Part 2: Test Under Dynamic Transmission Condition

Test Report No. :	:	13760834H-I
Applicant	:	Panasonic Corporation of North America
Type of EUT	:	Personal Computer
Model number of EUT	:	FZ-G2
FCC ID	:	ACJ9TGFZG2

Date of test(s): September 30, 2021 to October 5, 2021

Representative test operator:

T. Nakagawa

Tomohisa Nakagawa
Engineer

Issued by:

Takayuki. S

Takayuki Shimada
Leader

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

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

2 Customer information

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

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

3 Equipment under test (EUT)

3.1 Identification of EUT

Type	:	Personal Computer
Model Number	:	FZ-G2
Serial number	:	0LTSA00729 for PD measurement 0LTSA00732 for other testing
Rating	:	DC 3.0 V to 3.6 V
Receipt Date	:	March 30, 2021
Condition	:	Production prototype (Not for Sale: This sample is equivalent to mass-produced items.)
Modification	:	No Modification by the test lab.

3.2 Product description

Model: FZ-G2 (referred to as the EUT in this report) is a Personal Computer.
EFS version 14.

5G NR (FR2)	TDD	120 kHz	n258	Pi/2 BPSK (DFT-s-OFDM), QPSK (CP-OFDM/DFT-s-OFDM)
	TDD	120 kHz	n260	16QAM (CP-OFDM/DFT-s-OFDM),
	TDD	120 kHz	n261	64QAM (CP-OFDM/DFT-s-OFDM)
	-	-	-	
	-	-	-	MIMO Support: No
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

Radio Module (Tested inside of Panasonic Tablet PC FZ-G2) Model : WW21A (FCC ID ACJ9TGWW21A / ISED certification number 216H-CFWW21A)				
Wireless technologies	Dup.	Band		Mode
WCDMA	FDD		2	UMTS Rel. 99 (Data) HSDPA (Rel. 5)
	FDD		4	HSUPA (Rel. 6), HSPA+ (Rel. 7), DC-HSDPA (Rel. 8)
	FDD		5	
LTE	FDD		2	QPSK, 16QAM, 64AQM, 256QAM
	FDD		4	
	FDD		5	Downlink MIMO Support: Yes(2x2, 4x4)
*B42: not used in US (FCC)	FDD		7	Supported band : B2, B4, B7, B25, B38, B41, B42, B48, B66
	FDD		12	
*B48: not used in	FDD		13	Uplink MIMO Support: No
Canada(ISED)	FDD		14	Uplink transmission is limited to a single output stream.
	FDD		17	
	FDD		25	
	FDD		26	
	FDD(RX only)		29	
	TDD		38	
	TDD		41	
	TDD		42	
	TDD(Rx only)		46	
	TDD		48	
	FDD		66	
	FDD		71	
LTE CA	Downlink			Uplink *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, 48C <Inter-band> Not supported
5G NR (FR1)	FDD	15 kHz	n2	Pi/2 BPSK (DFT-s-OFDM),
	FDD	15 kHz	n5	QPSK (CP-OFDM/DFT-s-OFDM),
*n77, n78: not used in US	TDD	15 kHz	n41	16QAM (CP-OFDM/DFT-s-OFDM),
(FCC)	FDD	15 kHz	n66	64QAM (CP-OFDM/DFT-s-OFDM),
	FDD	15 kHz	n71	256QAM (CP-OFDM/DFT-s-OFDM)
	TDD	30 kHz	n77	Downlink MIMO Support: Yes(2x2, 4x4)
	TDD	30 kHz	n78	Supported band : n2, n41, n66, n77, n78
	-	-	-	Uplink MIMO Support: No
	-	-	-	Uplink transmission is limited to a single output stream.
EN-DC(LTE-FR1 Sub6)	Supported combination			*n77, n78: not used in US (FCC)
(NSA mode only)	LTE Anchor Bands for NR band n2			LTE Band 5/12/13
	LTE Anchor Bands for NR band n5			LTE Band 2/7/66
	LTE Anchor Bands for NR band n41			LTE Band 2/25/26/66
	LTE Anchor Bands for NR band n66			LTE Band 5/12/13/14/71
	LTE Anchor Bands for NR band n71			LTE Band 2/7/66
	LTE Anchor Bands for NR band n77*			LTE Band 41
	LTE Anchor Bands for NR band n78*			LTE Band 2/5/7/12/38/66

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

*This report is for mmW range

4 Location

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

5 References

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

6 Definitions, symbols, and abbreviations

6.1 Definitions

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

SAR_design_target_extremity : SAR_design_target for limbs

Tx_power_at_SAR_design_target : Transmit level that matches SAR_design_target

Δ min : housing material influence

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

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

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

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

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

$$S_{av} = \frac{1}{AT}\int\int(\mathbf{E}\times\mathbf{H})\cdot\hat{\boldsymbol{n}}\,\mathrm{d}A\,\mathrm{d}T$$

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:

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

6.2 Symbols

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

6.3 Abbreviations

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

7 Qualcomm® Smart Transmit Operation Description

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

7.1 Feature description

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

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

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

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

- Therefore, for a characterized device, RF exposure compliance can be achieved through Tx power control and management.

