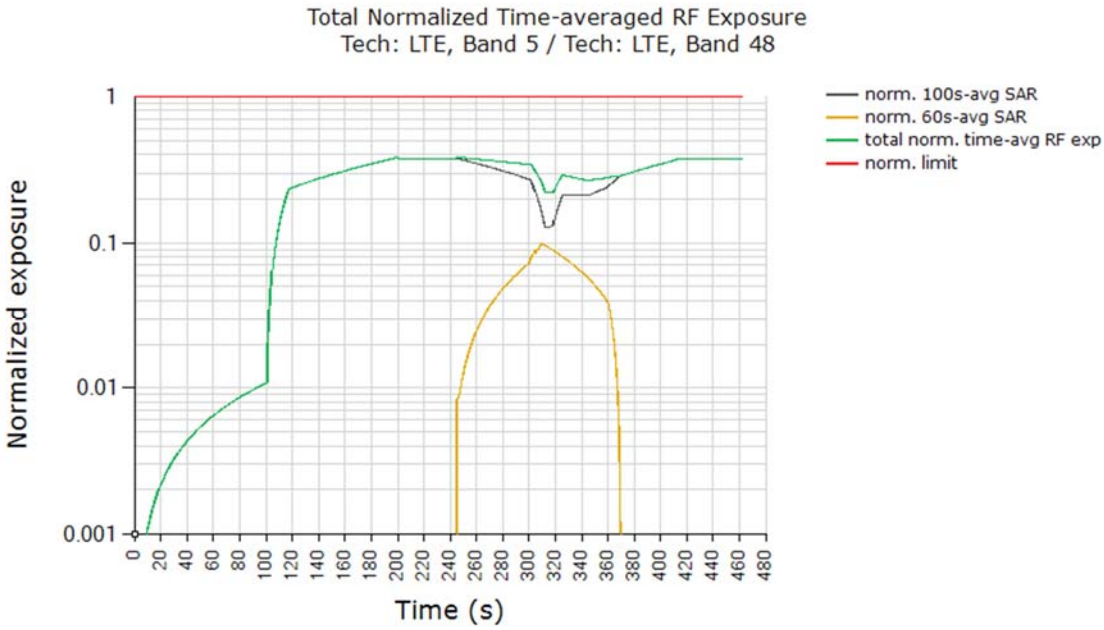
DSI	meas.SAR [W/kg]	norm SAR	Criteria
From 1	0.782	0.488	Lower limit = 0.456 - 1dB = 0.362
To 0	0.731	0.456	Higher limit = 0.488 + 1dB = 0.614

Validated

17.8 Change in Time Window

This test was conducted with callbox requesting maximum power, and with time-window from 100s window to 60s window vice and versa. Following procedure detailed in Section 11.6, and using the measurement setup shown in Figure 5 (a), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level.

17.8.1 100 sec to 60 sec to 100 sec

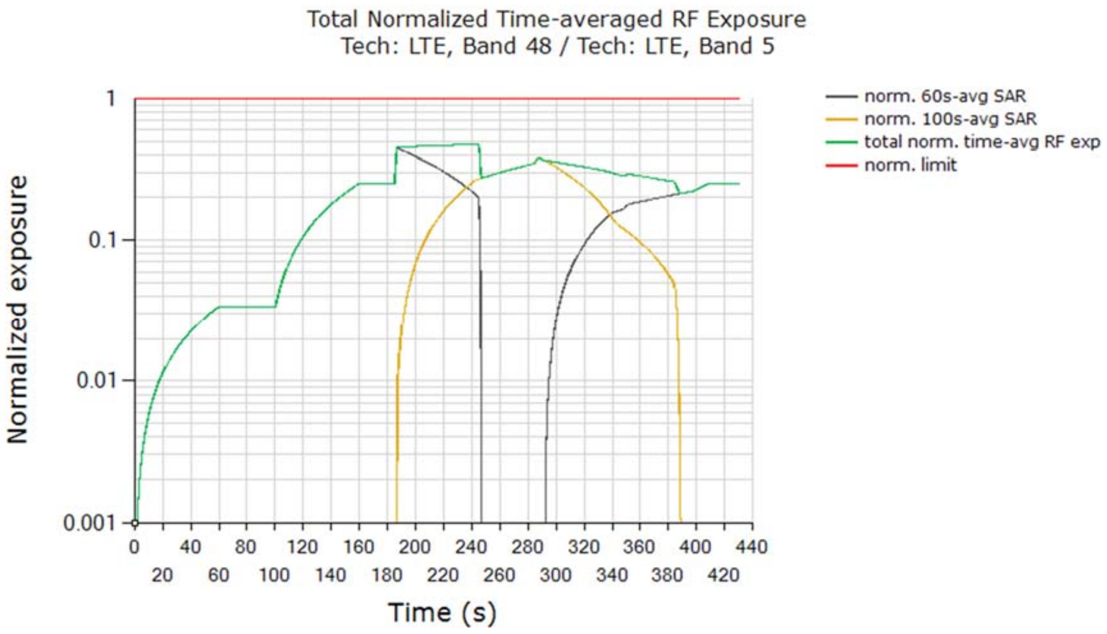


Switch time 1 = 245.000 sec
Switch time 2 = 310.000 sec
Max Norm. 100s SAR = 0.386
Max Norm. 60s SAR = 0.099
Max Norm. Total time-avg. SAR = 0.387

