Qualcomm Technologies, Inc.

Qualcomm® Smart Transmit Algorithm Validation for FCC Equipment Authorization of HP Tablet Model HSN-I06C

FCC Report

80-W5017-1 Rev. A

June 12, 2018

Qualcomm Technologies, Inc.
5775 Morehouse Drive
San Diego, CA 92121
U.S.A.

Revision history

Revision	Date	Description
A	June 12, 2018	Initial release

Contents

1 Document Scope **5**

2 Qualcomm Smart Transmit Operation Description **6**

2.1 Algorithm description 6
2.2 Configurable parameters 7

3 Product Description **9**

4 Strategy for Compliance Demonstration **12**

4.1 Overall strategy 12
4.2 Validation strategy 13

5 Validation Test Plan **14**

5.1 Test sequence determination for validation 14
5.2 Test configuration selection criteria for validating smart transmit algorithm 14
5.2.1 Test configuration selection for time-varying Tx power transmission 14
5.2.2 Test configuration selection for change in call 15
5.2.3 Test configuration selection for change in technology/band 15
5.3 Test procedures for conducted power measurements 16
5.3.1 Time-varying Tx power scenario 16
5.3.2 Change in call scenario 17
5.3.3 Change in technology and band 17
5.4 Test procedure for SAR measurements 18

6 Conducted Power Measurement for Smart Transmit Algorithm Validation **22**

6.1 Measurement setup 22
6.2 Time-varying transmit power measurement results 24
6.2.1 LTE Band 4 26
6.2.2 LTE Band 5 29
6.2.3 WCDMA Band IV 32
6.2.4 WCDMA Band V 35
6.3 Call Drop Test Results 38
6.4 Change in technology/band test results 38

7 SAR Measurement for Smart Transmit Algorithm Validation **41**

7.1 Measurement setup 41
7.1.1 Setup for path loss calibration 42
7.2 SAR measurement results 43
7.2.1 LTE Band 4 SAR test results 45
7.2.2 LTE Band 5 SAR test results 47
7.2.3 WCDMA Band IV SAR test results 49
7.2.4 WCDMA Band V SAR test results 51

8 Conclusions **53**

A Test Sequences 54

B Test Procedure for Technology/Band Switch with Callbox 57

C Test Procedure for Calibrating Setup Loss Between Callbox and EUT Positioned Against Flat Section of SAM Phantom 64

D Test Procedure for Time-Averaged SAR Validation Using cDASY6 68

E SAR Measurement Plots 71

F cDASY6 System Check 75

F.1 System components 75
F.2 SAR system verification 75
F.3 SAR system verification 76

G Speag Certificates of SAR Probe, DASY DAE, and Dipoles 78

Figures

Figure 2-1 Smart Transmit Operation: (a) Transmit at high power when needed and permitted; (b) Transmit with reserve power to support continuous transmission at a minimum power level ($P_{reserve}$). 7
Figure 3-1 HP Tablet model HSN-I06C: (a) perspective view of the 2-in-1 device; (b) tablet Only 9
Figure 3-2 WWAN and WLAN antenna locations 11
Figure 5-1 100s running average illustration 16
Figure 5-2 Test positions of EUT for SAR assessment 19
Figure 6-1 Conducted power measurement setup 23
Figure 6-2 Sample plot of time-varying conducted power for LTE Band 4 25
Figure 7-1 SAR measurement setup 41
Figure 7-2 Path loss calibration setup 43

Tables

Table 3-1 Specification of HP Tablet Model HSN-I06C 10
Table 3-2 EFS input parameters for Smart Transmit 11
Table 4-1 Algorithm accuracy and RF tune-up tolerance 12
Table 5-1 P_{limit} and worst case 1gSAR extracted from SGS report 20
Table 5-2 Selections for validation measurements 21
Table 6-1 Path loss in conducted power measurement setup 23
Table 6-2 Test sequence 1 for LTE Band 4 measurement 26
Table 6-3 Test sequence 2 for LTE Band 4 measurement 27
Table 6-4 Test sequence 1 for LTE Band 5 measurement 29
Table 6-5 Test sequence 2 for LTE Band 5 measurement 30
Table 6-6 Test sequence 1 for WCDMA Band IV measurement 32
Table 6-7 Test sequence 2 for WCDMA Band IV measurement 33
Table 6-8 Test sequence 1 for WCDMA Band V measurement 35
Table 6-9 Test sequence 2 for WCDMA Band V measurement 36
Table F-1 Measurement equipment 75

1 Document Scope

The WWAN modem embedded in HP tablet Model HSN-I06C is enabled with Qualcomm® Smart Transmit, which controls and manages transmit power in real time to ensure the device is compliant with FCC time-averaged SAR requirement at all times. HP tablet Model HSN-I06C also supports WLAN 802.11 a/b/g/n/ac and Bluetooth, but Qualcomm® Smart Transmit feature is not implemented for WLAN and Bluetooth.

HP will submit the FCC application containing the overall compliance document for HP tablet Model HSN-I06C equipment authorization. All normally required SAR testing, i.e., compliance SAR measurement, is performed at SGS lab, while the testing for Smart Transmit algorithm validation is done in Qualcomm Technologies, Inc. lab.

This standalone report is generated to demonstrate the validity of the Smart Transmit algorithm implemented in MDM9625 Modem inside HP tablet Model HSN-I06C, which is aimed to serve as part of the overall SAR compliance document to support this HP application. The overall SAR assessment for all radios that this HP device supports are evaluated in a separate SAR compliance report from SGS lab.

This report is structured as follows:

- Chapter 2: Qualcomm® Smart Transmit Operation Description
- Chapter 3: Product Description
- Chapter 4: Validation Strategy
- Chapter 5: Validation Test Plan
- Chapter 6: Test Configurations
- Chapter 7: Conducted Power Measurement for Qualcomm Smart Transmit Algorithm Validation
- Chapter 8: SAR Measurement for Qualcomm Smart Transmit Algorithm Validation
- Chapter 9: Conclusions

2 Qualcomm Smart Transmit Operation Description

2.1 Algorithm description

FCC SAR limit is defined based on time average RF exposure. Qualcomm® Smart Transmit algorithm developed by Qualcomm, when running in a wireless device, will ensure the wireless device is in compliance with FCC limit of SAR averaged over a defined time window, denoted as *SAR_time_window*, at all times. It enables more "elegant" power control mechanisms for RF exposure management. The Smart Transmit algorithm will not only ensure the wireless device to comply with RF exposure requirement, but also will improve the user experience and network performance.

For a given wireless device, SAR is proportional to the transmitting power, in other words, once the SAR of the wireless device is characterized at a transmit power level via SAR measurement, SAR at a different power level for the characterized configuration(s) can be scaled by the change in the corresponding power level. Therefore, for a characterized device, SAR compliance can be achieved through transmit power control and management.

The Smart Transmit algorithm incorporated in Qualcomm modems reliably controls the transmit power of the wireless device in real-time to maintain the time-averaged transmit power (in turn, time-averaged SAR) below the threshold predefined for a given technology and band. This predefined average power limit, denoted as P_{limit}, is determined so that the wireless device when continuously transmitting at P_{limit} level complies with the FCC SAR limit. The basic concept of the algorithm is that if time-averaged transmit power approaches the P_{limit}, then the modem needs to limit instantaneous transmit power to make sure that the time-averaged transmit power does not exceed the P_{limit} in any *SAR_time_window* (i.e., the time-averaged SAR complies with the FCC SAR limit in any *SAR_time_window*). The wireless device can instantaneously transmit at high transmit powers and exceed the P_{limit} for a short duration before limiting the power to maintain the time-averaged transmit power under the P_{limit}.

The Smart Transmit algorithm can be configured to manage the instantaneous transmit power (Tx power) to keep the time-averaged power to not exceed P_{limit}. If the wireless device transmits at high power for a long duration, then the radio link needs to be dropped in order to be compliant with time-averaged Tx power requirement (as shown in Figure 2-1(a)). 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 that wireless device can maintain the radio link at a minimum reserve power level for as long as needed and at the same time ensure that the time-averaged Tx power over any *SAR_time_window* is less than P_{limit} at all times (see Figure 2-1(b)). At all times, Smart Transmit meets the below equation (1):

$$time\ avg.Tx\ power = \frac{1}{T}\int_{t}^{t+T} inst.Tx\ power(t)\,dt \leq P_{limit} \qquad (1)$$

where, $time\ avg.Tx\ power$ is the power averaged between t and $t+T$ time period; T is *SAR_time_window*; *inst. Tx power (t)* is the instantaneous transmit power at t time instant; P_{limit} is the predefined time averaged power limit.

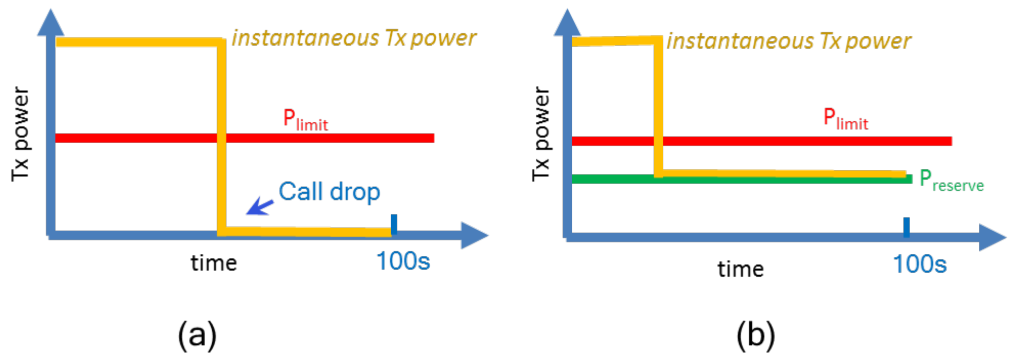


Figure 2-1 Smart Transmit Operation: (a) Transmit at high power when needed and permitted; (b) Transmit with reserve power to support continuous transmission at a minimum power level ($P_{reserve}$).

See Qualcomm Smart Transmit Operation Description document for details.

2.2 Configurable parameters

The input parameters required for functionality of Smart Transmit algorithm are listed below. All these parameters are entered via Embedded File System (EFS) entries by OEM at the factory, and the end user has no access to these parameters.

1. *SAR_time_window*

   Time, in seconds, over which to average SAR. Note, for the frequency range used by HP tablet HSN-I06C, it has been determined through FCC's KDB inquiry that a time-averaging window of 100 seconds is acceptable for this device to support equipment certification.

2. *Tx_power_at_SAR_design_target* (P_{limit})

   The maximum time average 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 device related tolerances. The time-averaged SAR is assessed against this *SAR_design_target* in real time to determine the compliance. The P_{limit} could vary with technology and/or band, therefore it has the unique value for each technology and band.

3. *Reserve_power_margin* (dB)

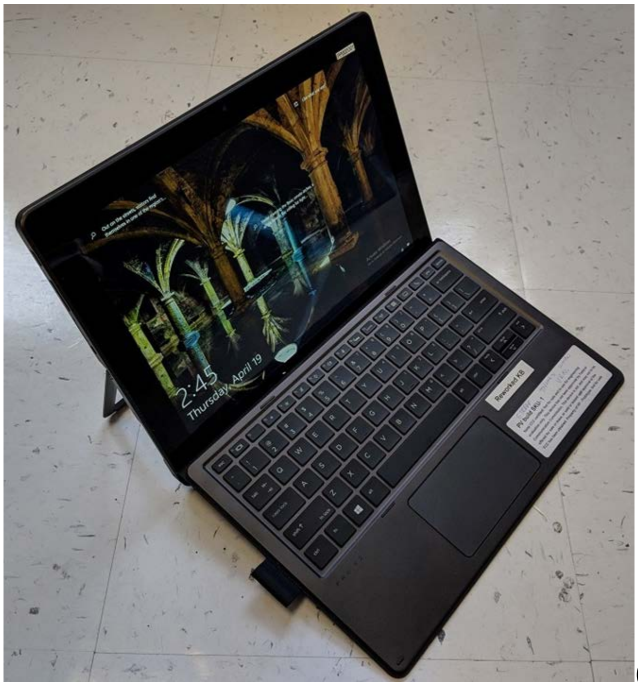
   The relative margin, in dB, below the P_{limit} to reserve for future transmission with a minimum transmit power ($P_{reserve}$):

   $$P_{reserve}\,(\text{dBm}) = P_{limit}\,(\text{dBm}) - Reserve\_power\_margin\,(\text{dB})$$

   The *Reserve_power_margin* is a global parameter, meaning the same *Reserve_power_margin* applies to all the radio configurations where Smart Transmit is enabled (for example, in this report, all the technologies and bands that HP model HSN-I06C WWAN module supports). The greater the *Reserve_power_margin* is, the lower the Tx power ($P_{reserve}$) reserved for the ongoing transmission will be, resulting in longer high power bursts; while with smaller *Reserve_power_margin*, the Tx power reserved for the ongoing transmission ($P_{reserve}$) is higher, resulting in shorter high power bursts. In the extreme case, when the *Reserve_power_margin* is set to zero dB, which leads to $P_{reserve}$ (dBm) = P_{limit} (dBm), Smart Transmit effectively limits the upper bound of wireless device Tx power to P_{limit}. In this case, when the device is requested to transmit at maximum power, the device transmits continuously at P_{limit} when there is no additional MPR enforced from other creteria, i.e., no high power burst is allowed.

3 Product Description

HP tablet model HSN-I06C is shown in Figure 3-1.



(a)

(b)

Figure 3-1 HP Tablet model HSN-I06C: (a) perspective view of the 2-in-1 device; (b) tablet Only

Qualcomm Smart Transmit algorithm is implemented in MSM9625 modem. The FOXCONN T77W595 WWAN module containing MSM9625 is embedded in HP tablet model HSN-I06C. The specification of the HP tablet is listed in the Table 3-1 below:

Table 3-1 Specification of HP Tablet Model HSN-I06C

Equipment Under Test	Tablet	
Brand Name	HP	
Device Information	The device is a 2-in-1 device	
Model No.	HSN-I06C	
FCC ID	B94HNI06CAS	
Integrated Module	WWAN	Brand Name: FOXCONN Model Name: T77W595
	WLAN/BT	Brand Name: Intel Model Name: 8265D2W
Mode of Operation	WCDMA/HSDPA/HSUPA; LTE FDD; WLAN802.11a/b/g/n/ac (20MHz/40MHz/80MHz); Bluetooth	
Duty Cycle	WCDMA/HSDPA/HSUPA	1
	LTE FDD	1
	WLAN802.11 a/b/g/n/ac	1
	Bluetooth	1
Tx Frequency Range (MHz)	WCDMA II	1850 – 1910
	WCDMA IV	1710 – 1750
	WCDMA V	824 – 849
	LTE FDD band 2	1850 – 1910
	LTE FDD band 4	1710 – 1755
	LTE FDD band 5	824 – 849
	LTE FDD band 7	2500 – 2570
	LTE FDD band 12	699 – 716
	LTE FDD band 17	704 – 716
	WiFi 2.4GHz	2400 – 2483.3
	WiFi 5GHz	5150 – 5850
	Bluetooth	2400 – 2483.3
Channel Number (ARFCN)	WCDMA II	9262 – 9538
	WCDMA IV	1312 – 1513
	WCDMA V	4132 – 4233
	LTE FDD band 2	18607 – 19193
	LTE FDD band 4	19957 – 20393
	LTE FDD band 5	20407 – 20643
	LTE FDD band 7	20775 – 21425
	LTE FDD band 12	23017 – 23173
	LTE FDD band 17	23755 – 23825
	WiFi 2.4GHz	1 – 11
	WiFi 5GHz	36 – 165
	Bluetooth	0 – 78

The input parameters entered via EFS for Qualcomm Smart Transmit are listed in Table 3-2.

Table 3-2 EFS input parameters for Smart Transmit

SAR_time_window (seconds)	100
Reserve_power_margin (dB)	2
Tech/Band	***P_{limit}* (dBm)**
WCDMA Band II	17.5
WCDMA Band IV	17.5
WCDMA Band V	19
LTE Band 2	18
LTE Band 4	17
LTE Band 5	20
LTE Band 7	19
LTE Band 12	21.5
LTE Band 17	21.5

Figure 3-2 shows a view of all antenna locations inside the tablet. For WWAN radio, WWAN main antenna is capable of transmitting and receiving, the WWAN aux antenna is used for receiving only. For WLAN radio, both main and aux antenna could transmit.

Only Foxconn WWAN module embedded in HSN-I06C is enabled with Qualcomm Smart Transmit. The WLAN/Bluetooth module does not have this feature implemented.

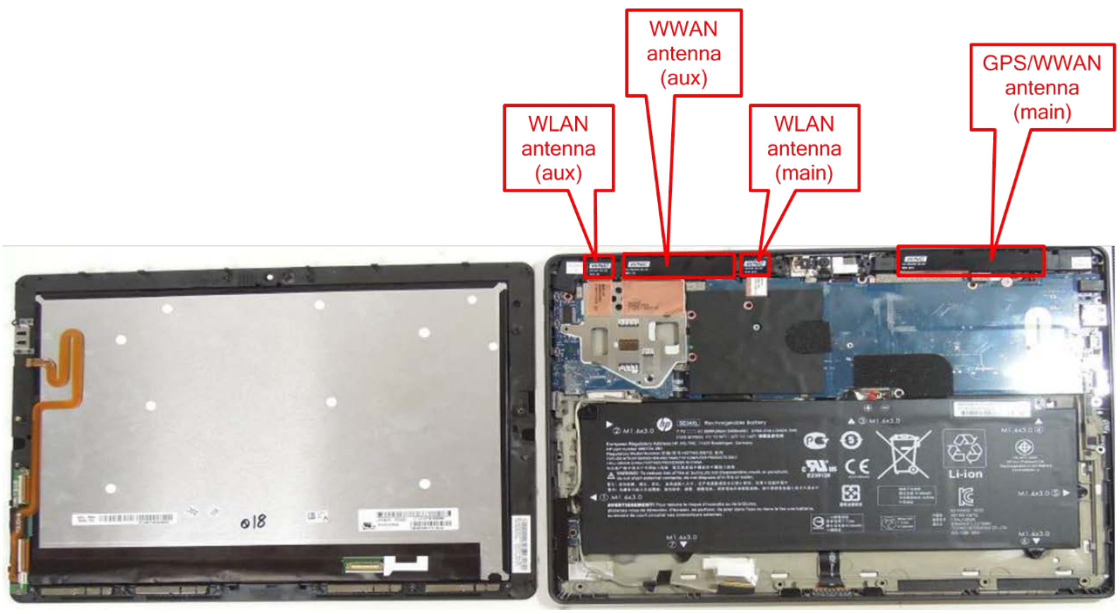


Figure 3-2 WWAN and WLAN antenna locations

4 Strategy for Compliance Demonstration

This section outlines the overall strategy to demonstrate the compliance for HP tablet HSN-I06C.