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

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

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

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

7.2 Basic concept of the algorithm

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

- If time-averaged Tx power approaches the P_{limit}, then the modem needs to limit instantaneous Tx power to ensure the time-averaged Tx power does not exceed the P_{limit} or *input.power.limit* in any T_{SAR} and T_{PD} time windows (i.e., the time-averaged RF exposure complies with the regulatory RF exposure limit in any T_{SAR} or T_{PD} time window).

- The wireless device can have high Tx powers at any instant and exceed the P_{limit} or *input.power.limit* level for a short duration before limiting the power to maintain the time-averaged Tx power under P_{limit} or *input.power.limit*.

- If the wireless device is at high Tx power for a long time, then the radio link needs to be dropped to be compliant with time-averaged Tx power requirement (see Figure 1 High Tx power when needed and permittedFigure 1).

- To avoid dropping the radio link, Smart Transmit algorithm starts the power limiting enforcement earlier in time to back off the Tx power to a reserve level (denoted as $P_{reserve}$), so the wireless device can maintain the radio link at a minimum reserve power level for as long as needed, and at the same time ensure the time-averaged Tx power over any defined time window is less than P_{limit} at all times (see Figure 2). At all times, Smart Transmit meets the below equation:

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

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

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

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.,

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

or

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

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

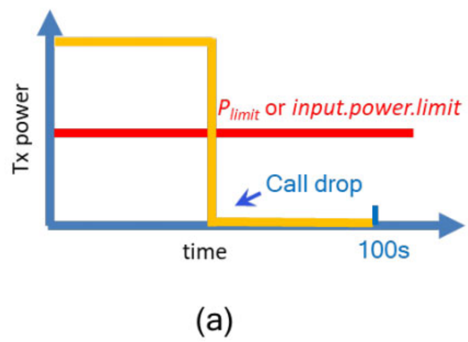


Figure 1 High Tx power when needed and permitted

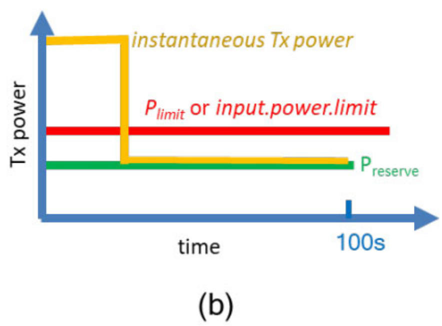


Figure 2 Tx power reduced to reserve power to support continuous transmission at a minimum power level ($P_{reserve}$)

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* (P_{limit} 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 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).
3. 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.
4. 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 4.

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.
    Max 100s SAR using Eq. 8-2
    Instantaneous value using Eq. 8-1
  - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios (i.e., transmission scenarios 1, 2, 3, 4, 5, 6, 7, and 8) at all times.
    Max Norm. 100s SAR using Eq. 8-5
    Max Norm. 4s PD using Eq. 8-6
    Max Norm. Total RF Exposure Eq. 8-7
    Instantaneous value Eq. 8-3 and Eq. 8-4

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

– 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. 8-3

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

Eq. 8-4

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

Eq. 8-5

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

Eq. 8-6

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

Eq. 8-7

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

For radiated testing

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged SAR and PD measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
    - For sub-6 transmission only, measure instantaneous SAR versus time; for LTE+sub6 NR transmission, request low power (or all-down bits) on LTE so that measured SAR predominantly corresponds to sub6 NR.
    - For LTE + mmW transmission, measure instantaneous E-field versus time for mmW radio and instantaneous conducted power versus time for LTE radio.
    - Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
    - Perform time averaging over FCC defined time window Max 100s SAR using Eq. 8-9