Band	meas.SAR [W/kg]	norm SAR	Criteria
5 (100 sec)	0.621	0.388	Lower limit = 0.259 - 1 dB = 0.206
48 (60 sec)	0.415	0.259	Higher limit = 0.388 + 1 dB = 0.488

Validated

17.8.2 60 sec to 100 sec to 60 sec



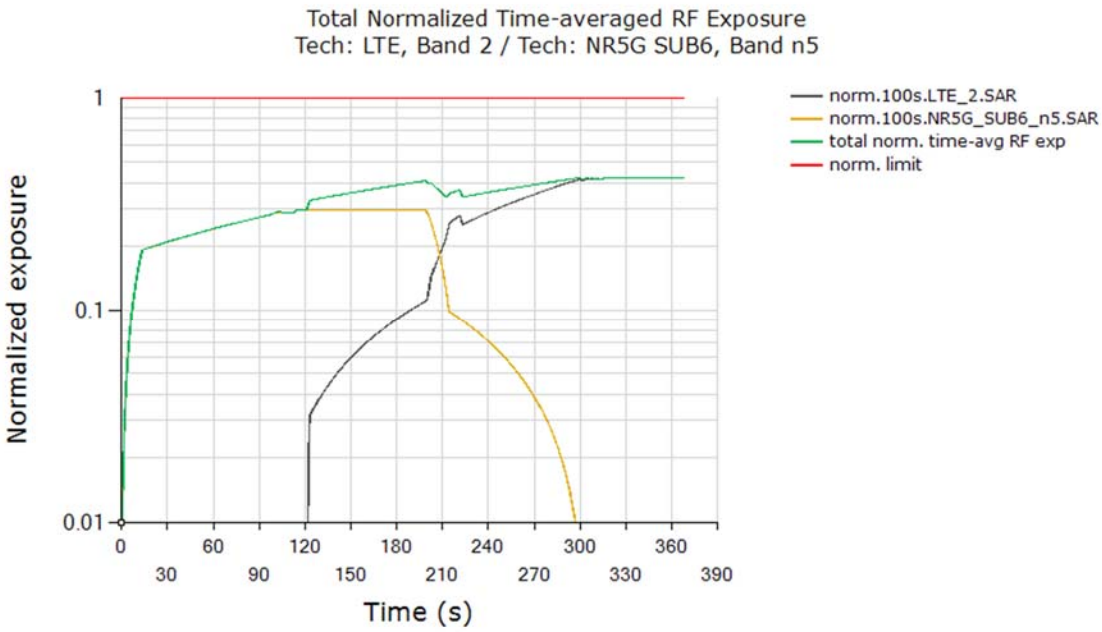
Switch time 1 = 187.000 sec
Switch time 2 = 292.000 sec
Max Norm. 60s SAR = 0.446
Max Norm. 100s SAR = 0.382
Max Norm. Total time-avg. SAR = 0.476

Band	meas.SAR [W/kg]	norm SAR	Criteria
48 (60 sec)	0.415	0.259	Lower limit = 0.259 - 1 dB = 0.206
5 (100 sec)	0.621	0.388	Higher limit = 0.388 + 1 dB = 0.488

Validated

17.9 Switch in SAR exposure test results

17.9.1 ENDC LTE band 2 / NR band n5



Max Norm. 100s SAR for LTE = 0.421
Max Norm. 100s SAR for Sub6NR = 0.300
Max Norm. Total time-avg. SAR = 0.423
Max Norm. 100s SAR for LTE / Norm. Meas. SAR @ Plimit for LTE = 0.009 dB
Max Norm. 100s SAR for Sub6NR / Norm. Meas. SAR @ Plimit for sub6NR / reserve factor for sub6NR = -0.384 dB

Band	meas.SAR [W/kg]	norm SAR	Criteria
2	0.672	0.420	Lower limit = 0.420 + 1 dB = 0.334
n5	0.698	0.436	Higher limit = 0.436 + 1 dB = 0.549

Validated

18 Test Configurations for mmW

18.1 LTE + mmW NR transmission

Based on the selection criteria described in Section Test configuration selection criteria for validating smart transmit algorithm10.2, the selections for LTE and mmW NR validation test are listed in Table 18-1. The radio configurations used in this test are listed in Table 18-2

Table 18-1 Selections for LTE + mmW NR validation measurements

Secnario	Test method	RAT	Beam ID	NR Band	Ant# LTE	LTE Band	meas. PD [W/m2]	Meas.SAR [W/kg]
Time-varying Tx power	Cond. & Rad. Power meas	NR+LTE	37	n261	#1	2	6.12	0.672
Time-varying Tx power	PD meas.	NR+LTE	37	n261	#1	2	6.12	0.672
Switch in SAR vs. PD exposure	Cond. & Rad. Power meas	NR+LTE	37	n261	#1	2	6.12	0.672

Change in antenna configuration test is omitted, because of only related between mmW antenna.
Due to other tests are in conjunction with anchor band, test is required.