4.1 Overall strategy

Demonstrating compliance of HP tablet model HSN-I06C with Qualcomm Smart Transmit is done in two parts:

I. Perform compliance SAR measurements for all supported transmission scenarios with the equipment under test (EUT) transmitting at its corresponding maximum time average Tx power level (i.e., P_{limit}) for WWAN radios (enabled with Smart Transmit), and at EUT's full power for WLAN/Bluetooth radios (where no time averaging algorithm is implemented).

   For WWAN radios, all measured 1gSAR is scaled to *reported* 1gSAR to account for all device related tolerances, denoted as *total tolerance*. This *total tolerance* includes Smart Transmit algorithm accuracy as well as maximum RF tune-up tolerance, which for HP model HSN-I06C are (extracted from SGS compliance report):

Table 4-1 Algorithm accuracy and RF tune-up tolerance

Technology	MDM9625 Smart Transmit algorithm accuracy (dB)	Maximum RF tune-up tolerance (dB)	Total tolerance (dB)
WCDMA	±0.40	±0.59	±0.70
LTE	±0.40	±0.63	±0.73

   SAR compliance is demonstrated with the *reported* 1gSAR meeting the FCC SAR limit (1.6W/kg), i.e.,

$$\textit{reported}\ \text{1gSAR} = \text{measured 1gSAR} @ \textit{reported}\ P_{limit} < \text{FCC SAR limit} \qquad (2)$$

   where, *reported* P_{limit} = P_{limit} (in EFS entry) + *total tolerance*.

   SAR compliance for simultaneous transmission of WWAN and WLAN scenarios is assessed by combining the time average power based *reported* 1gSAR of WWAN radio with full power based *reported* 1gSAR of relevant WLAN/Bluetooth radio.

   See SGS SAR report for details of the compliance SAR measurement and assessment for HP model HSN-I06C.

II. Perform time-averaging validation to show that, with the Smart Transmit enabled, the HP tablet Tx power of WWAN radio when averaged over any 100s-time window, i.e., time-averaged Tx power, does not exceed *reported* P_{limit} when accounting for *total tolerance*, i.e., equation (1) is re-written as to account for *total tolerance*:

$$time\ avg.Tx\ power = \frac{1}{T}\int_{t}^{t+T} inst.Tx\ power(t)\,dt \le reported\ P_{limit} \qquad (3a)$$

In other words, as described in Section 2, since the HP tablet is SAR-calibrated in Part I, equation (3a) also effectively expresses that 100s-time averaged SAR does not exceed the SAR assessed at the power level of *reported_*P_{limit}, i.e.,

$$time\ avg.SAR = \frac{1}{T}\int_{t}^{t+T} inst.SAR(t)\,dt \le SAR@reported\ P_{limit} \qquad (3b)$$

where, $time\ avg.Tx\ power$ or $time\ avg.SAR$ is the Tx power or SAR averaged between *t* and $t+T$ time period; *T* is *SAR_time_window* which corresponds to 100s-time window for this device as determined through FCC's KDB inquiry; *inst. Tx power (t)* or $inst.SAR(t)$ is the instantaneous Tx power or instantaneious SAR at *t* time instant; $reported\ P_{limit}$ is the pre-defined time averaged power limit after accounting for the *total tolerance*.

The validation test is performed by Qualcomm Technologies, Inc., this report documents the test plan for validation, test procedures and measurement results.

The compliance SAR measurement (Part I) in combination with the time-averaging algorithm validation (Part II) is used to demonstrate that the time-averaged SAR of HP model HSN-I06C is compliant with the FCC SAR limit.

4.2 Validation strategy

Validation of time-averaging algorithm covers the following scenarios:

1. During a time-varying Tx power transmission: to prove that the Smart Transmit algorithm accounts for Tx power variations in time accurately.
2. During a call drop and re-establish scenario: to prove that the Smart Transmit algorithm accounts for history of past Tx power transmissions accurately.
3. During technology/band handover: to prove that the Smart Transmit algorithm functions correctly during transitions in technology/band.

As described in Section 2, the SAR is proportional to the Tx power for a SAR-characterized wireless device. Thus, the algorithm validation can be effectively performed through conducted power measurement. To have high confidence in this validation but also be practical, the strategy for the validation is outlined as below:

- Demonstrate the Tx power averaged over a 100s-time window does not exceed *reported* P_{limit}, i.e., Eq. (3a), through conducted power measurements for all transmission scenarios (i.e., above scenarios 1 through 3);
- Demonstrate the SAR averaged over a 100s-time window does not exceed SAR level assessed at *reported_*P_{limit}, i.e., Eq. (3b), through time-averaged SAR measurements for only scenario 1 to add confidence in the algorithm validation while avoiding the complexity in SAR measurement (in particular, for scenario 3 requiring change in SAR probe calibration file to accommodate different bands and/or tissue simulating liquid).

5 Validation Test Plan

This section provides the test plan for validating Qualcomm Smart Transmit algorithm.

5.1 Test sequence determination for validation

Following FCC recommendation, two test sequences having time-variation in Tx power are pre-defined for this validation:

- Test sequence 1: requesting EUT to transmit at maximum power, measured $P_{max}^{\dagger}$, for 80s, and then requesting for half of the maximum power, i.e., measured $P_{max}/2$, for the rest of the time.
- Test sequence 2: requesting EUT to transmit at time-varying Tx power levels. This sequence is generated relative to measured P_{max}, measured P_{limit} and calculated $P_{reserve}$ (= measured P_{limit} - *Reserve_power_margin*) of EUT based on measured P_{limit}.

For easier computation of 100s running average, 0 dBm for 100s is added at the beginning of test sequences so that the 100s running average can be directly performed starting with the first 100-seconds data using excel spreadsheet.

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

† It should be noted that for test sequence generation, "measured P_{limit}" and "measured P_{max}" are used instead of the "P_{limit}" specified in EFS entry and "P_{max}" specified for the device, because Smart Transmit algorithm operates against the actual power level of the "P_{limit}" that was calibrated for the EUT. The "measured P_{limit}" accurately reflects what the algorithm is referencing to, therefore, it should be used during algorithm validation testing. The RF tune up and device-to-device variation are taken into account in SAR compliance assessment in SGS SAR report.

5.2 Test configuration selection criteria for validating smart transmit algorithm

5.2.1 Test configuration selection for time-varying Tx power transmission

The Smart Transmit time averaging algorithm 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 is: based on the compliance SAR test report provided by SGS lab, select two bands* in each supported technology (i.e., WCDMA and LTE for HP model HSN-I06C) that correspond to least** and highest*** P_{limit} values for validating Smart Transmit.

* If one P_{limit} level applies to all the bands within a technology, then only one band needs to be tested. In this case, within the bands having the same P_{limit}, the radio configuration (e.g., # of RBs, channel#) and device position that correspond to the highest *reported* 1gSAR shown in the compliance SAR test report provided by SGS lab should be selected.

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

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

5.2.2 Test configuration selection for change in call

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

- select technology/band with least P_{limit} among all supported technologies/bands, and select the radio configuration (e.g., # of RBs, channel#) in this technology/band that corresponds to the highest *reported* 1gSAR listed in the compliance SAR test report provided by SGS lab
- in case of multiple bands having same least P_{limit}, then select the band having the highest *reported* 1gSAR

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, at that time, call change (call drop/re-establish) is performed. One test is sufficient as the algorithm operation is independent of technology and band.

5.2.3 Test configuration selection for change in technology/band

The selection criteria for this measurement is to have EUT switch from a technology/band with lowest P_{limit} within the technology group (in case of multiple bands having the same P_{limit}, then select the band with highest *reported* 1gSAR) to a technology/band with highest P_{limit} within the technology group (in case of multiple bands having the same P_{limit}, then select the band with lowest *reported* 1gSAR).

This test is performed with the EUT being requested to transmit at maximum power, the above selection for first technology/band will result in Tx power enforcement (i.e., EUT forced to transmit at $P_{reserve}$) for longest duration, at that time, the technology/band switch is performed. One test is sufficient as the algorithm operation is independent of technology and band.

5.3 Test procedures for conducted power measurements

Perform conducted power measurement to validate Smart Transmit time averaging algorithm in all the transmission scenarios described in Section 4.2.

5.3.1 Time-varying Tx power scenario

This test is performed with the two pre-defined test sequences described in Section 5.1 for all the technologies and bands selected in Section 5.2.1. The purpose of the test is to demonstrate that the time-averaged power does not exceed the corresponding *reported* P_{limit} level at all times (see Eq. (3a)).

Test procedure:

1. Measure P_{max}, measure P_{limit} and calculate $P_{reserve}$ (= measured $\mathrm{P_{limit}}$ – *Reserve_power_margin*) and follow Section 5.1 to generate the test sequences for all the technologies and bands selected in Section 5.2.1. Both test sequence 1 and test sequence 2 are created based on measured P_{max} and measured P_{limit} of the EUT. Test condition to measure P_{max} and P_{limit} is:
   - ◻ Measure P_{max} with Smart Transmit disabled and callbox set to request maximum power.
   - ◻ Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value (see Table 3-2), with callbox requesting the EUT to transmit at pre-defined test sequence 1 (generated in Step 1), measure and record Tx power versus time. Once the measurement is done, extract instantaneous Tx power versus time, and perform 100s running average to determine time-averaged Tx power versus time as illustrated in below Figure 5-1.

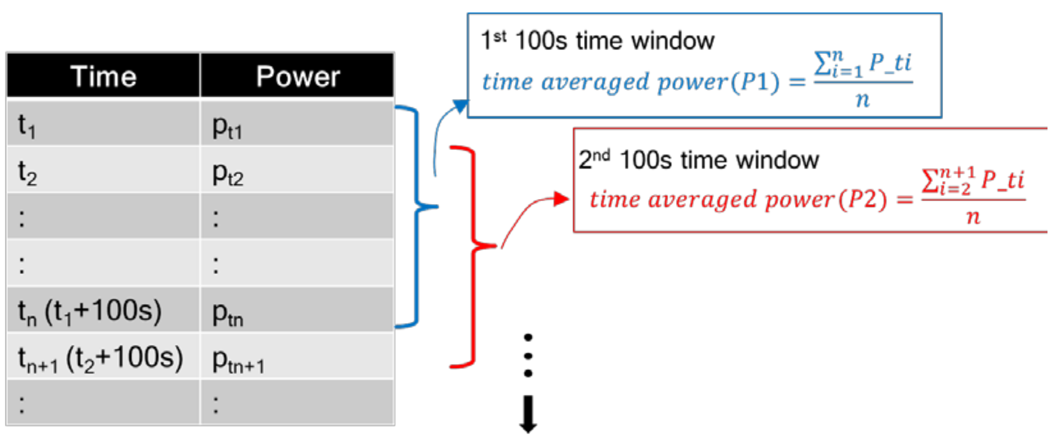


Figure 5-1 100s running average illustration

3. Make one plot containing (a) instantaneous Tx power versus time measured in Step 2, (b) time-averaged Tx power versus time determined in Step 2, (c) requested transmit power used in Step 2 (test sequence 1), and (d) corresponding *reported* P_{limit}.
4. Repeat Steps 2~3 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 3c with test sequence 2.
5. Repeat Steps 2~4 for all the selected technologies and bands.

The validation criteria is, at all times, the time-averaged Tx power versus time determined in Step 2 shall not exceed the *reported* P_{limit} of the corresponding technology/band (i.e., as shown in Section 4.1, Eq. (3a)).

5.3.2 Change in call scenario

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

The call drop and re-establishment needs to be performed during power limit enforcement, i.e., when the EUT transmits at $P_{reserve}$ level (see Figure 3-1b), to demonstrate the continuity of power management and limiting in call change scenario. In other words, the power averaged over any 100s-time window (including the time windows containing the call change) doesn't exceed the corresponding *reported* P_{limit}.

Test procedure:

1. Set *Reserve_power_margin* to actual (intended) value (see Table 3-2) and enable Smart Transmit
2. Establish radio link with callbox in technology/band selected in Section 5.2.2.
3. 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 for a total test time of 500 seconds. Measure and record Tx power versus time.
4. Once the measurement is done, extract instantaneous Tx power versus time, and perform 100s running average to determine time-averaged Tx power versus time as illustrated in Figure 5-1.
5. Make one plot containing (a) instantaneous Tx power versus time measured in Step 3, (b) time-averaged Tx power versus time determined in Step 4, and (c) corresponding *reported* P_{limit}.

The validation criteria is, at all times, the time-averaged Tx power versus time shall not exceed the *reported* P_{limit} of the corresponding technology/band (i.e., as shown in Section 4.1, Eq. (3a)).

5.3.3 Change in technology and band

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

Similar to the change in call test in Section 5.3.2, to validate the continuity of power 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). As described in Section 2, the P_{limit} could vary with technology and band, but different P_{limit} levels refer to the same *SAR_design_target* for a SAR-characterized wireless device. Thus, the equation (3a) in Section 4.1 can be written as below for transmission scenario having change in technology/band,

$$\frac{1}{T}\int_{t}^{t1}\frac{P1(t)}{reported\ P_{limit\_1}}dt+\frac{1}{T}\int_{t1}^{t+T}\frac{P2(t)}{reported\ P_{limit\_2}}dt\le 1 \qquad (4)$$

where, $P1(t)$ and *reported* P_{limit_1} correspond to the instantaneous Tx power and *reported* P_{limit} of technology1/band1; $P2(t)$ and P_{limit_2} correspond to the instantaneous Tx power and *reported* P_{limit} of technology2/band2.

Therefore, the validation criteria is that, at all times, the ratio of time-averaged Tx power to *reported* P_{limit} versus time in any 100s-time window shall not exceed 1.

The step-by-step test procedure for this measurment is provided in Appendix B.

5.4 Test procedure for SAR measurements

To validate time averaging algorithm through SAR measurement, 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.

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

1. “Path Loss” calibration: Place the EUT against the flat section of the SAM Twin phantom in the worst-case position determined based on Section 5.2.1. 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, extreme care needs to be taken to avoid the influence from reflections. The test setup is described in Section 7.1 and the step-by-step test procedure for “path loss” calibration is provided in Appendix C.

2. Time averaging algorithm validation:

    i For a given radio configuration (technology/band) selected in Section 5.2.1, 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 pointSAR value corresponds to pointSAR at the measured P_{limit} obtained in Step 1 of Section 5.3.1. Scale this pointSAR at measured P_{limit} to *reported* P_{limit}, to obtain *point*SAR$_{reported_Plimit}$.

    ii Set *Reserve_power_margin* to actual (intended) value (see Table 3-2), with callbox requesting the EUT to transmit at power levels described by test sequence 1 in Step 1 of Section 5.3.1, conduct pointSAR measurement versus time at peak location of the area scan determined in this section Step 2.i. Once the measurement is done, extract instantaneous pointSAR vs time data, and perform 100s running average to determine time-averaged pointSAR versus time.

    iii Make one plot containing (a) instantaneous pointSAR versus time measured in this section Step 2.ii, (b) time-averaged pointSAR versus time determined in this section Step 2.ii, (c) $pointSAR_{reported\_Plimit}$ obtained in this section Step2.i, and (d) requested Tx power (test sequence 1 using secondary Y-axis scale) versus time.

iv Repeat 2.ii ~ 2.iii for test sequence 2 generated in Step 1 of Section 5.3.1

v Repeat 2.i ~ 2.iv for all the technologies and bands selected in Section 5.2.1.

The time-averaging validation criteria for SAR measurement is that, at all times, time-averaged pointSAR obtained in this section Step 2.ii shall not exceed the corresponding $pointSAR_{reported\_Plimit}$ determined in this section Step 2.i (i.e., Eq. (3b)).

Test Configurations

Based on the compliance SAR measurement report provided by SGS lab, the back side of device against the SAM flat phantom is the worst-case position resulting in the highest 1gSAR. Figure 5-2 shows the test positions of EUT for SAR assessment. The summary of worst-case 1gSAR data, P_{limit} values set in EFS entry and *reported* P_{limit} for each technology and band supported is extracted from SGS report and listed in Table 5-1.

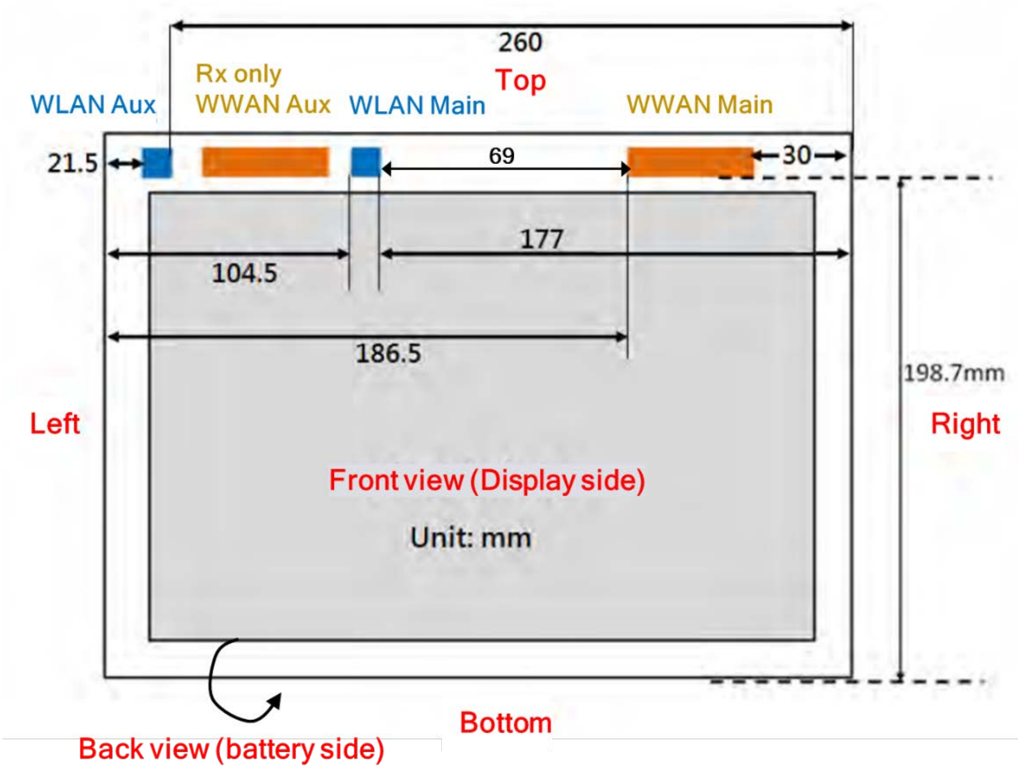


Figure 5-2 Test positions of EUT for SAR assessment

Table 5-1 P_{limit} and worst case 1gSAR extracted from SGS report

Tech	Band	P_{limit} EFS setting (dBm)	*reported* P_{limit} (dBm)	Back side ***reported*** 1g SAR (mW/g)	Channel/RB configuration for worst-case SAR in Back Side position
WCDMA (R99)	Band II	17.5	18.20	0.858	CH 9538
	Band IV	17.5	18.20	0.983	CH 1312
	Band V	19	19.70	1.212	CH 4233
LTE (QPSK)	Band 2	18	18.73	1.105	20MHz, CH19100 / RB size:100 / RB offset:0
	Band 4	17	17.73	0.860	20MHz, CH20175 / RB size:100 / RB offset:0
	Band 5	20	20.73	0.940	10MHz, CH20600 / RB size:25 / RB offset:25
	Band 7	19	19.73	0.523	20MHz, CH 20850 / RB size:50 / RB offset:0
	Band 12	21.5	22.23	1.251	10MHz, CH 23130 / RB size:50 / RB offset:0
	Band 17	21.5	22.23	1.269	10MHz, CH 23790 / RB size:25 / RB offset:0

Based on the selection criteria described in Section 5.2, the selections for validation test are:

1. Technologies and bands for time-varying Tx power transmission: For WCDMA, bands IV and V corresponding to least and highest P_{limit} values are selected. WCDMA band IV is selected over band II, as band IV has higher *reported* 1gSAR. For LTE, Band 4 corresponding to least P_{limit} is selected. LTE Bands 12 & 17 have too high P_{limit} setting (21.5dBm) that mostly do not require power limiting enforcement when testing the pre-defined test sequences described in Section 5.1*. Hence, LTE Band 5 having the next highest P_{limit} is selected for testing. All these bands are highlighted in above table.