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

    - Eq. 8-8
- Demonstrate that the total normalized time-averaged RF exposure is always less than 1 for transmission scenario 1.
    - Max Norm. 100s SAR using Eq. 8-12
    - Max Norm. 4s PD using Eq. 8-13
    - Max Norm. Total RF Exposure Eq. 8-14
    - Instantaneous value $1g\_or\_10gSARt$= $conducted\_Tx\_power(t)conducted\_Tx\_power\_Plimit$×$1g\_or\_10gSAR\_P$?$limit$?
    - Eq. 8-8, Eq. 8-10 and Eq. 8-11

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. 8-8

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

Eq. 8-9

- For LTE+mmW transmission:

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

Eq. 8-10

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

Eq. 8-11

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

Eq. 8-12

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

Eq. 8-13

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

Eq. 8-14

where, $pointSAR(t)$, $pointSAR\_P_{limit}$, and $1g\_or\_10gSAR\_\ P_{limit}$ correspond to the measured instantaneous point SAR, measured point SAR at P_{limit}, and measured 1gSAR or 10gSAR values at P_{limit} corresponding to sub-6 transmission. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm2PD\_input.power.limit$ 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 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.

9.1 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.

9.2 Test configuration selection criteria for validating smart transmit algorithm

9.2.1 Test configuration selection for time-varying Tx power transmission

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 in any one band/mode/channel per technology is sufficient.

9.2.2 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.

9.2.3 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.

9.3 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

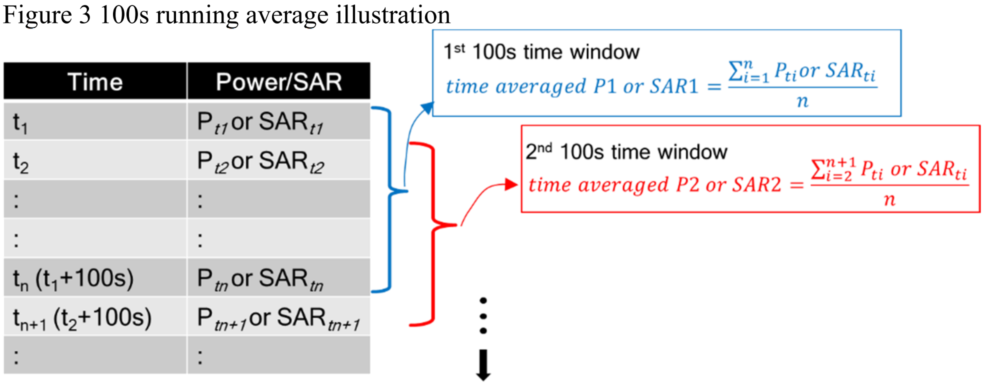
1. Measure P_{max}, measure P_{limit} and calculate $P_{reserve}$ (= measured P_{limit} in dBm – *Reserve_power_margin* in dB).
   Test condition to measure P_{max} and P_{limit} is:

- Measure P_{max} with Smart Transmit disabled and callbox set to request maximum power.
- Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

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

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

Figure 3 100s running average illustration



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

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

Eq. 9-1

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

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

Eq. 9-2

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. 9-1), 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).

9.3.1 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 Eq. 8-3 , Eq. 8-4 & Eq. 8-7 in Section 8).

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} 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 P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit. 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. 8-3 and P_{limit} 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. 8-3, 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. 8-4 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. 8-4, 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 Eq. 9-1 and Eq. 9-2, 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. 8-7) 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. 8-7).

9.3.2 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. 8-3, Eq. 8-4 and Eq. 8-7 in Section 2 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. 9-3

$$4cm^2PD1(t) = \frac{\text{radiated\_Tx\_power\_1(t)}}{radiated\_Tx\_Power\_input.power.limit\_1} \times 4cm^2PD\_input.power.limit\_1$$
Eq. 9-4

$$4cm^2PD2(t) = \frac{\text{radiated\_Tx\_power\_2(t)}}{radiated\_Tx\_Power\_input.power.limit\_2} \times 4cm^2PD\_input.power.limit\_2$$
Eq. 9-5

$$\frac{\frac{1}{Tsar}\int_{t-Tsar}^{t} 1g\_or10gSAR(t)dt}{FCC\ SAR\ Limit} + \frac{\frac{1}{TPD}\left[\int_{t-Tpd}^{t1} 4cm^2PD1(t)dt + \int_{t1}^{t} 4cm^2PD2(t)dt\right]}{FCC\ 4cm^2PD\ Limit} \leq 1$$
Eq. 9-6

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR or 10gSAR* values at P_{limit} corresponding to 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:

6. Measure conducted Tx power corresponding to P_{limit} 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 P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

7. 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.