Table 18-2 Test configuration for LTE + mmW NR validation

NR config		
Freq.[MHz]	Mod.	DSI
27925	QPSK	N/A

*Require duty: 84.3%

LTE config		
Freq.[MHz]	Mod.	DSI
1860	QPSK	1

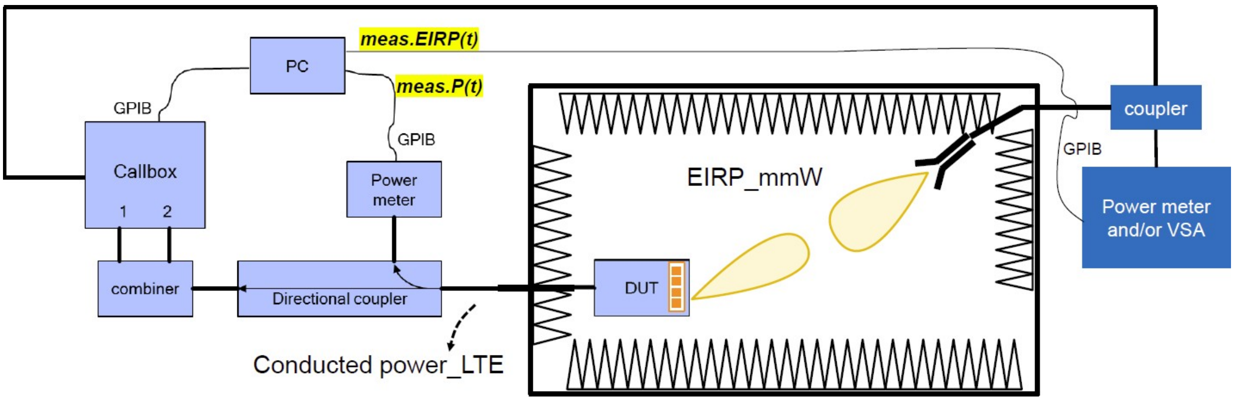
Band	Beam ID1	Beam ID2	Mmwave num	# of Antenna port	input power limit
N261	37		0	4	3.7

19 Radiated Power / PD Test Results for mmW Smart Transmit Feature Validation

19.1 Measurement Setup

The Keysight Technologies E7515B UXM callbox is used in this test. The test setup is shown in Figure 6. The UXM callbox has two RF radio heads to up/down convert IF to mmW frequencies, which in turn are connected to two horn antennas for V- and H-polarizations for downlink communication. In the uplink, a directional coupler is used in the path of one of the horn antennas to measure and record radiated power using a Rohde & Schwarz NR50S power sensor and NRP2 power meter. Note here that the isolation of the directional coupler may not be sufficient to attenuate the downlink signal from the callbox, which will result in high noise floor masking the recording of radiated power from EUT. In that case, either lower the downlink signal strength emanating from the RF radio heads of callbox or add an attenuator between callbox radio heads and directional coupler. Additionally, note that since the measurements performed in this validation are all relative, measurement of EUT's radiated power in one polarization is sufficient. The EUT is placed inside an anechoic chamber with V- and H-pol horn antennas to establish the radio link as shown in Figure 6. The callbox's LTE port is directly connected to the EUT's RF port via a directional coupler to measure the EUT's conducted Tx power using a Rohde & Schwarz NRP50S power sensor and NRP2 power meter. Additionally, EUT is connected to the PC via USB connection for sending beam switch command. Care is taken to route the USB cable and RF cable (for LTE connection) away from the EUT's mmW antenna modules.