   * The calculated maximum value of 100s running average power for test sequence 2 is 21.55dBm. Hence, measuring test sequence 2 for LTE Bands 12 and 17 with P_{limit} setting of 21.5dBm will not result in any observable power limit enforcement during validation testing. Note for estimation, the test sequence 2 was generated using 21.5dBm of EFS P_{limit}, 23dBm of typical P_{max}, and 2dB *reserve_power_margin*.

     Similiarly for LTE Band 5 having P_{limit} of 20dBm, the estimated maximum 100s-avearge power for test sequence 2 is 21.17dBm. Therefore, power limit enforcement will be required for Band 5 and should be clearly observed when testing with test sequence 2. Hence this next highest P_{limit} Band 5 having P_{limit} of 20dBm was selected for validation testing.

2. Technology and band for change in call test: LTE Band 4 having the least P_{limit} among all technologies and bands supported is selected for performing the call drop test.

3. Technologies and bands for change in technology/band test: Following the guidelines in Section 5.2.3, handover test is performed from a technology/band with lowest P_{limit} within the technology group (LTE Band 4), to a technology/band with highest P_{limit} within the technology group (WCDMA Band V). These values are marked in red text in the Table 5-1.

The technologies and bands selected for conducted power measurement and SAR measurement are listed in Table 5-2.

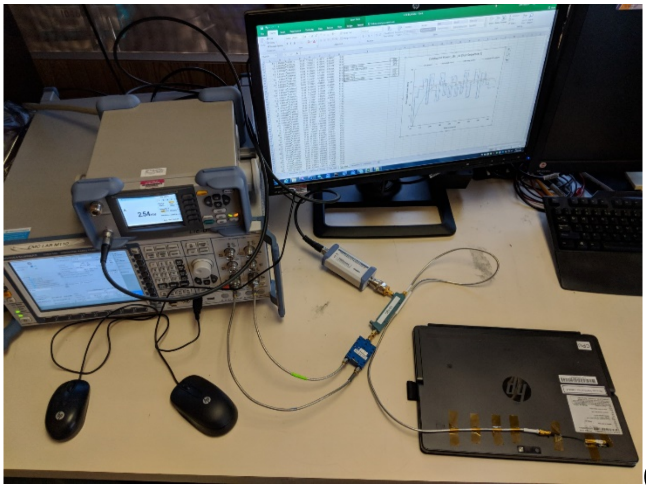
Table 5-2 Selections for validation measurements

Transmission Scenario	Test	Technology and Band	Notes
Time-varying power test	Cond. Power meas. SAR meas.	WCDMA (Rel 99) Band IV WCDMA (Rel 99) Band V LTE Band 4 LTE Band 5	Same channel # and/or RB configuration listed in Table 5-1 is used in validation tests
Call drop test	Cond. Power meas.	LTE Band 4	
Tech/Band switch test	Cond. Power meas.	LTE Band 4 to WCDMA Band V	

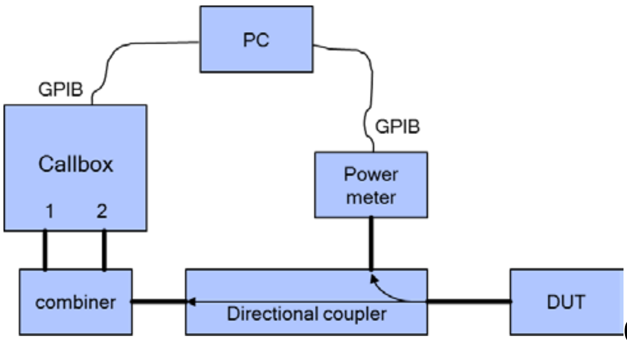
6 Conducted Power Measurement for Smart Transmit Algorithm Validation

6.1 Measurement setup

Rohde & Schwarz's CMW500 callbox is used in this test. The test setup is shown in Figure 6-1a and the schematic of the setup used to measure conducted powers for HP model# HSN-I06C is shown in Figure 6-1b. Two ports (RF1 COM and RF3 COM) of the callbox are connected to a combiner, which is connected to the RF port of the EUT (HP tablet) using a directional coupler. Note that this HP tablet has only one transmit/receive RF port which is shared for low and high bands. Power meter is used to tap the directional coupler for measuring the conducted output power of the EUT. For time averaging validation test (Section 5.3.1) and call drop test (Section 5.3.2), only one port (RF1 COM) of the callbox is used to communicate with the EUT, for technology/band switch measurement (Section 5.3.3), both ports (RF1 COM and RF3 COM) of callbox are used to switch from one technology (say, LTE) communicating on RF1 COM port to another technology (say, WCDMA) communicating on RF3 COM port. All the path losses from RF port of EUT to the callbox RF COM port and to the power meter are calibrated (listed in Table 6-1) and manually entered as offsets in the callbox and the power meter, respectively.



(a)



(b)

Figure 6-1 Conducted power measurement setup

Table 6-1 Path loss in conducted power measurement setup

Frequency (MHz)	Callbox Path Loss (dB)	Power Meter Path Loss (dB)
850	5.43	10.8
1750	6.14	10.6

Both the callbox and power meter are connected to the PC using GPIB cables. Two test scripts are custom made for automation: one is for time-varying transmit power measurement, another is for call drop and technology/band switch tests. 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 command sent to the callbox to request power are:

1. 0dBm for 100 seconds
2. test sequence 1 or test sequence 2 (defined in Section 5.1 and generated in Section 5.3.1), for 360 seconds
3. stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

Power meter readings are periodically recorded every 0.5s. A running average of this measured Tx power over 100 seconds (i.e., 200 data points collected with 0.5s sampling rate) is performed in the post-data processing to determine the 100s-time averaged power.

For call drop and technology/band switch tests, the callbox is set to request maximum power all the time. When the call is established, the 2nd test script runs at the same time to start recording the Tx power measured at EUT RF port using the power meter, the call drop/re-establish or technology/band switch is manually performed when the Tx power of EUT is at $P_{reserve}$ level. See Section 6.3 for detailed test procedure of call drop test, and Appendix B for detailed test procedure of technology/band switch test.

6.2 Time-varying transmit power measurement results

The measured P_{max} and measured P_{limit} of each selected radio configuration are used for generation of test sequences following the test plan in Section 5.3.1. The purpose of the time-varying transmit power measurement is to demonstrate the effectiveness of power limiting enforcement and that the time averaged transmit power does not exceed the *reported* P_{limit} corresponding to the tested technology/band.

As described in Section 2, Smart Transmit algorithm allows a wireless device to transmit at requested power levels as long as the time-averaged power is less than P_{limit}, as well as, there is enough margin left for future transmission at the corresponding reserve level $P_{reserve}$ (i.e., P_{limit} - *Reserve_power_margin*). This concept is evident in the time-varying transmit power tests. A sample test plot (LTE Band 4) is shown in Figure 6-2, where requested Tx power levels from callbox (test sequence 2) is shown in dotted line, measured instantaneous Tx power is shown in blue curve, 100s running averaged Tx power is shown in green curve, and the *reported* P_{limit} for LTE Band 4 is shown in red line. The P_{limit} for LTE Band 4 is 17dBm and the *Reserve_power_margin* is set to 2dB, resulting in 15dBm of $P_{reserve}$ for LTE Band 4. As can be seen, before 180 second time mark in Figure 6-2, the EUT transmit power (blue curve) follows the requested power level as the time averaged power (green curve) is well below the *reported* P_{limit}. Around 180 second time mark (circled region in black in Figure 6-2), Smart Transmit algorithm starts limiting the EUT Tx power (blue curve) before the time averaged power (green curve) reaches *reported* P_{limit} (red line) in order to preserve enough margin for future at ~15dBm of $P_{reserve}$ (from 180s to 210s), instead of forcing the EUT to drop call to meet Eq. (3a), i.e.,

$$time\ avg.Tx\ power = \frac{1}{T}\int_{t}^{t+T} inst.Tx\ power(t)\,dt \le reported\ P_{limit}$$

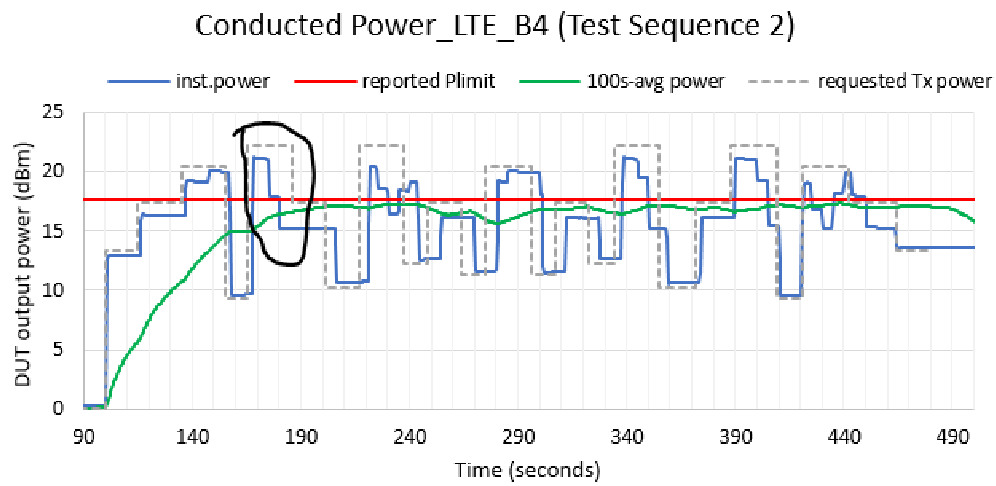


Figure 6-2 Sample plot of time-varying conducted power for LTE Band 4

Additionally, it should be noted that even at times when there is sufficient margin between time-averaged power and P_{limit} (i.e., between green curve and red line, as seen for example between 110s and 130s time mark in Figure 6-2), the discrepancy between requested transmit power (dotted line) and actual measured power (blue curve) is introduced by protocol level power control when the EUT is set in a closed loop mode and operates in an uncontrolled environment or in a non-ideally calibreated environment.

The conducted Tx power measurement results after following the test procedure in Section 5.3.1 for all technologies and bands listed in Table 6-2 are reported in this section. In all the plots, the dotted line represents the requested power by callbox (test sequence 1 or test sequence 2); the blue curve represents the instantaneous conducted Tx power measured using power meter; the green curve represents the 100s-time averaged power calculated based on measured instantaneous power; and the red line limit represents the *reported* P_{limit}.

As can be seen, the power limiting enforcement is effective in all the tests, and the time-averaged Tx power does not exceed the *reported* P_{limit} for all the tested technologies/bands. Therefore, Qualcomm® Smart Transmit time averaging algorithm is validated.

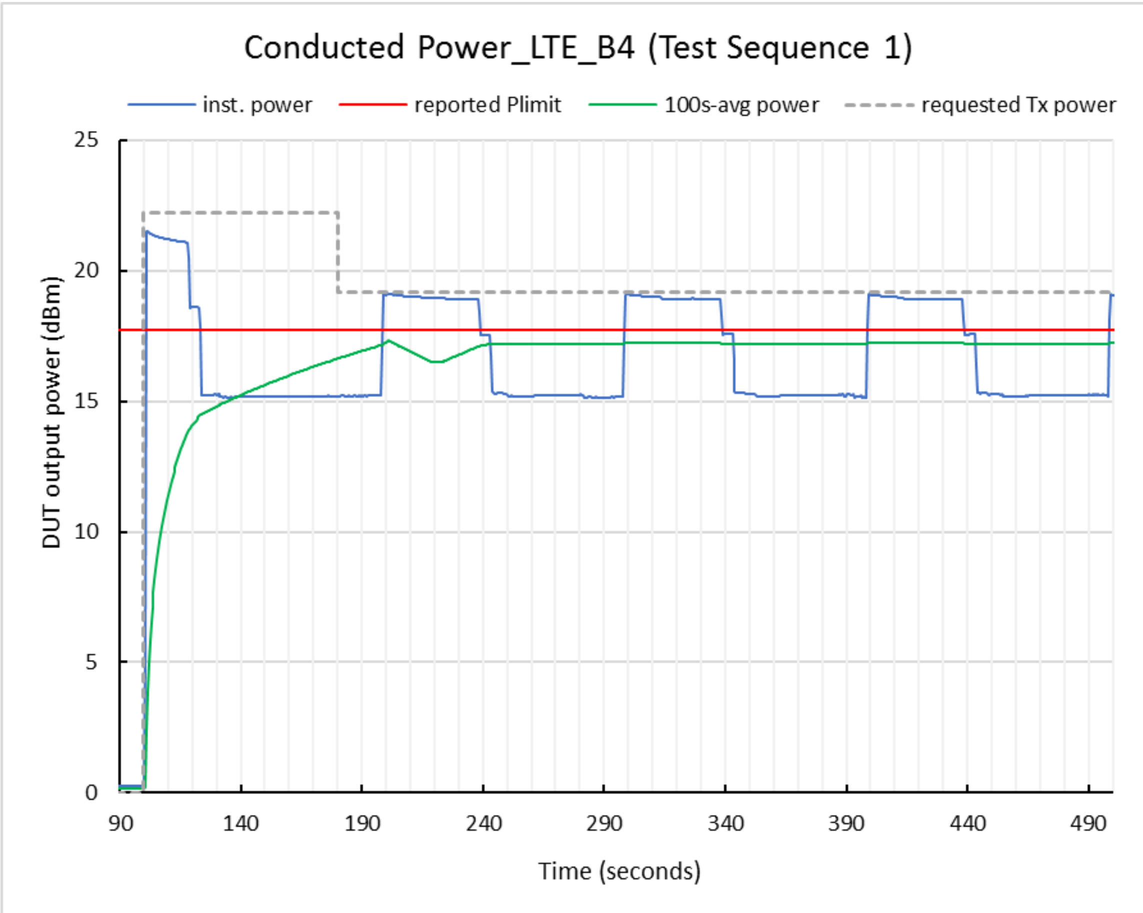
6.2.1 LTE Band 4

Test sequence 1:

Table 6-2 Test sequence 1 for LTE Band 4 measurement

Duration (seconds)	Tx_power(dBm)	Notes
100	0	
80	22.2	meas. P_{max}
320	19.2	meas. P_{max} - 3dB

Test result for test sequence 1:



	Power (dBm)
Max 100s-time averaged power (green curve)	17.33
reported P_{limit} (red line)	17.73
Validated	

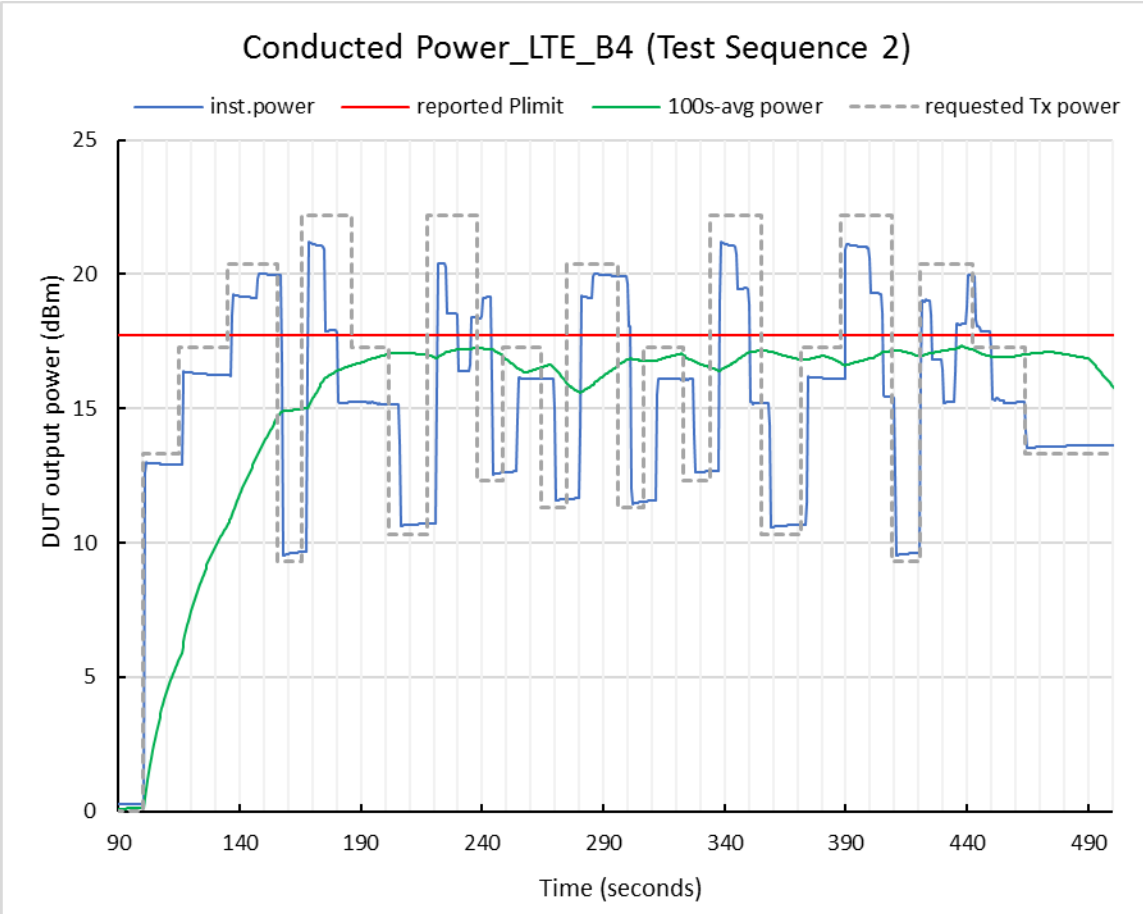
Test sequence 2:

Table 6-3 Test sequence 2 for LTE Band 4 measurement

Duration*(seconds)	Tx_power(dBm)	Notes
100	0	
15	13.3	meas. P_{limit} – reserve_power_margin - 2dB
20	17.3	meas. P_{limit}
20	20.4	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	9.3	meas. P_{limit} - reserve_power_margin - 6dB
20	22.2	meas. P_{max}
15	17.3	meas. P_{limit}
15	10.3	meas. P_{limit} - reserve_power_margin - 5dB
20	22.2	meas.P_{max}
10	12.3	meas. P_{limit} - reserve_power_margin - 3dB
15	17.3	meas. P_{limit}
10	11.3	meas. P_{limit} - reserve_power_margin - 4dB
20	20.4	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	11.3	meas. P_{limit} - reserve_power_margin - 4dB
15	17.3	meas. P_{limit}
10	12.3	meas. P_{limit} - reserve_power_margin - 3dB
20	22.2	meas.P_{max}
15	10.3	meas. P_{limit} - reserve_power_margin - 5dB
15	17.3	meas. P_{limit}
20	22.2	meas.P_{max}
10	9.3	meas. P_{limit} - reserve_power_margin - 6dB
20	20.4	(meas. P_{limit} + meas.P_{max})/2 rounded to 0.1dB step
20	17.3	meas. P_{limit}
15	13.3	meas. P_{limit} - reserve_power_margin - 2dB

*It should be noted that callbox-PC communication takes about 0.05 ~ 0.1 seconds for each power step, which results in an accrued delay throughout the test sequence. For visualization purposes in the plot below, the requested power test sequence (dotted line) is adjusted to compensate for this accumulated delay using 0.075 seconds, resulting in the best alignment with instantaneous Tx power (blue curve).