8. 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.

9. Similarly, convert the radiated Tx power for mmW NR into 4cm2PD value using Eq. 9-4, Eq. 9-5 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 4cm2PD versus time.

   NOTE: In Eq. 9-4 and Eq. 9-5, instantaneous radiated Tx power of beam 1 and beam 2 is converted into instantaneous 4cm2PD 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.

10. 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.

11. 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.

12. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR 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. 9-6) 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. 9-6).

9.3.3 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 P_{limit} 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 P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserve_power_margin* to actual (intended) value and reset power 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 $P_{limit} > P_{max}$.

   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. 8-3 and P_{limit} 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. 8-3, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

4. Similarly, convert the radiated Tx power for mmW into $4cm^2$PD value using Eq. 8-4 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 $4cm^2$PD versus time. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

   NOTE: In Eq. 8-4, 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 Eq. 9-1 &Eq. 9-2, 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 4cm$_2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (Eq. 8-7) 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. 8-7).

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

   d. 10gSAR value using Eq. 8-10 and P_{limit} 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. 8-10, instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band 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 4cm2PD 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. 8-14).

10 Validation criteria

The overall validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed 1 normalized value.

10.1.1 FR2 max 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.

10.1.2 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

10.1.3 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

Note: Measured normalized PD@input.power.limit = measured PD@input.power.limit / RF exposure limit such as 10 W/m^2.
Note: For NR including both FR1 / FR2, reserved factor might be needed to calculation for RF exposure value per EFS version, such as 0.75 for EFS version 15 or below and 1.00 for equal of 16 or later.

EUT has the uncertainties 2.0 dB for sub 6 and 2.1 dB for mmW range, these values are used for validation criteria.

11 Test Configurations

11.1 LTE + mmW NR transmission

Based on the selection criteria described in Section Test configuration selection criteria for validating smart transmit algorithm9.2, the selections for LTE and mmW NR validation test are listed in Table 11-1. The radio configurations used in this test are listed in Table 11-2

Table 11-1 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	149	n261	#1	2	5.94	0.692
Time-varying Tx power	PD meas.	NR+LTE	149	n261	#1	2	5.94	0.692
Change in antenna configuration	Cond. & Rad. Power meas	NR+LTE	37 & 1	n261	#1	2	5.21 & 5.58	0.692
Switch in SAR vs. PD exposure	Cond. & Rad. Power meas	NR+LTE	149	n261	#1	2	5.94	0.692

Table 11-2 Test configuration for LTE + mmW NR validation

NR config				
Freq.[MHz]	Mod.	RB num	RB posi	DSI
27925	QPSK	66	0	N/A

*Require duty: 84.3%

LTE config				
Freq.[MHz]	Mod.	RB num	RB posi	DSI
1880	QPSK	100	0	1

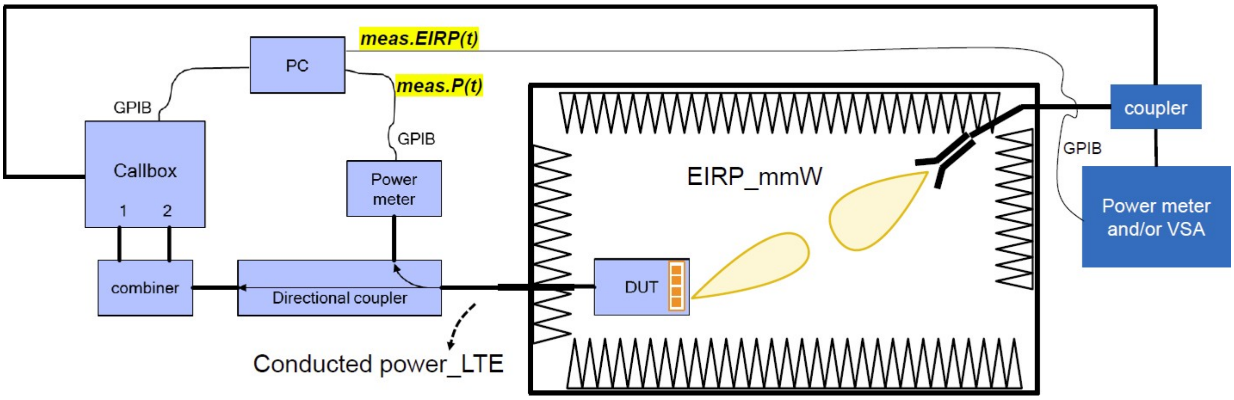
Beam ID1	Beam ID2	Mmwave num	# of Antenna port	input power limit
149		0	4	4.8
37		0	4	3.7
1		0	1	9.3