Figure 6 mmW NR radiated power measurement setup

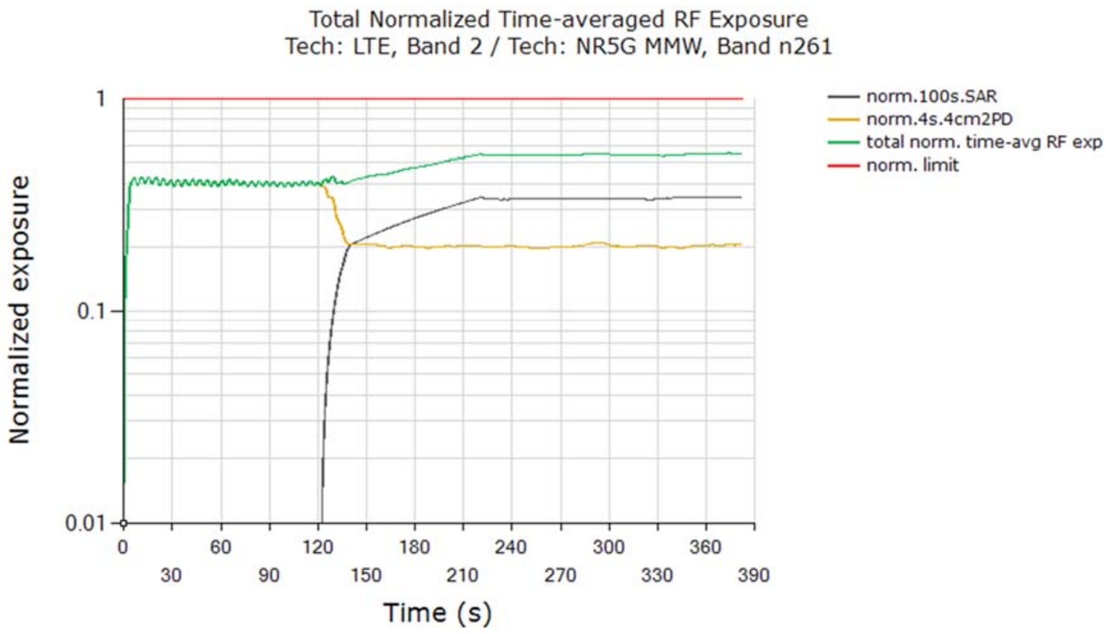


Both the callbox and power meters are connected to the PC using USB cables. Test scripts are custom made for automation of establishing LTE + mmW call, conducted Tx power recording for LTE and radiated Tx power recording for mmW. These tests are manually stopped after desired time duration. Test script is programmed to set LTE Tx power to all-down bits on the callbox immediately after the mmW link is established, and programmed to set toggle between all-up and all-down bits depending on the transmission scenario being evaluated. Similarly, test script is also programmed to send beam switch command manually to the EUT via USB connection. For all the tests, the callbox is set to request maximum Tx power in mmW NR radio from EUT all the time.

Test configurations for this validation are detailed in Section 18. Test procedures are listed in Section 11.