Test result for test sequence 2:



	Power (dBm)
Max 100s-time averaged power (green curve)	17.33
reported P_{limit} (red line)	17.73
Validated	

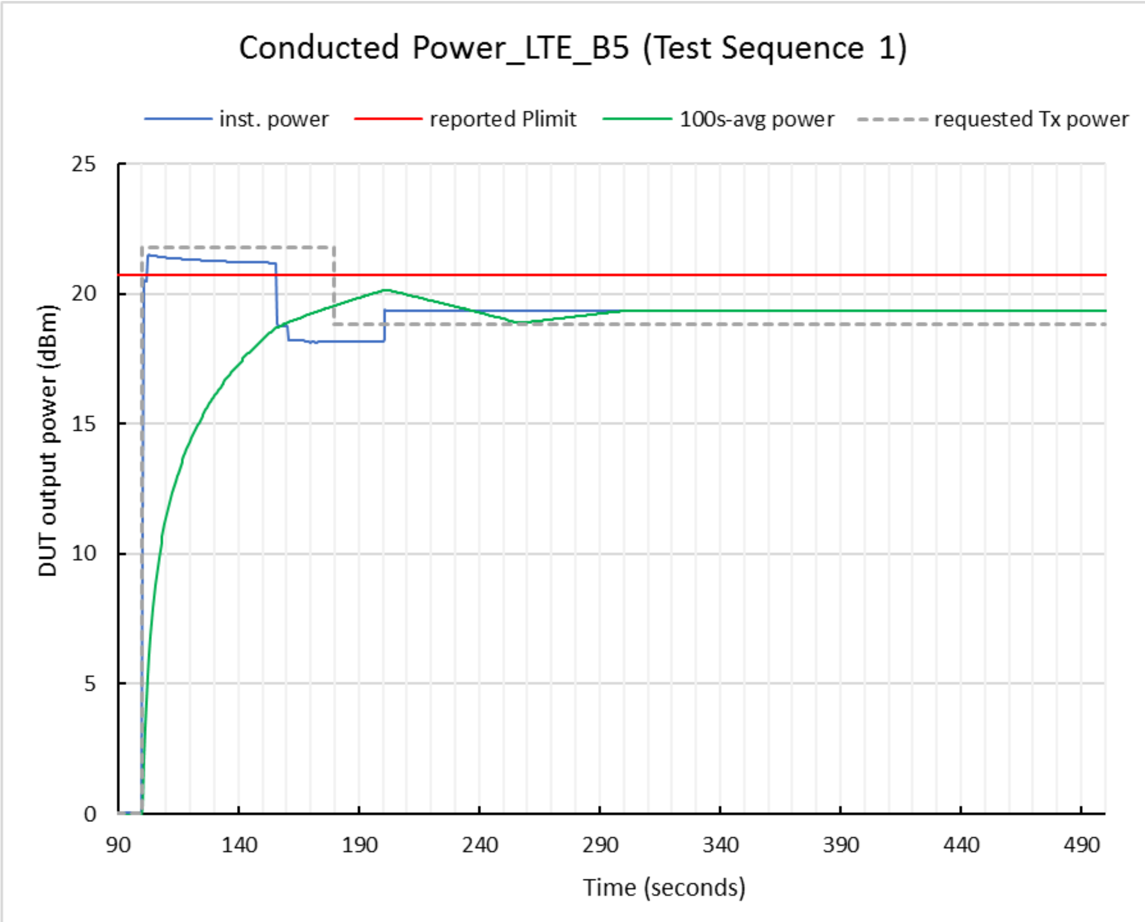
6.2.2 LTE Band 5

Test sequence 1:

Table 6-4 Test sequence 1 for LTE Band 5 measurement

Duration (seconds)	Tx_power(dBm)	Notes
100	0	
80	21.8	meas. P_{max}
320	18.8	meas. P_{max} - 3dB

Test result for test sequence 1:



	Power (dBm)
Max 100s-time averaged power (green curve)	20.15
reported P_{limit} (red line)	20.73
Validated	

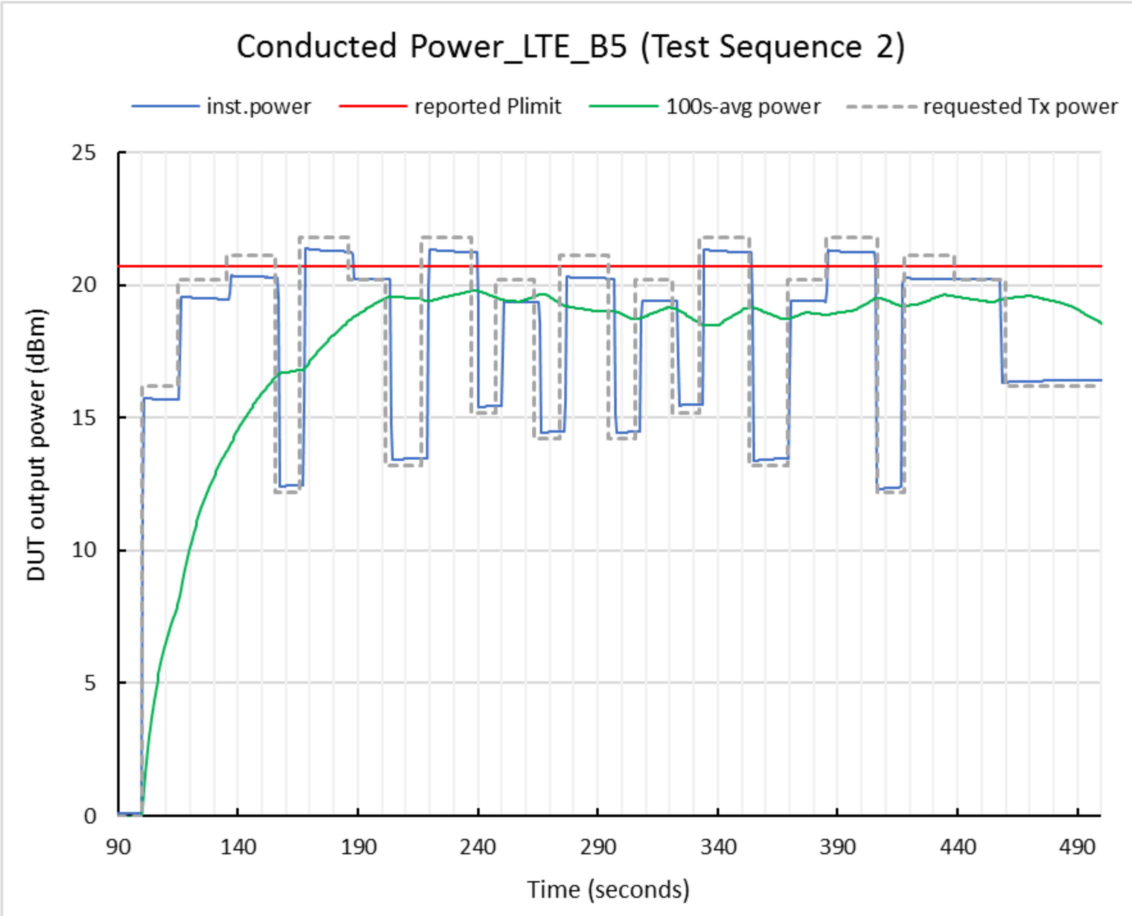
Test sequence 2:

Table 6-5 Test sequence 2 for LTE Band 5 measurement

Duration*(seconds)	Tx_power(dBm)	Notes
100	0	
15	16.2	meas. P_{limit} – reserve_power_margin - 2dB
20	20.2	meas. P_{limit}
20	21.1	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	12.2	meas. P_{limit} - reserve_power_margin - 6dB
20	21.8	meas. P_{max}
15	20.2	meas. P_{limit}
15	13.2	meas. P_{limit} - reserve_power_margin - 5dB
20	21.8	meas. P_{max}
10	15.2	meas. P_{limit} - reserve_power_margin - 3dB
15	20.2	meas. P_{limit}
10	14.2	meas. P_{limit} - reserve_power_margin - 4dB
20	21.1	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	14.2	meas. P_{limit} - reserve_power_margin - 4dB
15	20.2	meas. P_{limit}
10	15.2	meas. P_{limit} - reserve_power_margin - 3dB
20	21.8	meas. P_{max}
15	13.2	meas. P_{limit} - reserve_power_margin - 5dB
15	20.2	meas. P_{limit}
20	21.8	meas. P_{max}
10	12.2	meas. P_{limit} - reserve_power_margin - 6dB
20	21.1	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
20	20.2	meas. P_{limit}
15	16.2	meas. P_{limit} - reserve_power_margin - 2dB

*It should be noted that callbox-PC communication takes about 0.05 ~ 0.1 seconds for each power step, which results in an accrued delay throughout the test sequence. For visualization purposes in the plot below, the requested power test sequence (dotted line) is adjusted to compensate this accumulated delay using 0.06 seconds, resulting in the best alignment with instantaneous Tx power (blue curve).

Test result for test sequence 2:



	Power (dBm)
Max 100s-time averaged power (green curve)	19.79
reported P_{limit} (red line)	20.73
Validated	

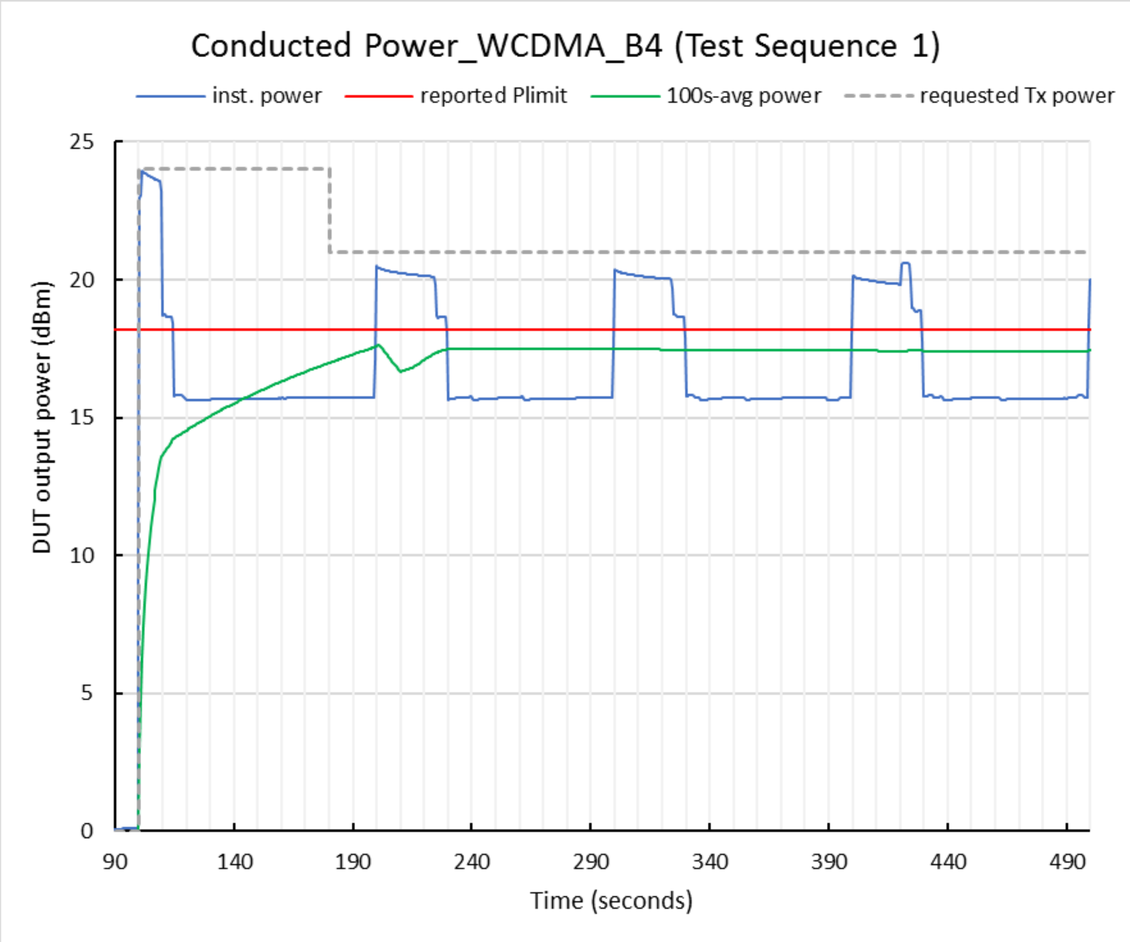
6.2.3 WCDMA Band IV

Test sequence 1:

Table 6-6 Test sequence 1 for WCDMA Band IV measurement

Duration (seconds)	Tx_power(dBm)	Notes
100	0	
80	24	meas. P_{max}
120	21	meas. P_{max} - 3dB

Test result for test sequence 1:



	Power (dBm)
Max 100s-time averaged power (green curve)	17.64
reported P_{limit} (red line)	18.20
Validated	

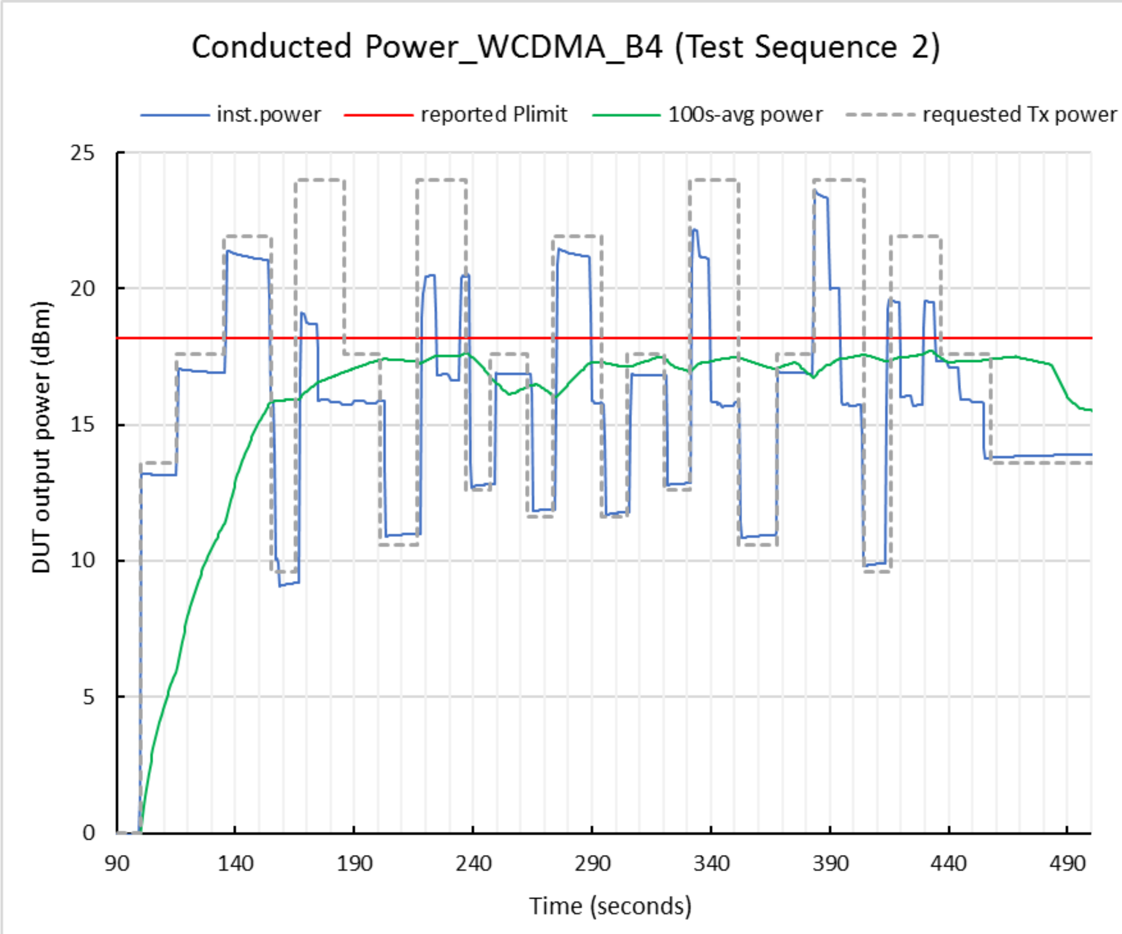
Test sequence 2:

Table 6-7 Test sequence 2 for WCDMA Band IV measurement

Duration*(seconds)	Tx_pwr(dBm)	Notes
100	0	
15	13.6	meas. P_{limit} – reserve_power_margin - 2dB
20	17.6	meas. P_{limit}
20	21.9	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	9.6	meas. P_{limit} - reserve_power_margin - 6dB
20	24	meas. P_{max}
15	17.6	meas. P_{limit}
15	10.6	meas. P_{limit} - reserve_power_margin - 5dB
20	24	meas. P_{max}
10	12.6	meas. P_{limit} - reserve_power_margin - 3dB
15	17.6	meas. P_{limit}
10	11.6	meas. P_{limit} - reserve_power_margin - 4dB
20	21.9	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	11.6	meas. P_{limit} - reserve_power_margin - 4dB
15	17.6	meas. P_{limit}
10	12.6	meas. P_{limit} - reserve_power_margin - 3dB
20	24	meas. P_{max}
15	10.6	meas. P_{limit} - reserve_power_margin - 5dB
15	17.6	meas. P_{limit}
20	24	meas. P_{max}
10	9.6	meas. P_{limit} - reserve_power_margin - 6dB
20	21.9	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
20	17.6	meas. P_{limit}
15	13.6	meas. P_{limit} - reserve_power_margin - 2dB

*It should be noted that callbox-PC communication takes about 0.05 ~ 0.1 seconds for each power step, which results in an accrued delay throughout the test sequence. For visualization purposes in the plot below, the requested power test sequence (dotted line) is adjusted to compensate this accumulated delay using 0.05 seconds, resulting in the best alignment with instantaneous Tx power (blue curve).