12 Radiated Power Test Results for mmW Smart Transmit Feature Validation

12.1 Measurement Setup

The Keysight Technologies E7515B UXM callbox is used in this test. The test setup is shown in Figure 4. 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 4. 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 4 mmW NR radiated power measurement setup

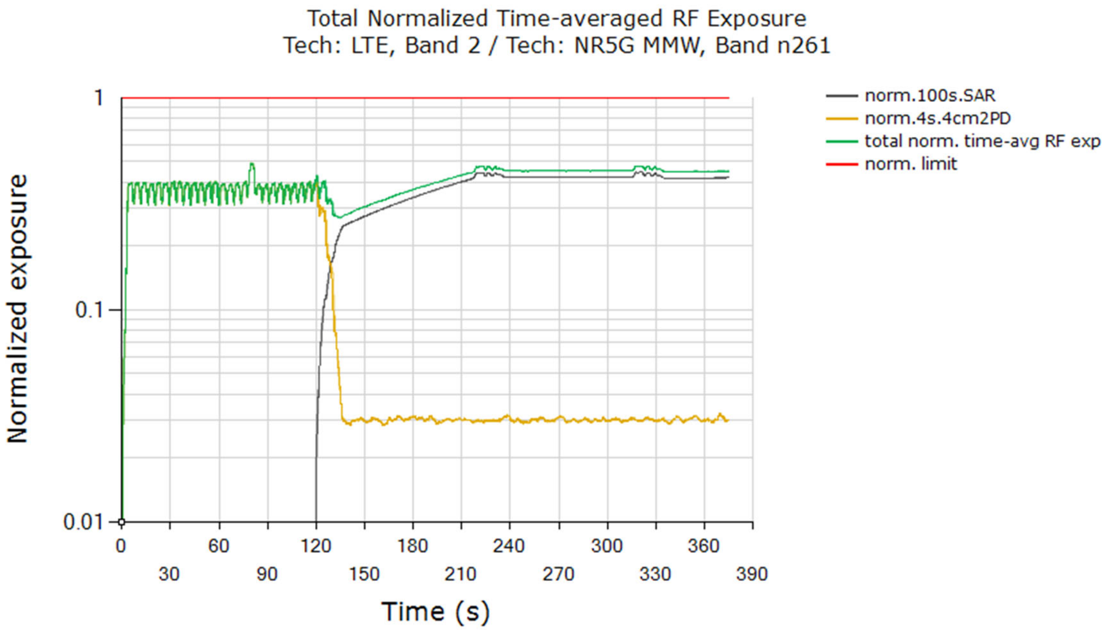


Both the callbox and power meters are connected to the PC using USB cables. Test scripts are custom made for automation of establishing LTE + mmW call, conducted Tx power recording for LTE and radiated Tx power recording for mmW. These tests are manually stopped after desired time duration. Test script 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 10. Test procedures are listed in Section 9.3.

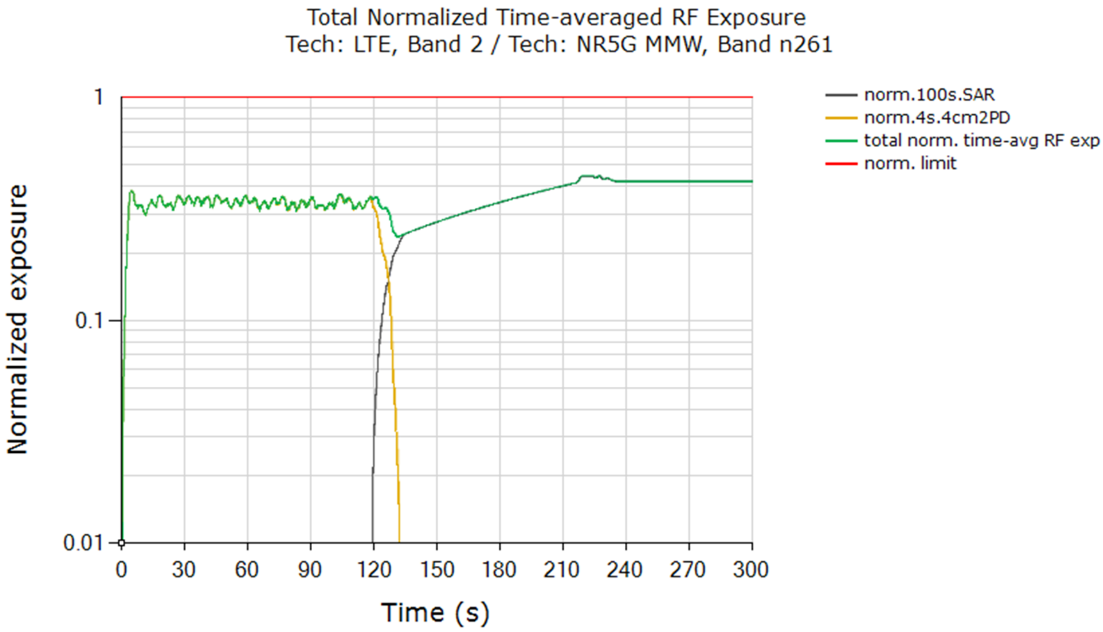
12.1.1 mmW NR radiated power test results