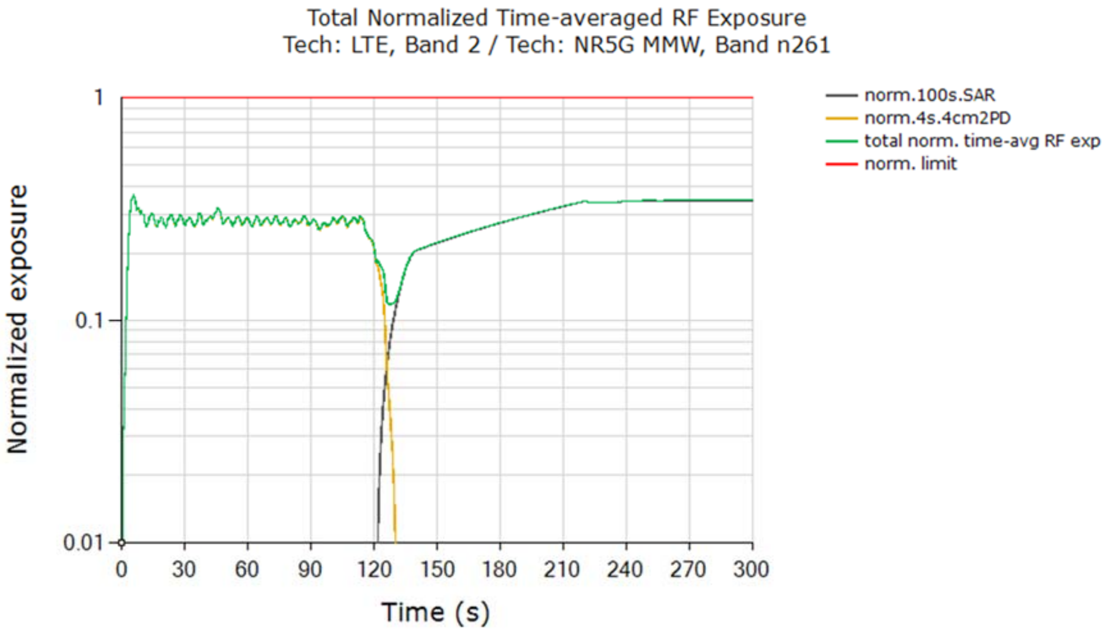
19.2 mmW NR radiated power test results

19.2.1 Time-varying Tx power conducted and radiated measurement



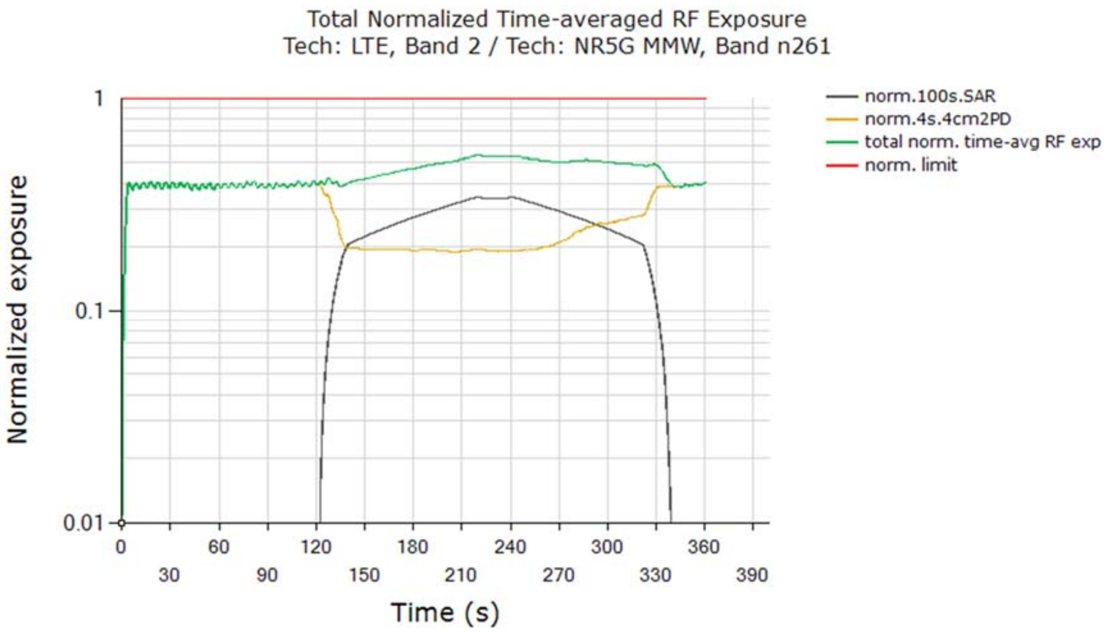
Max Norm. 100s SAR = 0.346
Max Norm. 4s PD = 0.431
Max Norm. Total RF Exposure = 0.554
Max Norm. 100s SAR / Norm. Meas. SAR @ Plimit = -0.839 dB
Max Norm. 4s PD / Norm. Meas. PD @ input.power.limit / reserve factor for mmW = -0.273 dB
Validated

19.2.2 Time-varying Tx power PD measurement test results



Max Norm. 100s SAR = 0.344
Max Norm. 4s PD = 0.365
Max Norm. Total RF Exposure = 0.365
Max Norm. 100s SAR / Norm. Meas. SAR @ Plimit = -0.863 dB
Max Norm. 4s PD / Norm. Meas. PD @ input.power.limit / reserve factor for mmW = -0.994 dB
Validated

19.2.3 Switch in SAR vs. PD exposure test results



Max Norm. 100s SAR = 0.347
Max Norm. 4s PD = 0.412
Max Norm. Total RF Exposure = 0.543
Max Norm. 100s SAR / Norm. Meas. SAR @ Plimit = -0.832 dB
Max Norm. 4s PD / Norm. Meas. PD @ input.power.limit / reserve factor for mmW = -0.466 dB
Validated

20 Test instrument

For SAR (1/2)