Test result for test sequence 2:



	Power (dBm)
Max 100s-time averaged power (green curve)	17.73
reported P_{limit} (red line)	18.20
Validated	

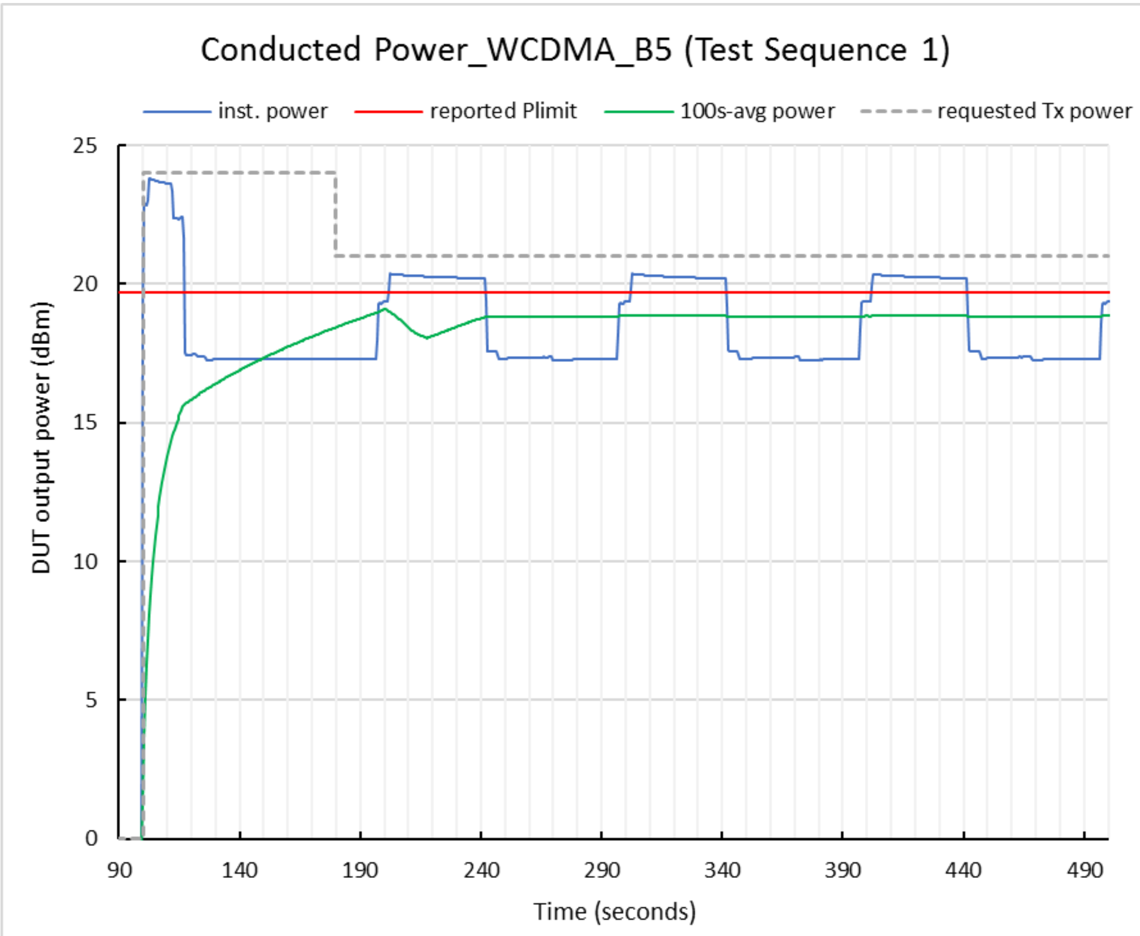
6.2.4 WCDMA Band V

Test sequence 1:

Table 6-8 Test sequence 1 for WCDMA Band V measurement

Duration (seconds)	Tx_pwr(dBm)	Notes
100	0	
80	24	meas. P_{max}
120	21	meas. P_{max} - 3dB

Test result for test sequence 1:



	Power (dBm)
Max 100s-time averaged power (green curve)	19.10
reported P_{limit} (red line)	19.70
Validated	

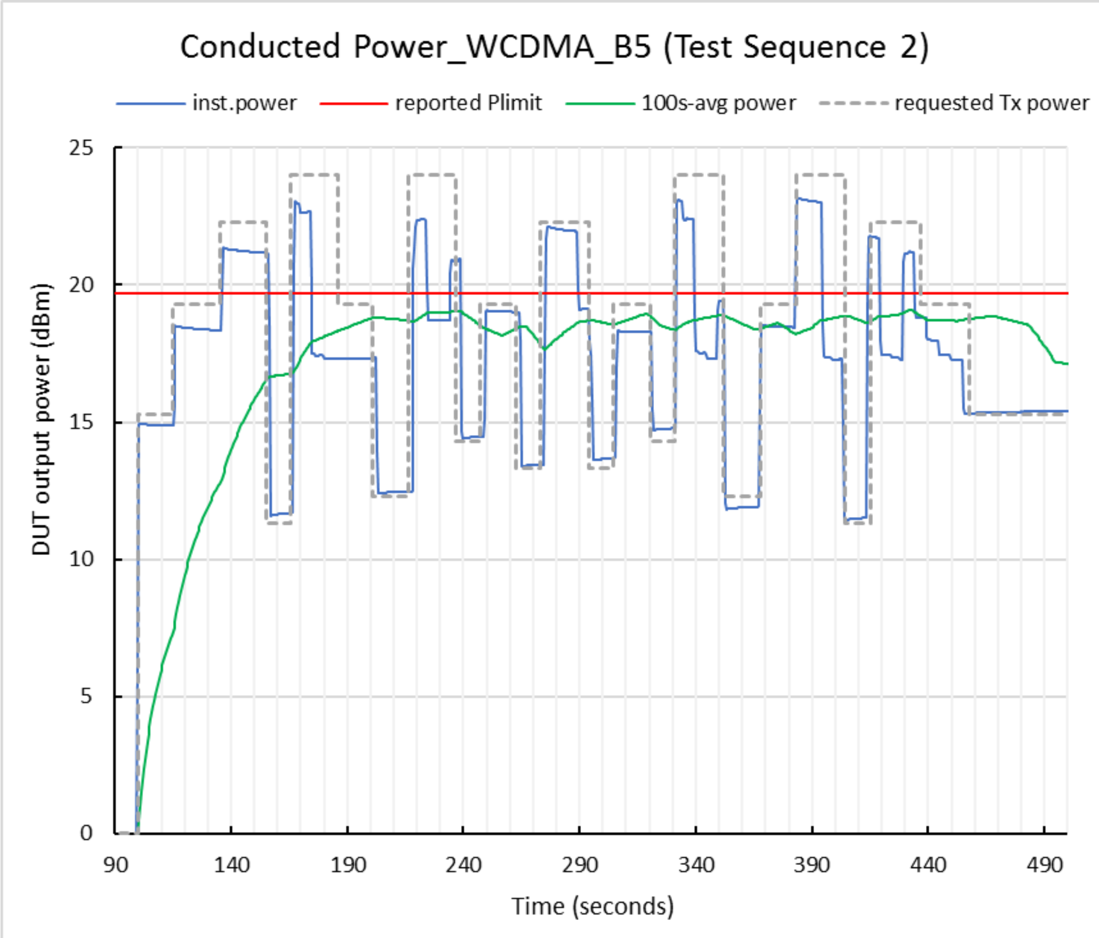
Test sequence 2:

Table 6-9 Test sequence 2 for WCDMA Band V measurement

Duration*(seconds)	Tx_pwr(dBm)	Notes
100	0	
15	15.3	meas. P_{limit} – reserve_power_margin - 2dB
20	19.3	meas. P_{limit}
20	22.3	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	11.3	meas. P_{limit} - reserve_power_margin - 6dB
20	24	meas. P_{max}
15	19.3	meas. P_{limit}
15	12.3	meas. P_{limit} - reserve_power_margin - 5dB
20	24	meas. P_{max}
10	14.3	meas. P_{limit} - reserve_power_margin - 3dB
15	19.3	meas. P_{limit}
10	13.3	meas. P_{limit} - reserve_power_margin - 4dB
20	22.3	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
10	13.3	meas. P_{limit} - reserve_power_margin - 4dB
15	19.3	meas. P_{limit}
10	14.3	meas. P_{limit} - reserve_power_margin - 3dB
20	24	meas. P_{max}
15	12.3	meas. P_{limit} - reserve_power_margin - 5dB
15	19.3	meas. P_{limit}
20	24	meas. P_{max}
10	11.3	meas. P_{limit} - reserve_power_margin - 6dB
20	22.3	(meas. P_{limit} + meas. P_{max})/2 rounded to 0.1dB step
20	19.3	meas. P_{limit}
15	15.3	meas. P_{limit} - reserve_power_margin - 2dB

*It should be noted that callbox-PC communication takes about 0.05 ~ 0.1 seconds for each power step, which results in an accrued delay throughout the test sequence. For visualization purposes in the plot below, the requested power test sequence (dotted line) is adjusted to compensate this accumulated delay using 0.05 seconds, resulting in the best alignment with instantaneous Tx power (blue curve).

Test result for test sequence 2:

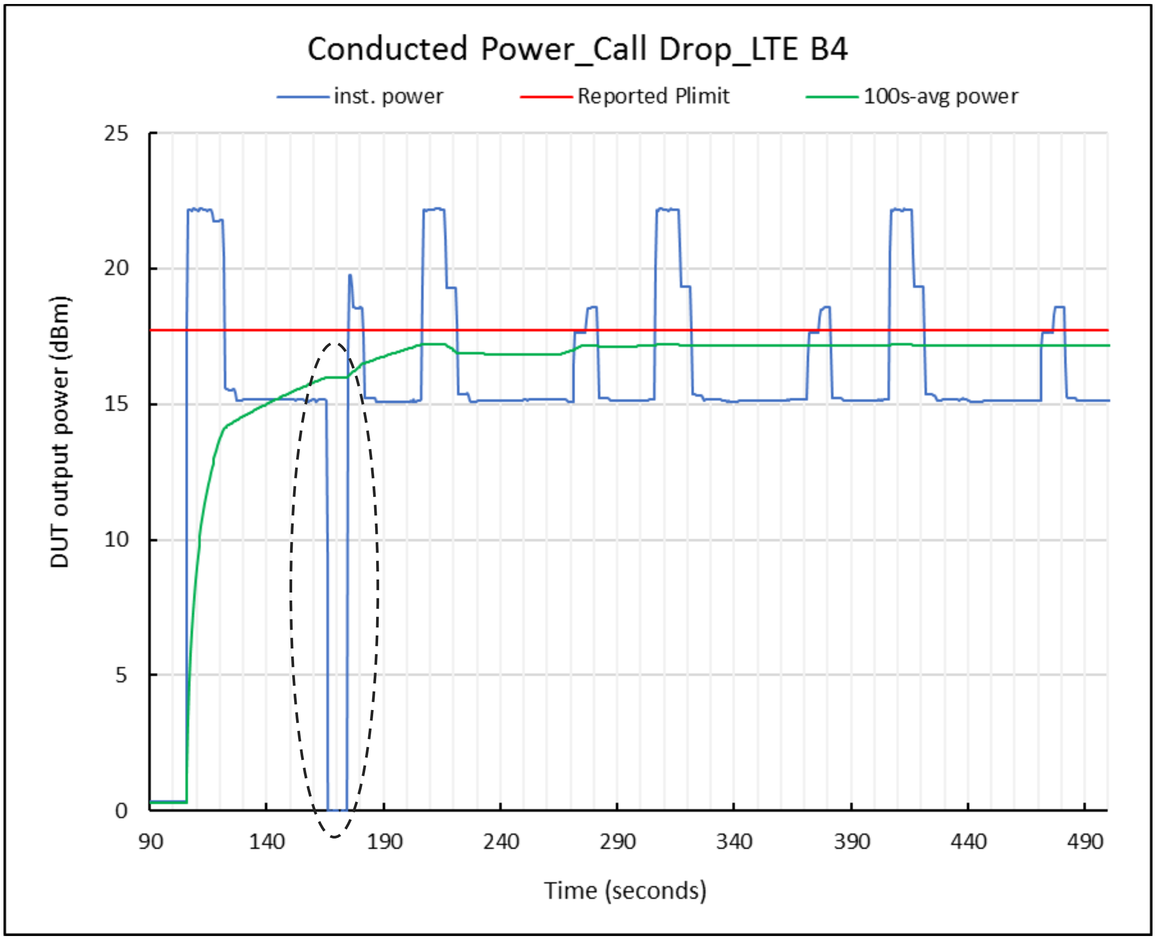


	Power (dBm)
Max 100s-time averaged power (green curve)	19.11
reported P_{limit} (red line)	19.70
Validated	

6.3 Call Drop Test Results

This test was measured with LTE Band 4 and with callbox requesting maximum power. The call drop was manually performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region). The measurement setup is shown in Figure 6-1, and the detailed test procedure is described in Section 5.3.2.

Call drop test result:



	Power (dBm)
Max 100s-time averaged power (green curve)	17.20
reported P_{limit} (red line)	17.73
Validated	

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

6.4 Change in technology/band test results

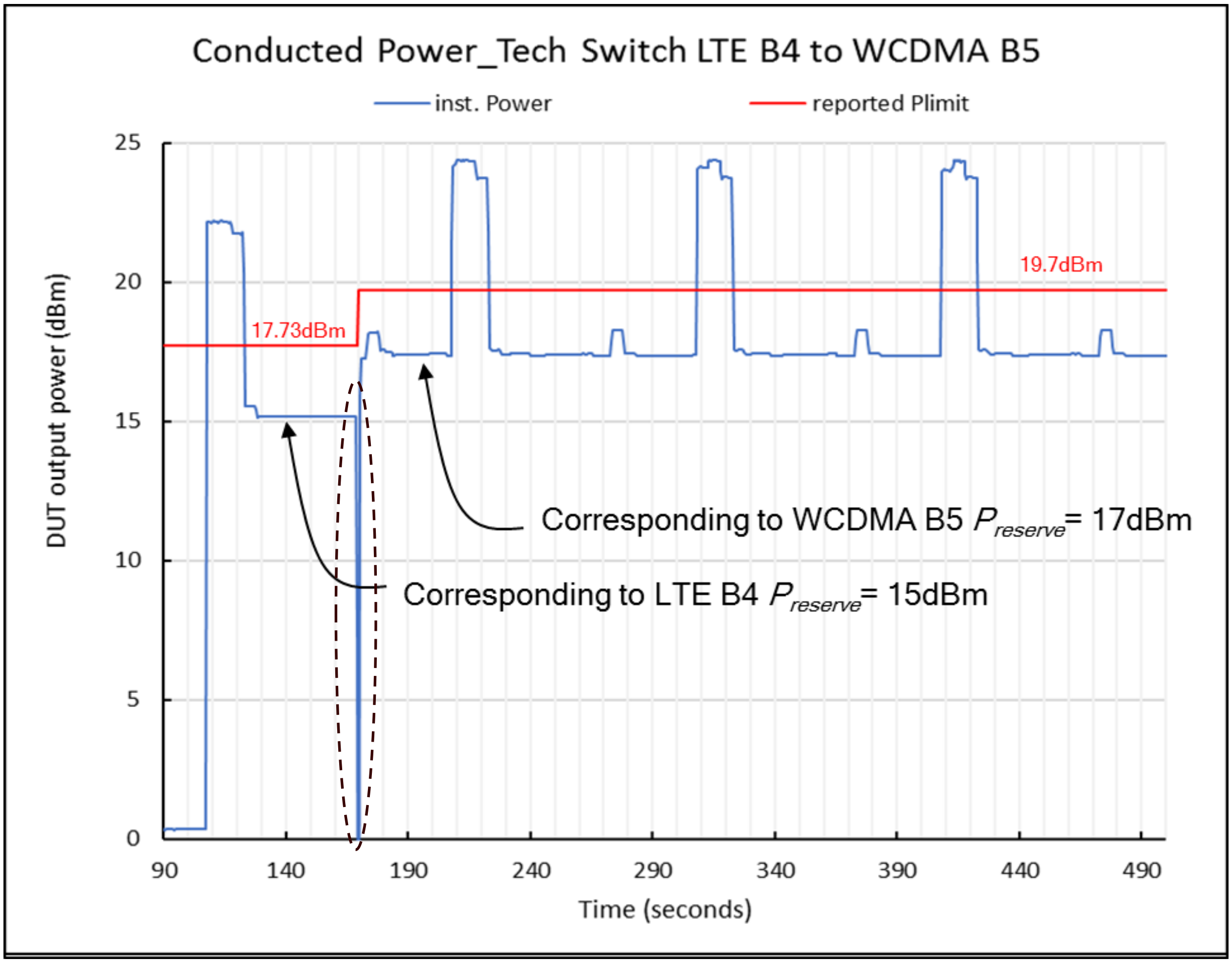
This test was conducted with callbox requesting maximum power, and with technology switch from LTE Band 4 to WCDMA Band V. Following procedure detailed in Section 5.3.3 and

Appendix B using the measurement setup shown in Figure 6-1, the technology/band switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region).