12.1.2 Time-varying Tx power conducted and radiated measurement



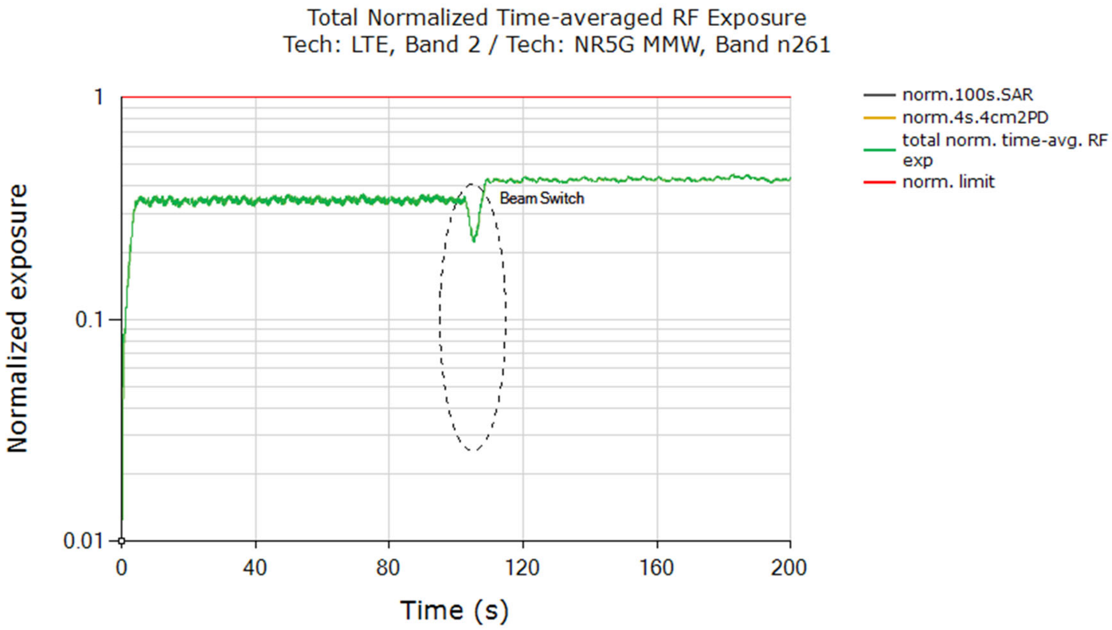
Max Norm. 100s SAR = 0.446
Max Norm. 4s PD = 0.492
Max Norm. Total RF Exposure = 0.492
Max Norm. 100s SAR / Meas. SAR @ Plimit = 0.130 dB
Max Norm. 4s PD / Meas. PD @ input.power.limit / reserve factor for mmW = 0.434 dB
Validated