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
MDAE-01	Data Acquisition Electronics	Schmid & Partner Engineering AG	DAE4	509	2022/07/13	12
MDAE-02	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	1369	2022/05/09	12
MPB-07	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3825	2022/07/20	12
MPB-08	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3917	2022/05/17	12
COTS-MSAR-05	cDASY6 Module SAR	Schmid & Partner Engineering AG	cDASY6 Module SAR	-	-	-
MDH-03	Device holder	Schmid & Partner Engineering AG	Mounting device for transmitter	-	2022/11/28	12
MDH-04	Device holder	Schmid & Partner Engineering AG	Mounting device for transmitter	-	2022/11/28	12
MRBT-04	SAR robot	Schmid & Partner Engineering AG	TX60 Lspeag	F13/5PP1A1/A/01	2022/04/26	12
MRBT-03	SAR robot	Schmid & Partner Engineering AG	TX60 Lspeag	F13/5PP1D1/A/01	2022/04/26	12
MOS-31	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	3101	2022/07/03	12
MOS-35	Digital thermometer	HANNA INSTRUMENTS	Checktemp 4	-	2022/07/03	12
COTS-MSAR-04	Dielectric assessment software	Schmid&Partner Engineering AG	DAK	-	-	-
COTS-MPSE-02	Software for MA24106A	Anritsu Corporation	Anritsu PowerXpert	-	-	-
MDPK-03	Dielectric assessment kit	Schmid & Partner Engineering AG	DAKS-3.5	0008	2022/04/19	12
MAT-78	Attenuator	Telegrartner	J01156A0011	42294119	-	-
MNA-03	Vector Reflectometer	COPPER MOUNTAIN TECHNOLOGIES	PLANAR R140	0030913	2022/04/18	12
MOS-37	Digital thermometer	LKM electronic	DTM3000	-	2022/07/03	12
MPM-11	Dual Power Meter	Keysight Technologies Inc	E4419B	MY45102060	2022/08/05	12
MPSE-20	Power sensor	Keysight Technologies Inc	N8482H	MY53050001	2022/06/16	12
MPSE-24	Power sensor	Anritsu Corporation	MA24106A	1026164	2022/03/17	12
MPSE-25	Power sensor	Anritsu Corporation	MA24106A	1031504	2022/03/17	12
MRFA-24	Pre Amplifier	R&K	R&K CGA020M602-2633R	B30550	2022/06/27	12
MHBBL600-10000	Head Simulating Liquid	Schmid & Partner Engineering AG	HBBL600-10000V6	SL AAH U16 BC	-	-
MSG-10	Signal Generator	Keysight Technologies Inc	N5181A	MY47421098	2022/11/04	12
MWTR-01	Water, distilled	KISHIDA CHEMICAL Co.,Ltd.	020-85566	K70244M	-	-
MAT-81	Attenuator	Weinschel Associates	WA1-20-33	100131	2022/04/06	12
MHDC-21	Dual Directional Coupler	Keysight Technologies Inc	778D	MY52180243	-	-
MHDC-12	Dual Directional Coupler	Hewlett Packard	772D	2839A0016	-	-
MPF-03	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1203	2022/05/24	12
MPF-04	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1207	2022/05/24	12
MURC-10	Wideband Radio Communication Tester	Rohde & Schwarz	CMW500	165750	2022/06/17	12
MURC-13	UXM 5G Wireless Test Platform	Keysight Technologies Inc	E7515B	MY59321679	2022/02/08	12

For SAR (2/2)

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
MHDC-32	Directional Coupler	NARDA	4216-10	02871	2022/04/04	12
MHDC-33	Directional Coupler	NARDA	4216-10	02868	-	-
MPSC-10	Power Splitter/Combiner	Mini-Circuits	ZN2PD2-63-S+	1919329	-	-
MHF-37	High Pass Filter	REACTEL	5HM-X1600/5500-S11	SN21-02	-	-
MHF-36	High Pass Filter	REACTEL	5HM-X1600/5500-S11	SN21-01	-	-
MLF-05	Low Pass Filter	Mini-Circuits	VLF-2250+	141983	-	-
MLF-03	Low Pass Filter	CRYSTEK	CLPFL-1000	1-0316	-	-
MCC-248	SMA Male to SMA Male RF Cables	Pasternack Enterprises	PE300-200CM	316_200CM_77	-	-
MCC-250	SMA Male to SMA Male RF Cables	Pasternack Enterprises	PE300-200CM	316_200CM_79	-	-
MPSE-28	RF Device, Active, Power Meter	Rohde & Schwarz	NRP8S	110600	2022/06/10	12
MPSE-29	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101418	2022/06/10	12
MPSE-30	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101419	2022/06/10	12

For PD

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
COTS-MSARm-01	cDASY6 Module mmWave	Schmid & Partner Engineering AG	cDASY6 Module mmWave	-	-	-
MDH-03	Device holder	Schmid & Partner Engineering AG	Mounting device for transmitter	-	2022/11/28	12
MOS-31	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	3101	2022/07/03	12
MRBT-04	SAR robot	Schmid & Partner Engineering AG	TX60 Lspeag	F13/5PP1A1/A/01	2022/04/26	12
MFPm-01	mmWave Phantom	Schmid & Partner Engineering AG	QD 015 025 CA	1038	-	-
MDAE-02	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	1369	2022/05/09	12
MPBm-01	mmWave probe	Schmid & Partner Engineering AG	EUmmWV4	9450	2022/11/17	12
MOS-33	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	-	2022/07/03	12
MHDC-33	Directional Coupler	NARDA	4216-10	02868	-	-
MPSE-28	RF Device, Active, Power Meter	Rohde & Schwarz	NRP8S	110600	2022/06/10	12
MPSE-30	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101419	2022/06/10	12
MHA-17	Horn Antenna 15-40GHz	Schwarzbeck Mess-Elektronik OHG	BBHA9170	BBHA9170307	2022/07/22	12
MURC-13	UXM 5G Wireless Test Platform	Keysight Technologies Inc	E7515B	MY59321679	2022/02/08	12
MCC-248	SMA Male to SMA Male RF Cables	Pasternack Enterprises	PE300-200CM	316_200CM_77	-	-
MCC-249	SMA Male to SMA Male RF Cables	Pasternack Enterprises	PE300-200CM	316_200CM_78	-	-
MCC-250	SMA Male to SMA Male RF Cables	Pasternack Enterprises	PE300-200CM	316_200CM_79	-	-
MCC-251	2.4mm cable	Huber+Suhner	SF102/11PC24/11PC24/3000	SN 804179/2	-	-
MCC-252	2.4mm cable	Huber+Suhner	SF102/11PC24/11PC24/3000	SN 804180/2	-	-
MCH-08	RF Chamber, Full-Anechoic	Bojay Electronics Co. , LTD	BJ-8827-UL2	ZHBJ2105-BU1-F282529	-	-
MHA-41	Horn Antenna	Bojay Electronics Co. , LTD	AQRH-15-2.4F	AQRH-15-000151	-	-