The power meter path loss setting was manually entered, path loss setting corresponding to LTE Band 4 (10.6 dB for 1750MHz) was used for the entire measurement. Since the path loss setting is different for WCDMA Band V (10.8 dB for 850MHz), during post-data processing, all the recorded power meter readings after technology/band was switched from LTE Band 4 to WCDMA Band V, were adjusted by the 0.2 dB difference in path loss.

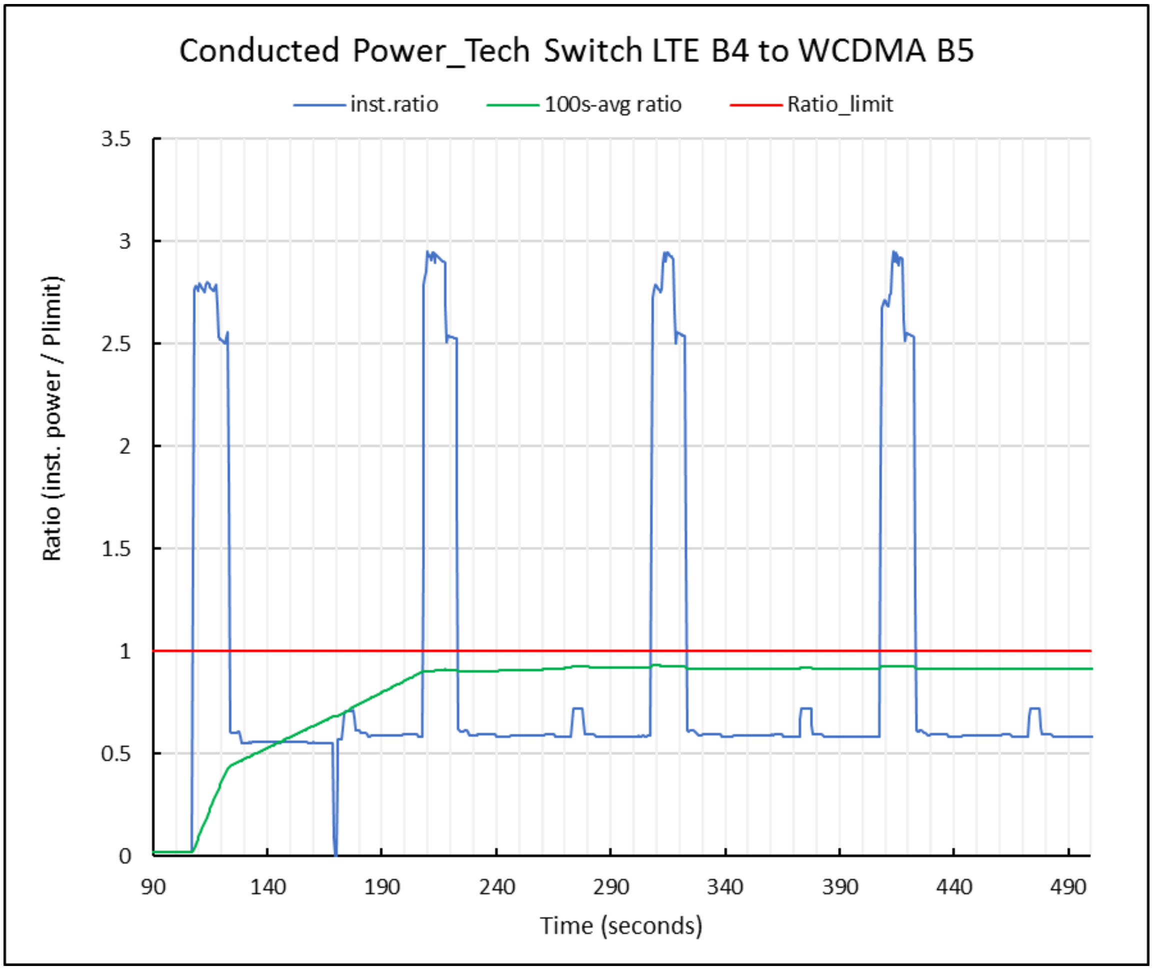
Test result for change in technology/band:

Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power changed from LTE Band 4 $P_{reserve}$ level to WCDMA Band V $P_{reserve}$ level:



Note: As per Table 3-2, with *Reserve_power_margin* = 2dB, P_{limit} = 17dBm for LTE Band 4, and P_{limit} = 19dBm for WCDMA Band V, it can be calcuated that $P_{reserve}$ = 15dBm and 17dBm for LTE Band 4 and WCDMA Band V, respectively.

Plot 2: Ratio of instantaneous Tx power (mW) to its corresponding *reported* P_{limit} versus time and the time averaged ratio does not exceed "1" in any 100s-time window (Eq. (4) in Section 5.3.3).



Max 100s-time averaged ratio (normalized power): green curve	0.93
Ratio_limit (red line)	1
Validated	

The test result (Plot 1 and Plot 2) validated the continuity of power limiting in technology/band switch scenario.

7 SAR Measurement for Smart Transmit Algorithm Validation

7.1 Measurement setup

The measurement setup is similar to normal SAR measurements, the EUT is positioned against the flat section of the SAM Twin phantom, and is 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 (see Figure 7-1) 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 in Section 5.4, 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" as explained further below. Detailed procedure to calibrate the "path loss" is provided in Appendix C.

The EUT is placed in worst-case position (listed in Table 5-1) against flat section of SAM Twin phantom as shown below:

Figure 7-1 SAR measurement setup

7.1.1 Setup for path loss calibration

Operator movements inside SAR chamber significantly influence the path loss between callbox and EUT, which in turn causes fluctuations in EUT Tx power during SAR measurements. Extreme care was taken to minimize effect of surroundings inside the SAR chamber, including placing absorber walls on all sides of flat section of the SAM Twin phantom to shield the setup from operator movements (see below photo). Without the absorber wall, when EUT is in closed loop power control mode, a significant change in EUT Tx power due to slight movement by the operator was observed. In the presence of the absorber wall (operator seated behind the wall), the EUT transmit power was less sensitive to operator movements, but not fully independent due to presence of reflections from other sides (including the ceiling). Therefore, cDASY6 operator is required to be as still as possible during SAR measurements.

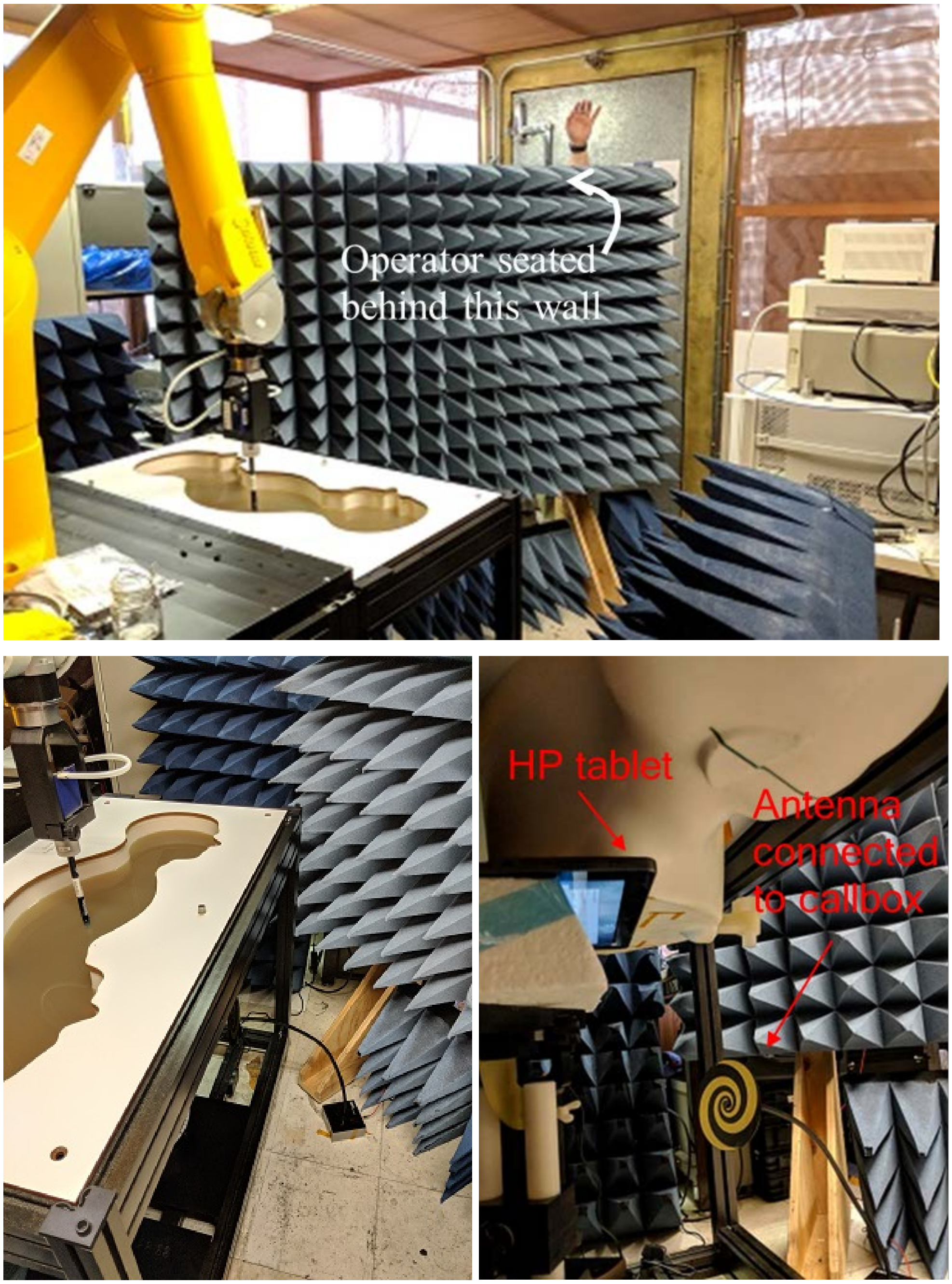


Figure 7-2 Path loss calibration setup

7.2 SAR measurement results

Following Section 5.4 procedure, 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. Appendix D furthermore detailed the steps for conducting time-averaged SAR measurements using cDASY6 SAR measurement system used for this validation. cDASY6 records pointSAR values periodically every X seconds, where

X = maximum (0.5s; least multiple of probe integration time ≥ 0.5s).

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.

Following Section 5.4 and Appendix D procedures, for each of selected technology/band:

i. With *Reserve_power_margin* set to 0 dB, area scan is performed at P_{limit}, and time-averaged pointSAR measurements are conducted to determine the pointSAR at *reported* P_{limit}, denoted as *point*SAR$_{reported_Plimit}$. The estimated 1gSAR from this area scan is shown in Appendix E plots, and also noted in the plots of the SAR test results for the test sequence 1 and 2 in Sections 7.2.1 to 7.2.4. Note that this estimated 1gSAR is not scaled to account for power tolerances.

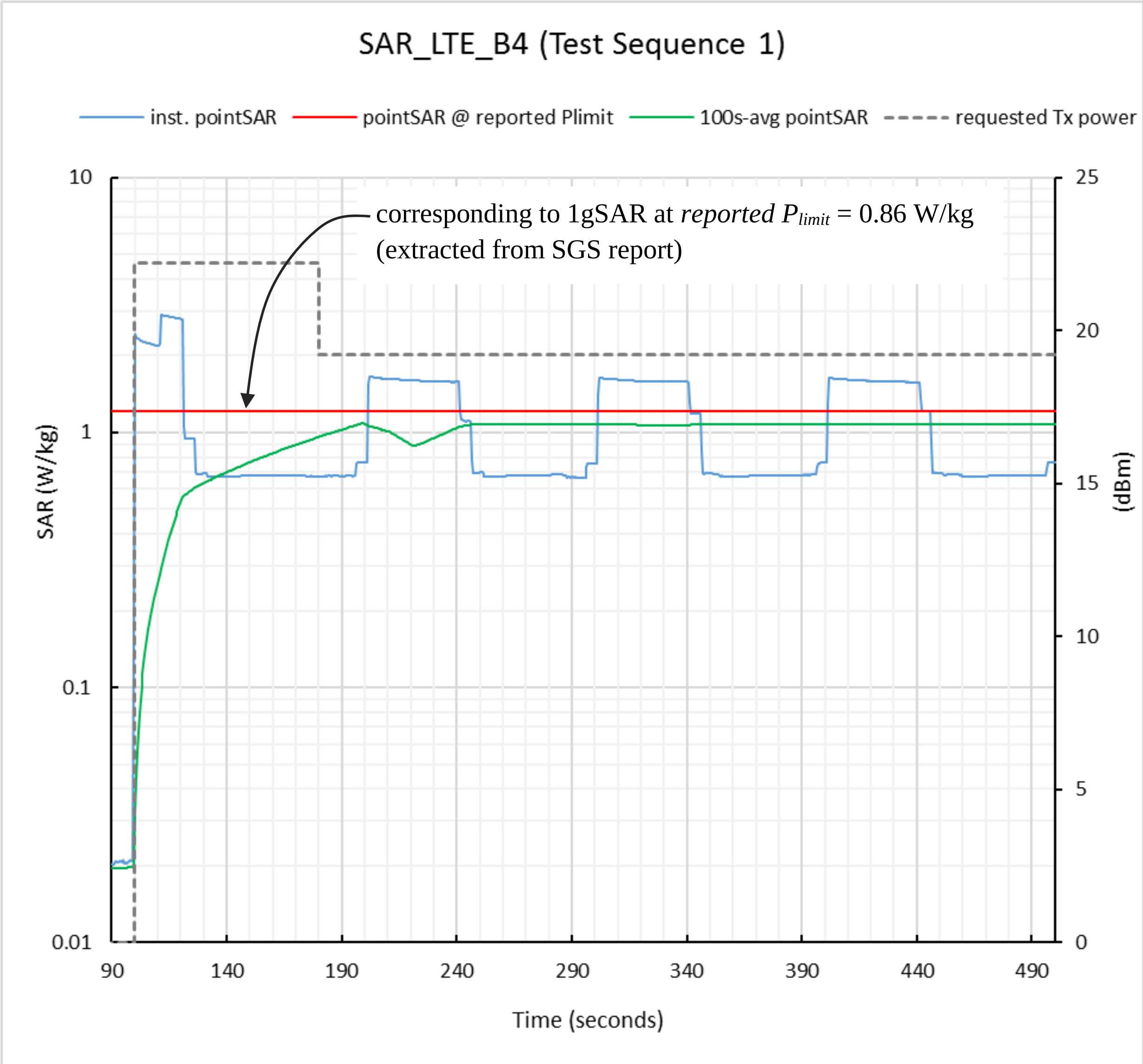
ii. With *Reserve_power_margin* to actual (intended) value (see Table 3-2), the area scan is performed at 1dB lower than $P_{reserve}$ to determine the peak SAR location, the time-averaged pointSAR measurements are then performed at this peak location for test sequences 1 and 2. Note that the area scan performed in this step is only to identify the peak SAR location for single point SAR probe measurement. Therefore, the exact power level is not important, as long as it is lower than P_{limit} so that EUT Tx power is constant during area scan.

7.2.1 LTE Band 4 SAR test results

Area scan

Test sequence 1: Same as shown in Table 6-2.

SAR test results for test sequence 1:

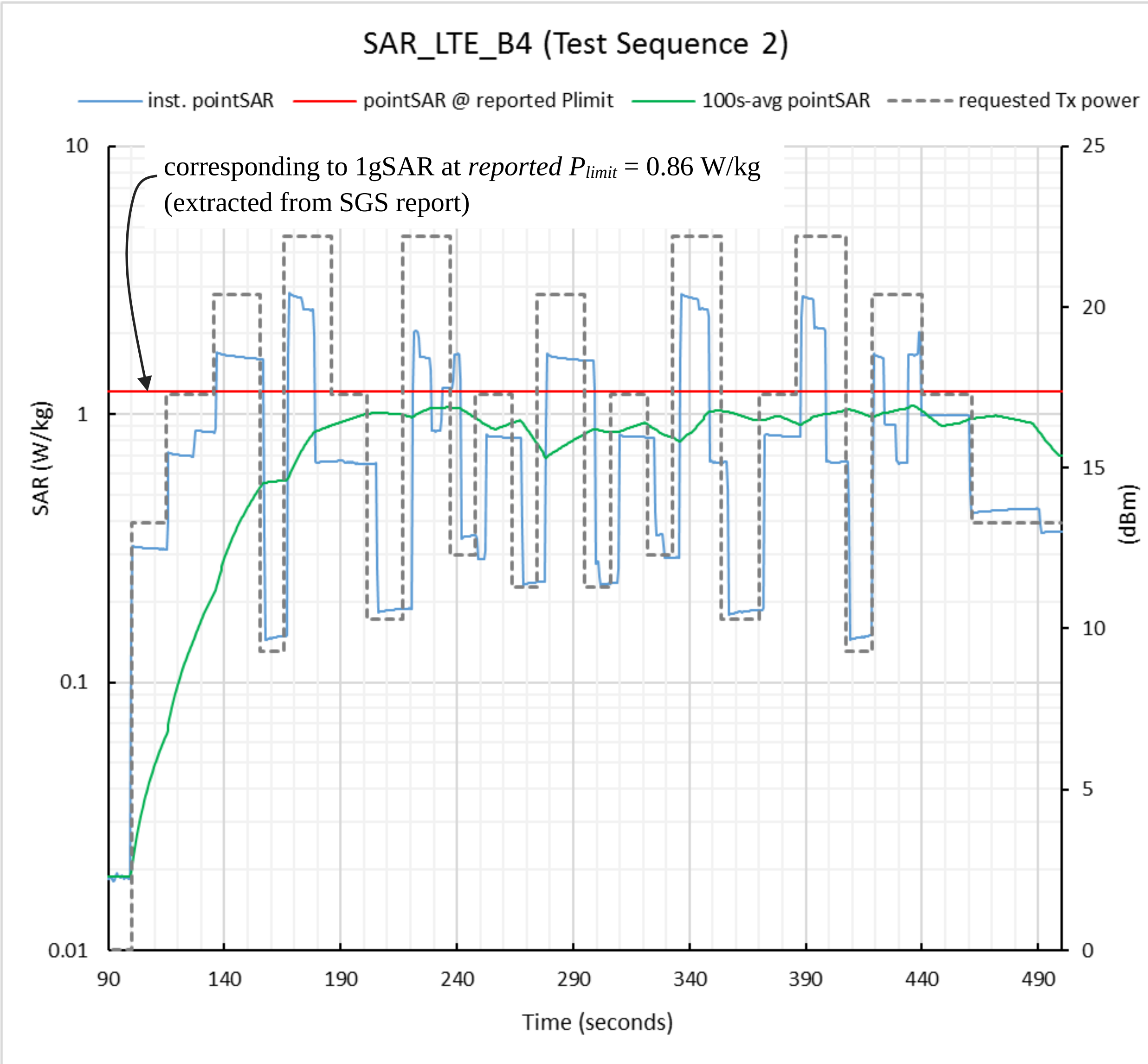


	(W/kg)
Max 100s-time averaged point SAR (green curve)	1.09
pointSAR @ reported P_{limit} (red line)	1.21*
Validated	