12.1.3 Time-varying Tx power PD measurement test results



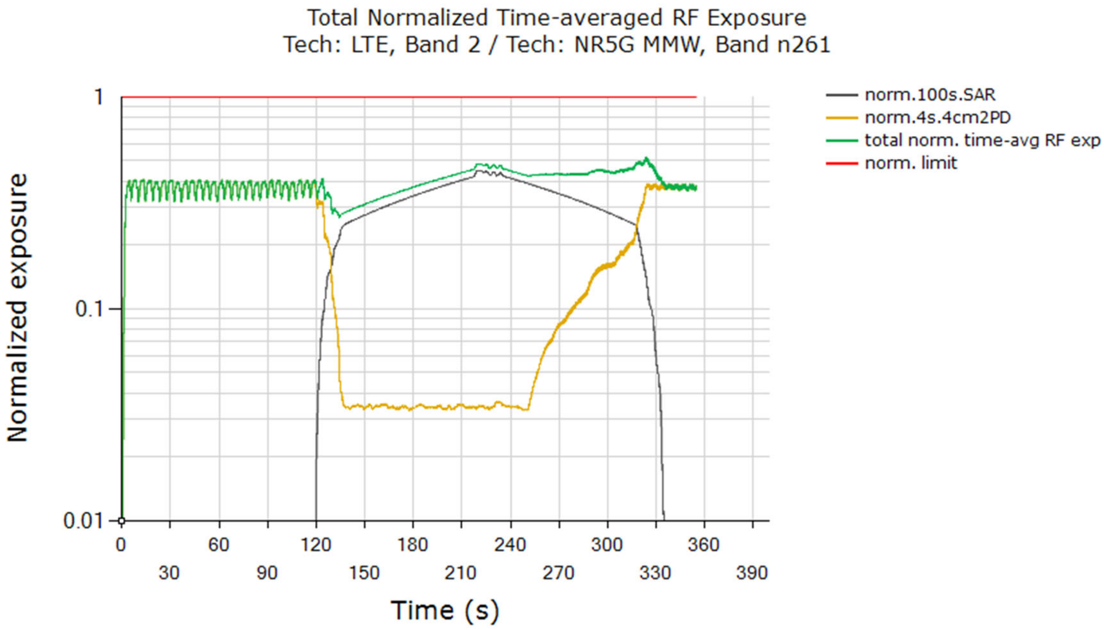
Max Norm. 100s SAR = 0.442
Max Norm. 4s PD = 0.379
Max Norm. Total RF Exposure = 0.443
Max Norm. 100s SAR / Meas. SAR @ Plimit = 0.099 dB
Max Norm. 4s PD / Meas. PD @ input.power.limit / reserve factor for mmW = -0.698 dB
Validated

12.1.4 Change in Beam test results



Beam 1 Max Norm. 4s PD = 0.365
Beam 2 Max Norm. 4s PD = 0.447
Beam 1 Max Norm. 4s PD / Meas.PD @ input.power.limit / reserve factor for mmW = -0.292 dB
Beam 2 Max Norm. 4s PD / Meas.PD @ input.power.limit / reserve factor for mmW = 0.282 dB
Max Norm. Total RF Exposure = 0.447
Validated

12.1.5 Switch in SAR vs. PD exposure test results



Max Norm. 100s SAR = 0.447
Max Norm. 4s PD = 0.407
Max Norm. Total RF Exposure = 0.519
Max Norm. 100s SAR / Meas. SAR @ Plimit = 0.144 dB
Max Norm. 4s PD / Meas. PD @ input.power.limit / reserve factor for mmW = -0.392 dB
Validated