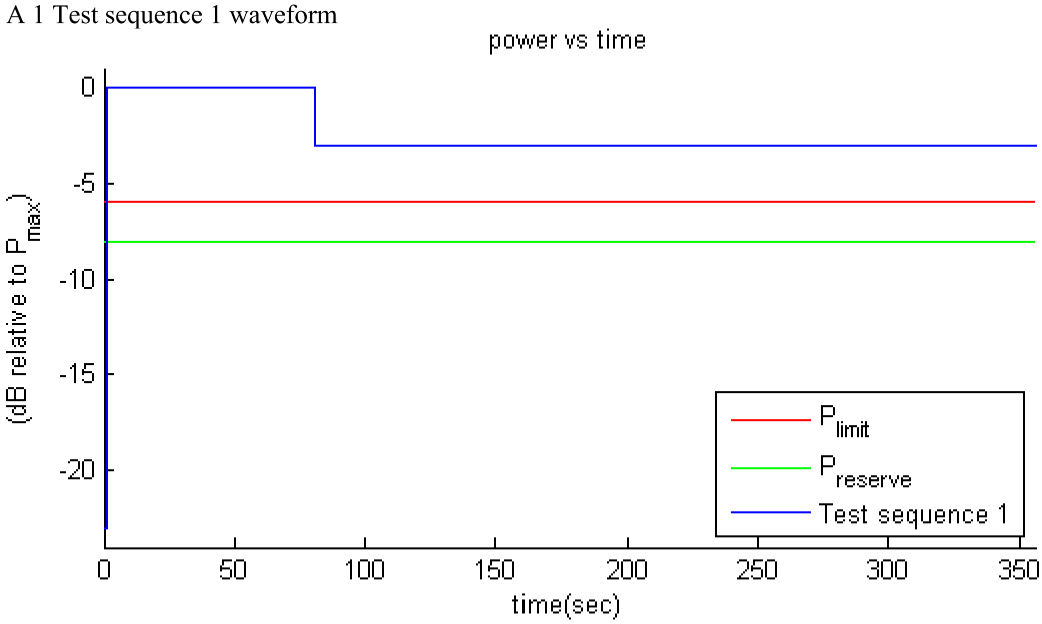
*Hyphens for Last Calibration Date and Cal Int (month) are instruments that Calibration is not required (e.g. software), or instruments checked in advance before use.
The expiration date of the calibration is the end of the expired month.
As for some calibrations performed after the tested dates, those test equipment have been controlled by means of an unbroken chains of calibrations.
The expiration*1) This test equipment was used for the tests before the expiration date of the calibration.
All equipment is calibrated with valid calibrations. Each measurement data is traceable to the national or international standards.

Appendix A Test Sequences

1. Test sequence is generated based on below parameters of the EUT:
    a. Measured maximum power (*Pmax*)
    b. Measured Tx_power_at_SAR_design_target (Plimit)
    c. Reserve_power_margin (dB)
        i. $P_{reserve}$ (dBm) = measured Plimit (dBm) – Reserve_power_margin (dB)
    d. *SAR_time_window* (100s for FCC)

2. Test Sequence 1 Waveform: Based on the parameters above, the Test Sequence 1 is generated with one transition between high and low Tx powers. Here, high power = *Pmax*; low power = *Pmax*/2, and the transition occurs after 80 seconds at high power *Pmax*. This 80s duration makes sure that EUT is enforced to limit power first before the transition from high (*Pmax*) to low (*Pmax*/2)occurs. If 80s is not long enough for power limiting enforcement (transition) to take place, then the high power duration needs to be increased accordingly. The Test sequence 1 waveform is shown below:

A 1 Test sequence 1 waveform

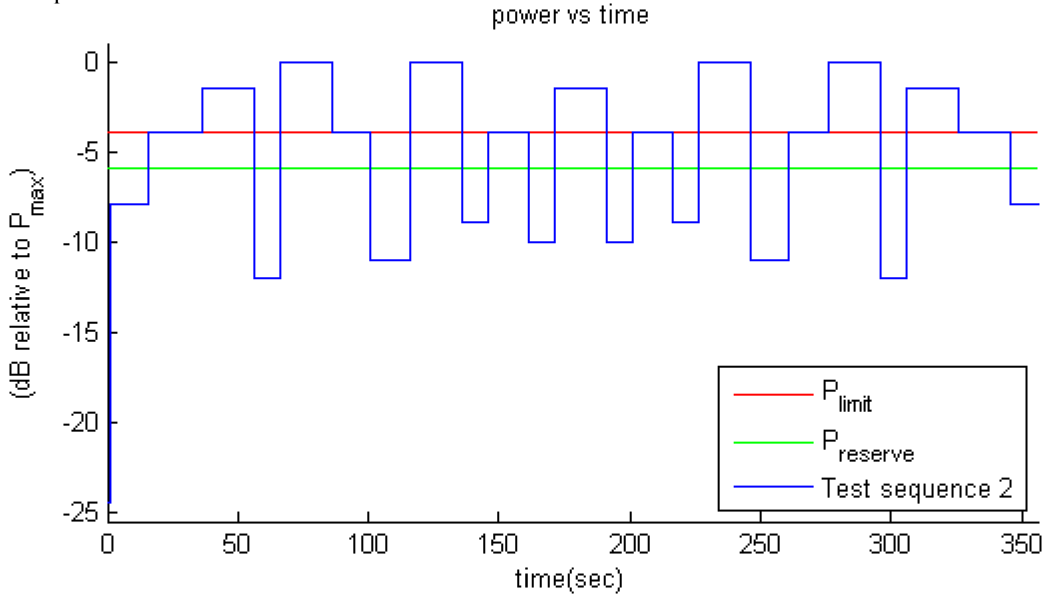


3. Test Sequence 2 Waveform: Based on the parameters in A-1, the Test Sequence 2 is generated as described in Table 10-1,which contains two 170 second-long sequences (yellow and green highlighted rows) that are mirrored around the center row of 20s, resulting in a total duration of 360 seconds:

A 2 Test Sequence 2

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

A 3 Test Sequence 2 waveform



Appendix B Uncertainty of measurement

Power measurement

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

SAR testing

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

PD

Error Description	Uncert. value (dB)	Probab. Distri.	Div.	(c_i)	Std. Unc. (±dB)	(v_i) v_{eff}
Uncertainty terms dependent on the measurement system						
Calibration	± 0.49	N	1	1	0.49	∞
Probe correction	± 0.00	R	√3	1	0.00	∞
Frequency response (BW <= 1 GHz)	± 0.20	R	√3	1	0.12	∞
Sensor cross coupling	± 0.00	R	√3	1	0.00	∞
Isotropy	± 0.50	R	√3	1	0.29	∞
Linearity	± 0.20	R	√3	1	0.12	∞
Probe scattering	± 0.00	R	√3	1	0.00	∞
Probe positioning o set	± 0.30	R	√3	1	0.17	∞
Probe positioning repeatability	± 0.04	R	√3	1	0.02	∞
Sensor mechanical o set	± 0.00	R	√3	1	0.00	∞
Probe spatial resolution	± 0.00	R	√3	1	0.00	∞
Field impedance dependance	± 0.00	R	√3	1	0.00	∞
Amplitude and phase drift	± 0.00	R	√3	1	0.00	∞
Amplitude and phase noise	± 0.04	R	√3	1	0.02	∞
Measurement area truncation	± 0.00	R	√3	1	0.00	∞
Data acquisition	± 0.03	N	1	1	0.03	∞
Sampling	± 0.00	R	√3	1	0.00	∞
Field reconstruction	± 0.95	R	√3	1	0.55	∞
Forward transformation	± 0.00	R	√3	1	0.00	∞
Power density scaling	-	R	√3	1	-	∞
Spatial averaging	0.10	R	√3	1	0.06	∞
System detection limit	± 0.04	R	√3	1	0.02	∞
Uncertainty terms dependent on the DUT and environmental factors						
Probe coupling with DUT	± 0.00	R	√3	1	0.00	∞
Modulation response	± 0.40	R	√3	1	0.23	∞
Integration time	± 0.00	R	√3	1	0.00	∞
Response time	± 0.00	R	√3	1	0.00	∞
Device holder influence	± 0.10	R	√3	1	0.06	∞
DUT alignment	± 0.00	R	√3	1	0.00	∞
RF ambient conditions	± 0.04	R	√3	1	0.02	∞
Ambient reflections	± 0.04	R	√3	1	0.02	∞
Immunity / secondary reception	± 0.00	R	√3	1	0.00	∞
Drift of the DUT	± 0.21	R	√3	1	0.12	∞
Combined Std. Uncertainty					0.87	∞
Expanded STD Uncertainty (k=2)					1.74	

Appendix C Revision history

Original Test Report No.: 14367173H-A

Revision	Test report No.	Date	Page revised	Contents
- (Original)	14367173H-A	February 15, 2023	-	-

End of Report