13 Test instrument

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
MMBBL600-6000	Body Simulating Liquid	Schmid & Partner Engineering AG	MBBL600-6000	SL AAM U16 BC	-	-
MOS-37	Digital thermometer	LKM electronic	DTM3000	-	2021/07/08	12
MNA-03	Vector Reflectometer	COPPER MOUNTAIN TECHNOLOGIES	PLANAR R140	0030913	2021/04/19	12
MDPK-03	Dielectric assessment kit	Schmid&Partner Engineering AG	DAKS-3.5	0008	2021/04/14	12
MAT-78	Attenuator	Telegrartner	J01156A0011	42294119	-	-
MHDC-21	Dual Directional Coupler	Keysight Technologies Inc	778D	MY52180243	-	-
MHDC-12	Dual Directional Coupler	Hewlett Packard	772D	2839A0016	-	-
MPSE-24	Power sensor	Anritsu Corporation	MA24106A	1026164	2021/08/17	12
MPSE-25	Power sensor	Anritsu Corporation	MA24106A	1031504	2021/08/17	12
MSG-10	Signal Generator	Keysight Technologies Inc	N5181A	MY47421098	2020/11/17	12
MRFA-24	Pre Amplifier	R&K	R&K CGA020M602-2633R	B30550	2021/06/16	12
MPSE-20	Power sensor	Keysight Technologies Inc	N8482H	MY53050001	2021/06/08	12
MPM-11	Dual Power Meter	Keysight Technologies Inc	E4419B	MY45102060	2021/08/10	12
MDA-19	Dipole Antenna	Schmid&Partner Engineering AG	D2600V2	1030	2019/03/14	36
MDA-23	Dipole Antenna	Schmid & Partner Engineering AG	D3500V2	1052	2019/12/11	24
SSDA-04	Dipole Antenna	Schmid&Partner Engineering AG	D835V2	4d149	2019/03/13	36
SSDA-06	Dipole Antenna	Schmid&Partner Engineering AG	D1750V2	1089	2019/03/12	36
COTS-MPSE-02	Software for MA24106A	Anritsu Corporation	Anritsu PowerXpert	-	-	-
COTS-MSAR-04	Dielectric assessment software	Schmid&Partner Engineering AG	DAK	-	-	-
COTS-MSAR-05	Dasy6	Schmid & Partner Engineering AG	DASY6	-	-	-
MPB-08	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3917	2021/05/20	12
MDAE-02	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	1369	2021/05/11	12
MOS-33	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	-	2021/07/08	12
MRBT-03	SAR robot	Schmid&Partner Engineering AG	TX60 Lspeag	F13/5PP1D1/A/01	2021/04/20	12
MPF-03	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1203	2021/05/28	12
MPB-07	Dosimetric E-Field Probe	Schmid&Partner Engineering AG	EX3DV4	3825	2021/07/21	12
MDAE-01	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	509	2021/07/13	12
MOS-31	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	3101	2021/07/08	12
MRBT-04	SAR robot	Schmid&Partner Engineering AG	TX60 Lspeag	F13/5PP1A1/A/01	2021/04/20	12
MPF-04	2mm Oval Flat Phantom	Schmid&Partner Engineering AG	QDOVA001BB	1207	2021/05/28	12
MURC-10	Wideband Radio Communication Tester	Rohde & Schwarz	CMW500	165750	2021/06/15	12
MURC-05	Wideband Radio Communication Tester	Rohde & Schwarz	CMW500	127576	-	-
MURC-13	UXM 5G Wireless Test Platform	Keysight Technologies Inc	E7515B	MY59321679	2021/03/29	12
MPSE-28	RF Device, Active, Power Meter	Rohde & Schwarz	NRP8S	110600	2021/06/15	12
MPSE-29	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101418	2021/06/15	12
MPSE-30	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101419	2021/06/15	12

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

PD

Local Id	Description	Manufacturer	Model	Serial	Last Cal Date	Interval
COTS-MSAR-05	Dasy6	Schmid & Partner Engineering AG	DASY6	-	-	-
MOS-31	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	3101	2021/07/08	12
MRBT-04	SAR robot	Schmid&Partner Engineering AG	TX60 Lspeag	F13/5PP1A1/A/01	2021/04/20	12
MDAE-01	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	509	2021/07/13	12
MFPm-01	mmWave Phantom	Schmid & Partner Engineering AG	QD 015 025 CA	1038	-	-
MPBm-01	mmWave probe	Schmid & Partner Engineering AG	EUmmWV4	9450	2020/10/21	12
MPBmD-01	Dummy probe 5G	Schmid & Partner Engineering AG	SP DP2 002 AA	-	-	-
COTS-MSARm-01	cDASY6 Module mmWave	Schmid & Partner Engineering AG	cDASY6 Module mmWave	-	-	-
MDAE-01	Data Acquisition Electronics	Schmid&Partner Engineering AG	DAE4	509	2021/07/13	-
MVSm-01	Verification Source	Schmid & Partner Engineering AG	5G Verification Source 30GHz	1053	2020/12/28	12
MDH-m01	Device Holder	Schmid & Partner Engineering AG	mmWave Device Holder V3	1130	-	-
MPSE-29	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101418	2021/06/15	12
MPSE-30	RF Device, Active, Power Meter	Rohde & Schwarz	NRP50S	101419	2021/06/15	12
MCH-08	RF Chamber, Full-Anechoic	Bojay Electronics Co. , LTD	BJ-8827-UL2	ZHBJ2105-BU1-F282529	-	-
MHA-39	RF Device, Passive, Antenna	Other	LB-28-20-C-24.F	2020056000967	-	-
MHA-37	Cross Polarization Horn Antenna	ERAVANT	SAV-0535031140-2F-U5-QR	08239-01	-	-
MURC-13	UXM 5G Wireless Test Platform	Keysight Technologies Inc	E7515B	MY59321679	2021/03/29	12

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

APPENDIX A UNCERTAINTY OF MEASUREMENT

Power measurement

The following uncertainties have been calculated to provide a confidence level of 95 % using a coverage factor k=2.
300 MHz to 6000 MHz 0.85 dB
20 GHz to 40 GHz 1.24 dB

SAR testing

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

Original Test Report No.: 13760834H-I

Revision	Test report No.	Date	Revision details
- (Original)	13760834H-I	November 25, 2021	-

End of Report