* Note that the estimated 1gSAR is 0.894 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

Test sequence 2: same as shown in Table 6-3

SAR test results for test sequence 2:



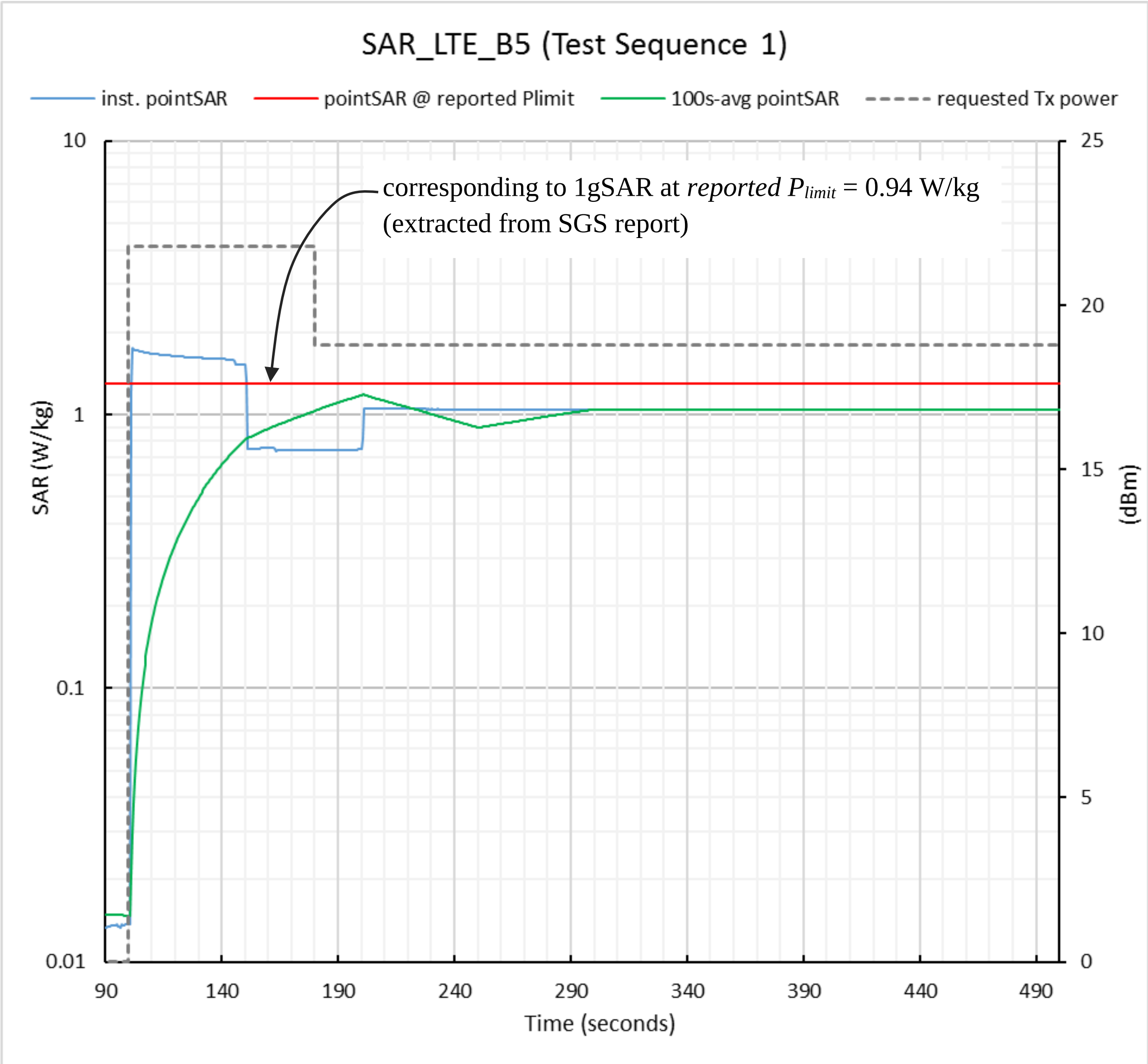
	(W/kg)
Max 100s-time averaged point SAR (green curve)	1.08
pointSAR @ reported P_{limit} (red line)	1.21*
Validated	

* Note that the estimated 1gSAR is 0.894 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

7.2.2 LTE Band 5 SAR test results

Test sequence 1: same as shown in Table 6-4

SAR test results for test sequence 1:

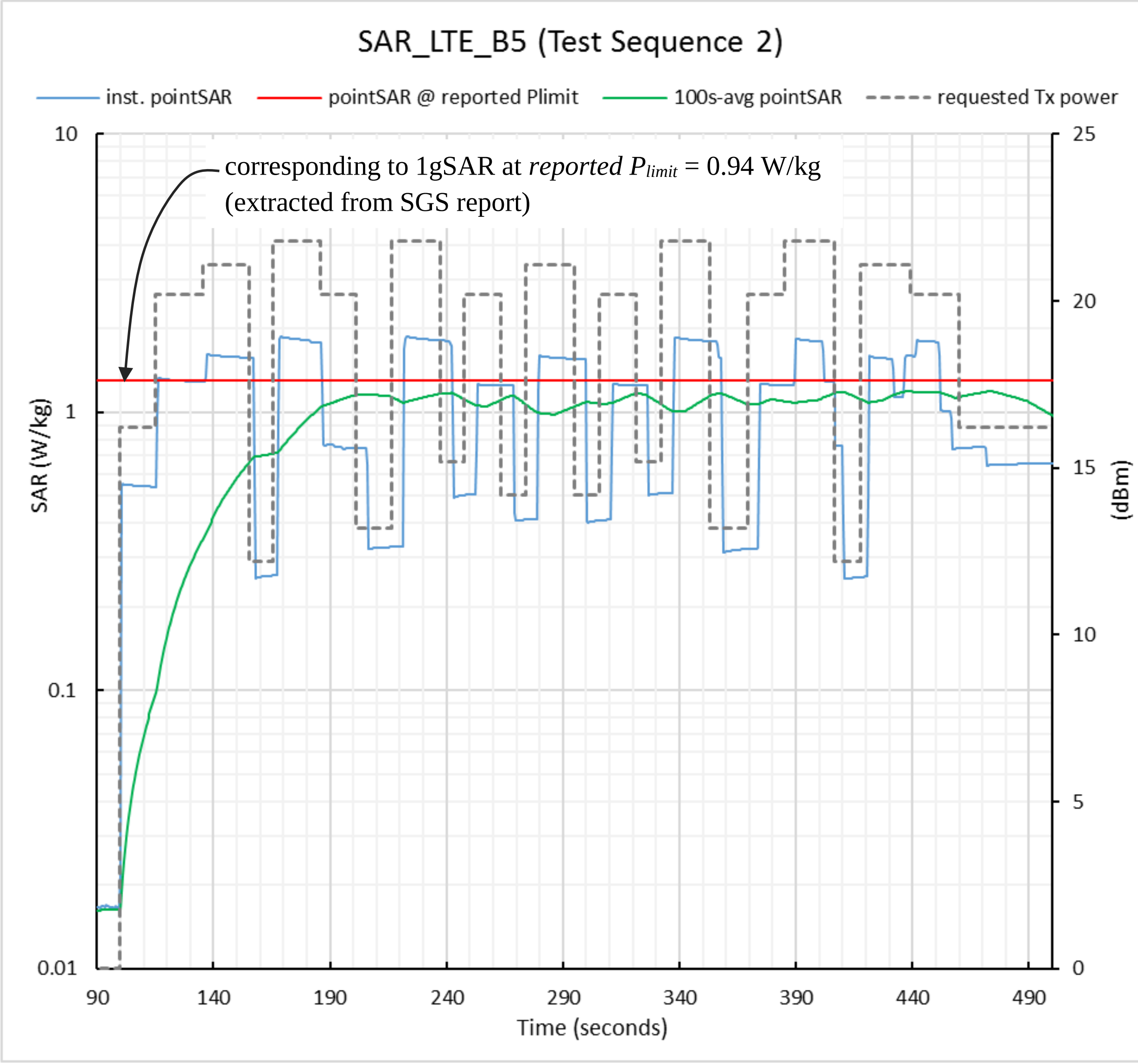


	(W/kg)
Max 100s-time averaged point SAR (green curve)	1.18
pointSAR @ reported P_{limit} (red line)	1.30*
Validated	

* Note that the estimated 1gSAR is 0.985 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported* P_{limit}.

Test sequence 2: same as shown in Table 6-5

SAR test results for test sequence 2:



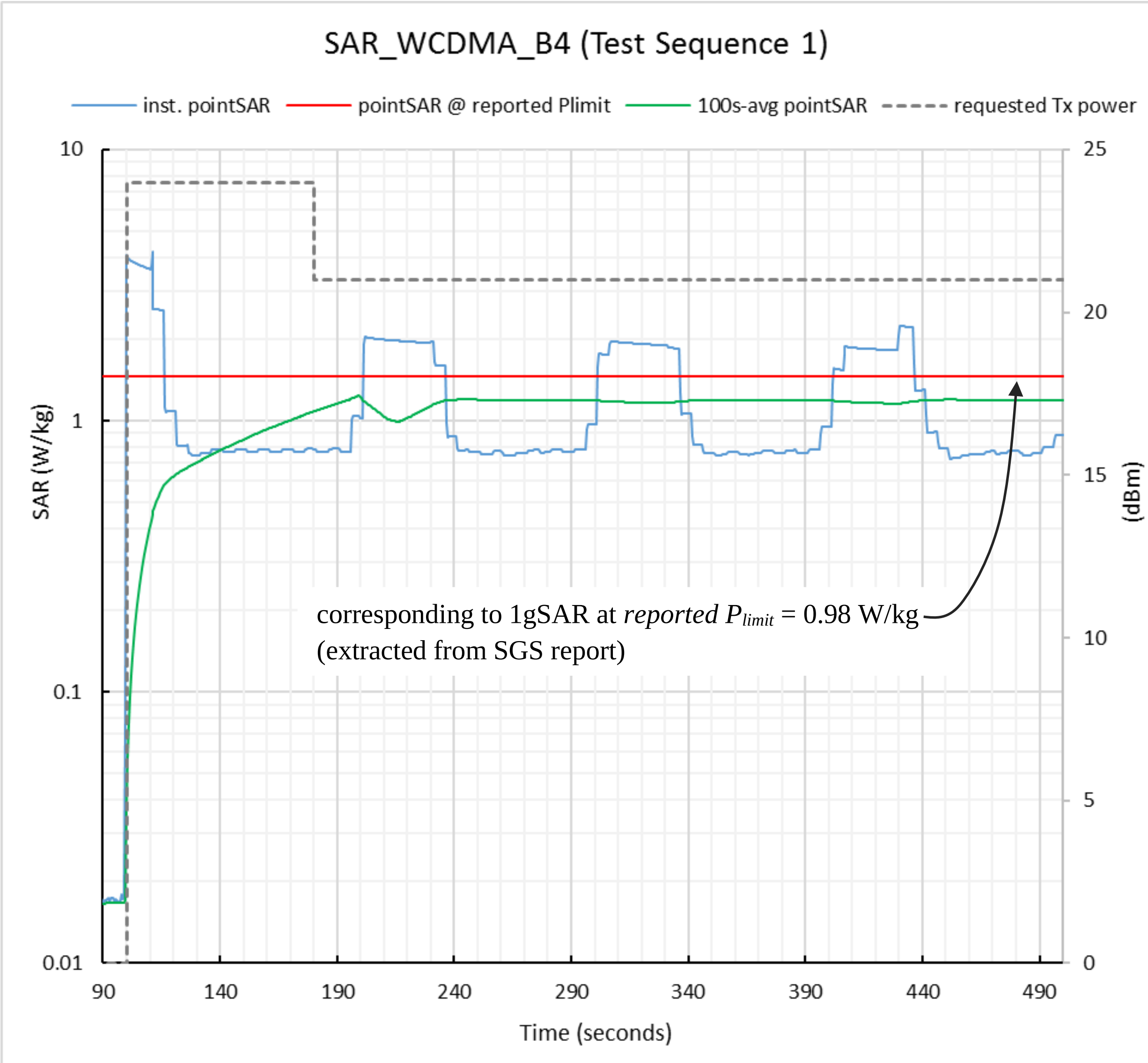
	(W/kg)
Max 100s-time averaged point SAR	1.19
point SAR @ reported_P_{limit}	1.30*
Validated	

* Note that the estimated 1gSAR is 0.985 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

7.2.3 WCDMA Band IV SAR test results

Test sequence 1: same as shown in Table 6-6

SAR test results for test sequence 1:

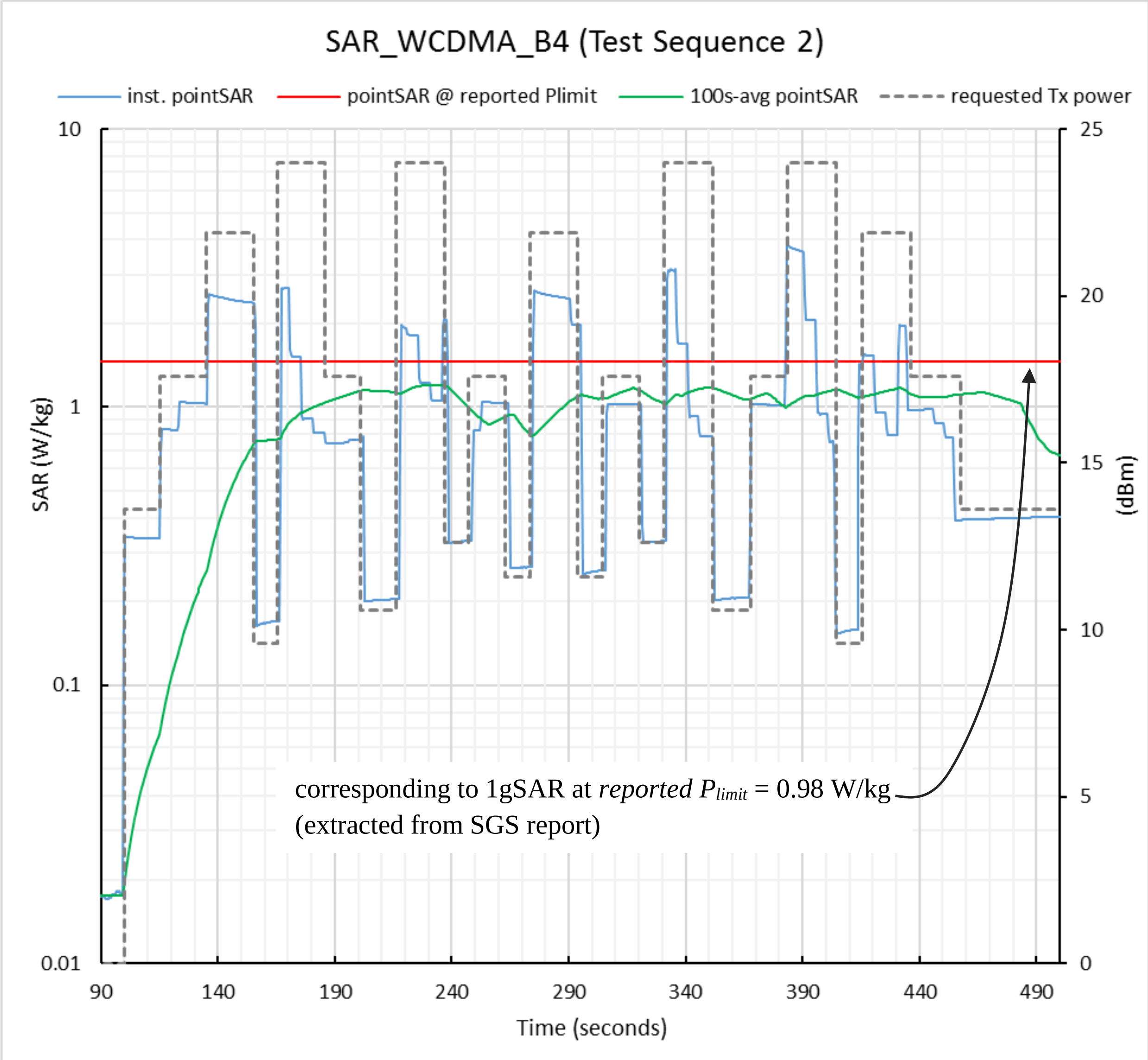


	(W/kg)
Max 100s-time averaged point SAR	1.24
pointSAR @ reported P_{limit}	1.46*
Validated	

* Note that the estimated 1gSAR is 1.0 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

Test sequence 2: same as shown in Table 6-7

SAR test results for test sequence 2:



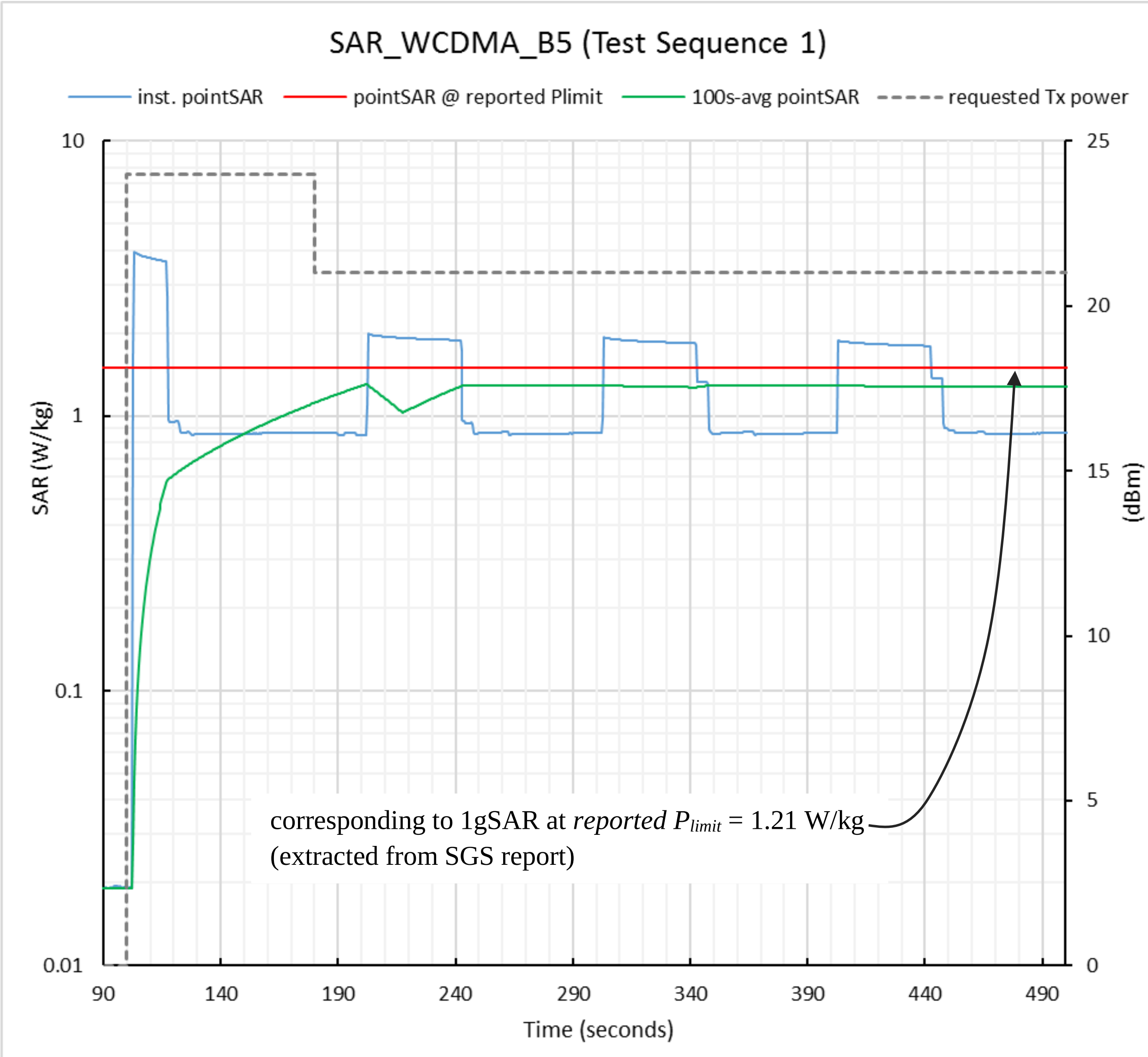
	(W/kg)
Max 100s-time averaged point SAR	1.20
pointSAR @ reported P_{limit}	1.46*
Validated	

* Note that the estimated 1gSAR is 1.0 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

7.2.4 WCDMA Band V SAR test results

Test sequence 1: same as shown in Table 6-8

SAR test results for test sequence 1:

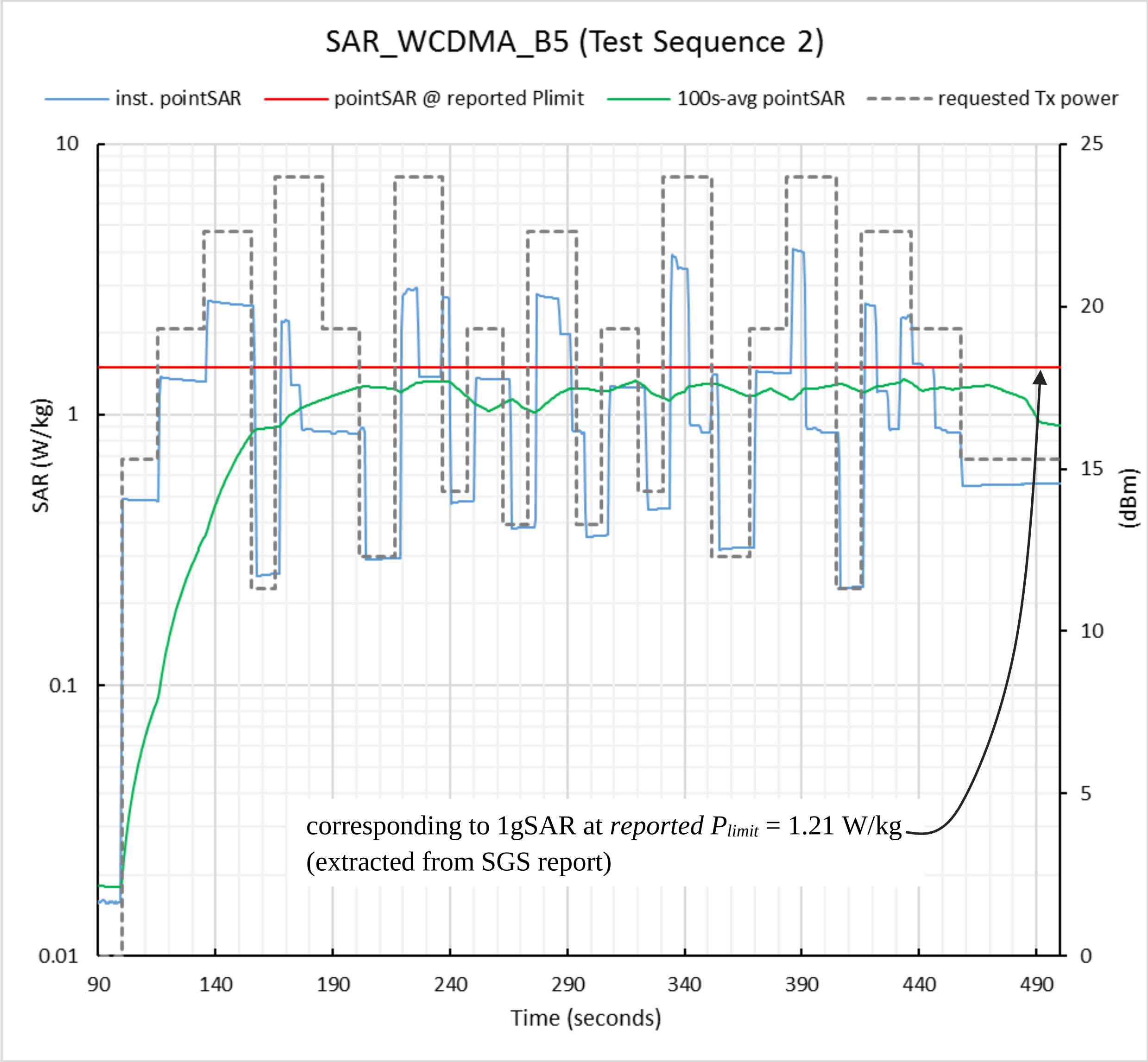


	(W/kg)
Max 100s-time averaged point SAR	1.30
pointSAR @ reported P_{limit}	1.49*
Validated	

* Note that the estimated 1gSAR is 1.20 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

<u>Test sequence 2</u>: same as shown in Table 6-9

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



	(W/kg)
Max 100s-time averaged point SAR	1.35
pointSAR @ reported P_{limit}	1.49*
Validated	

* Note that the estimated 1gSAR is 1.20 W/kg for the area scan (see Appendix E) used to determine this *pointSAR @ reported P_{limit}*.

8 Conclusions

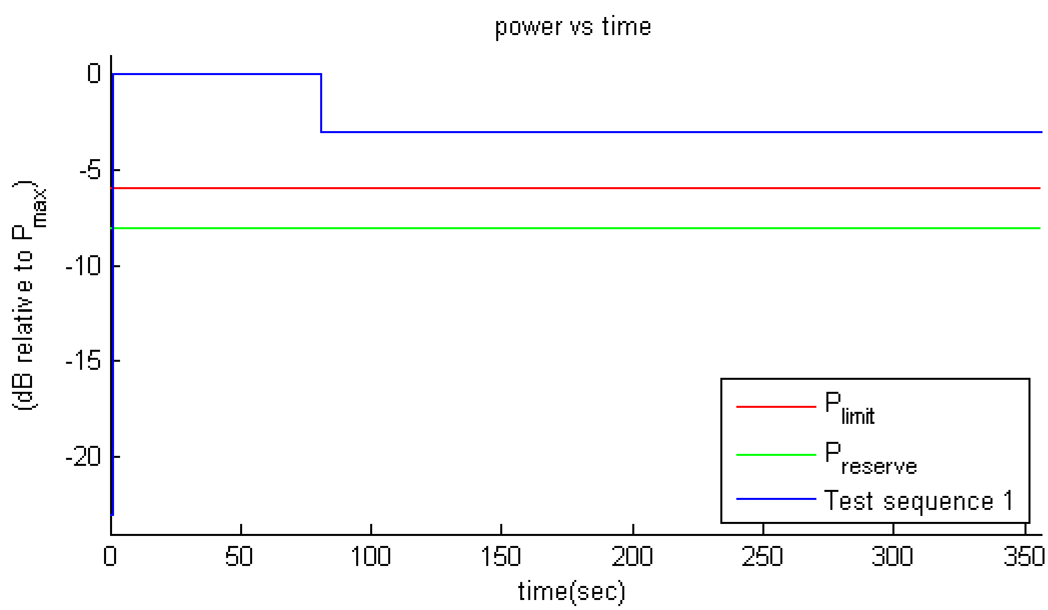
Qualcomm Smart Transmit employed in HP model# HSN-I06C has been validated through the conducted power measurement (as demonstrated in Chapter 6) and SAR measurement (as demonstrated in Chapter 7).

With the combination of the compliance SAR report by SGS lab and this validation report, it can be concluded that the time-averaged SAR for HP model# HSN-I06C is compliant with the FCC limit of 1.6W/kg in all transmission scenarios for all the supported radios.

A Test Sequences

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

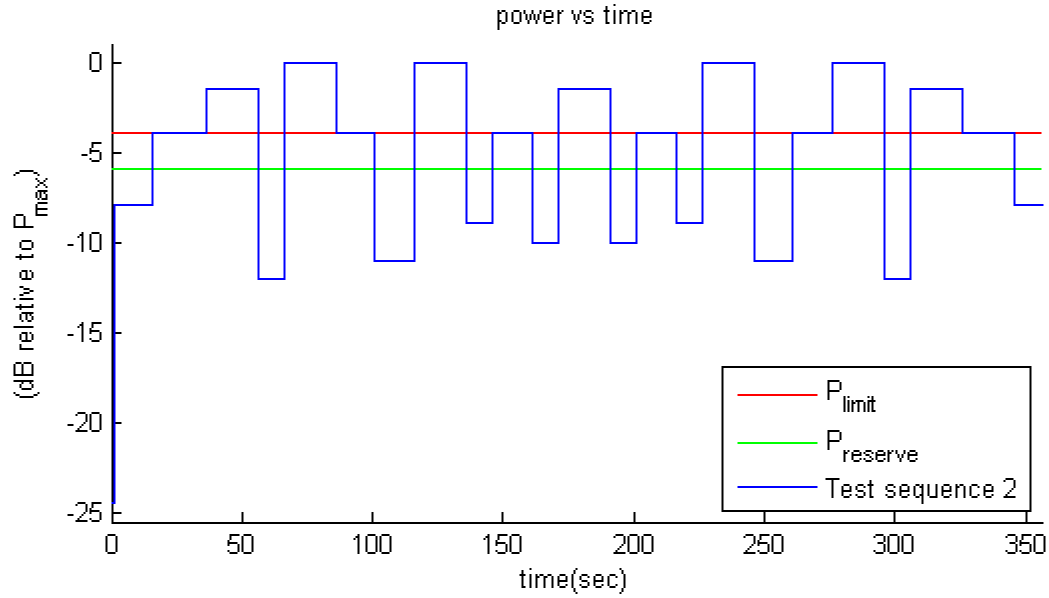


3. Test Sequence 2 Waveform:

   Based on the parameters in A.1, the Test Sequence 2 is generated as described in table below, 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:

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

The Test Sequence 2 waveform is shown as below:



B Test Procedure for Technology/Band Switch with Callbox

Prior to starting the test: Enable Smart Transmit and set *Reserve_power_margin* to 0 dB, set callbox to request max power in desired technology/band, and measure conducted output power of EUT throughout the test.

The test procedure is -

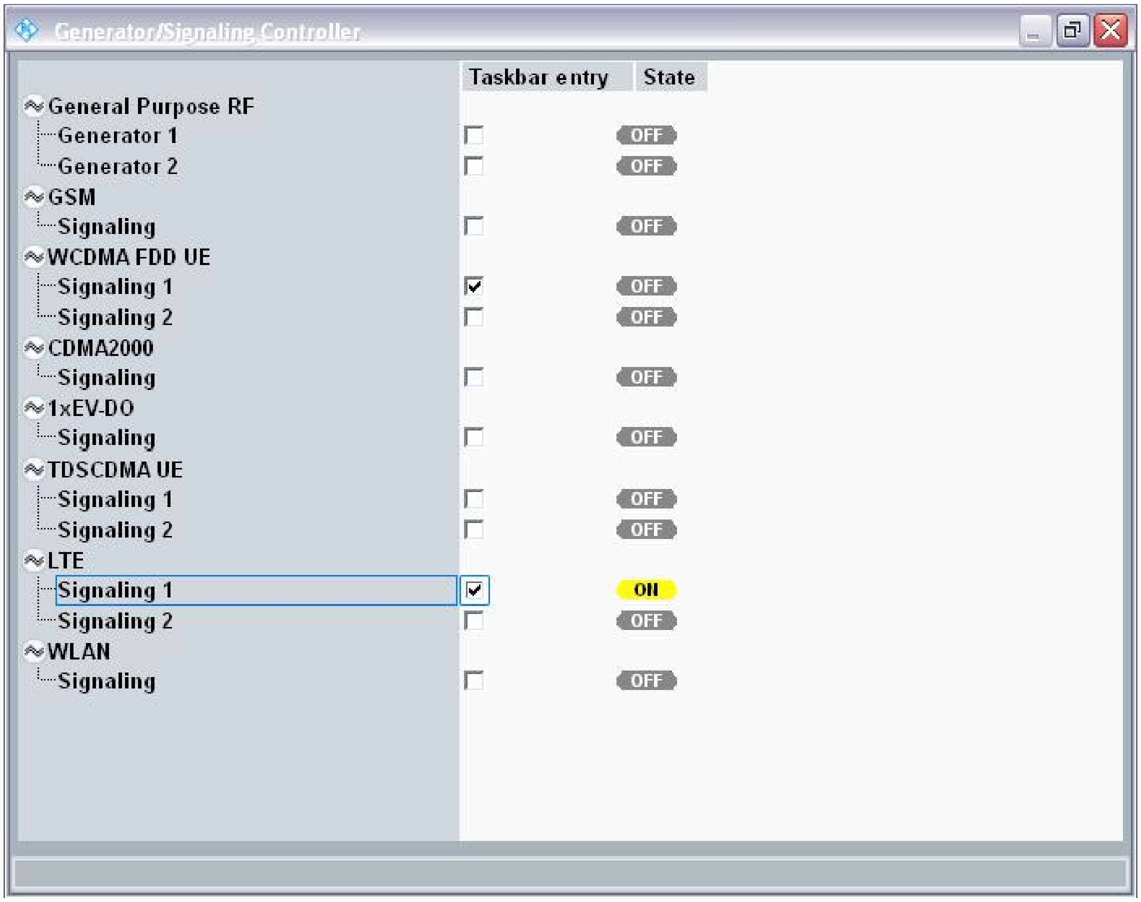
B.1. Establish radio link with callbox in desired technology1/band1 for DUT employing Qualcomm Smart Transmit algorithm.

B.2. Request EUT to transmit at 0 dBm for at least 100 seconds.

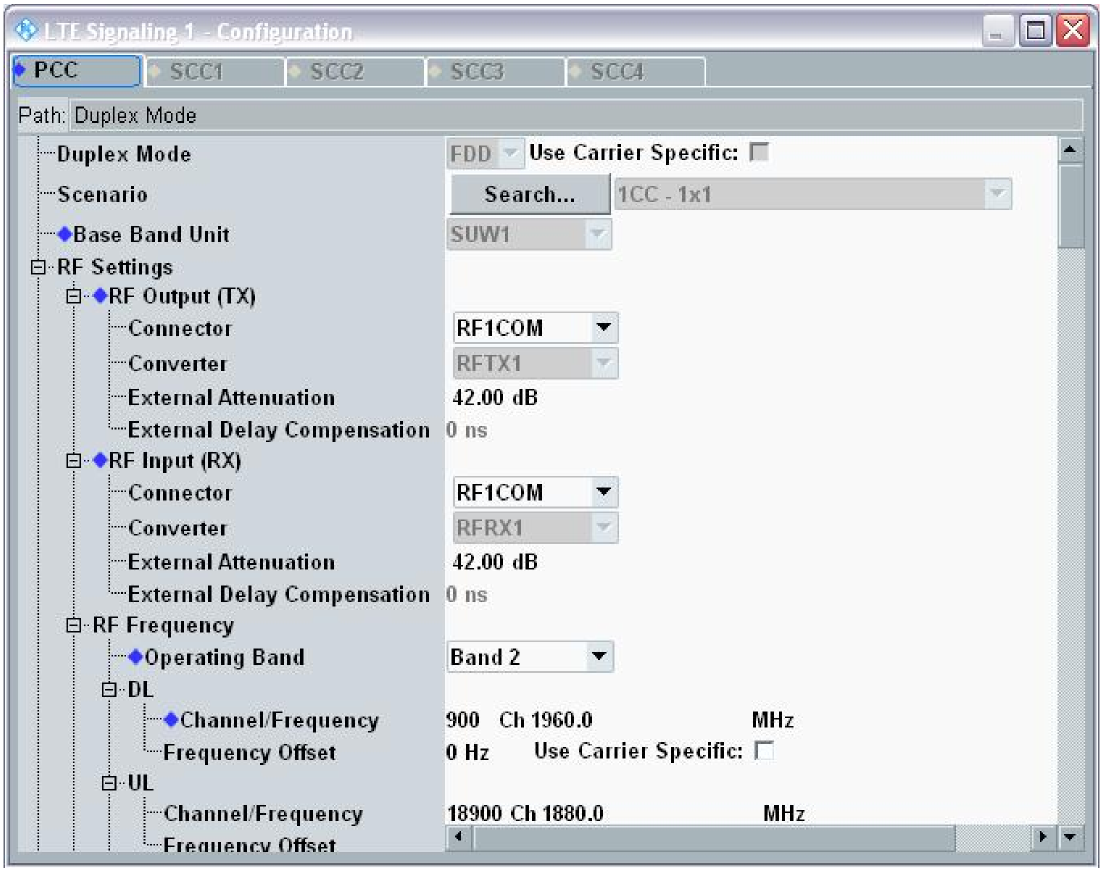
B.3. Request EUT to transmit at maximum transmit power for about ~60 seconds, and then handover to technology2/band2 (for example, see below steps to switch technology from LTE Band 2 to WCDMA Band 5 for Rohde & Schwarz CMW500 callbox) and continue callbox request EUT to transmit at maximum transmit power.

<u>Technology/band switch (LTE to WCDMA) instructions for Rohde & Schwarz CMW500 callbox:</u>

Step 1: Set the callbox to below (generator/signaling controller) settings prior to establishing call with the EUT:



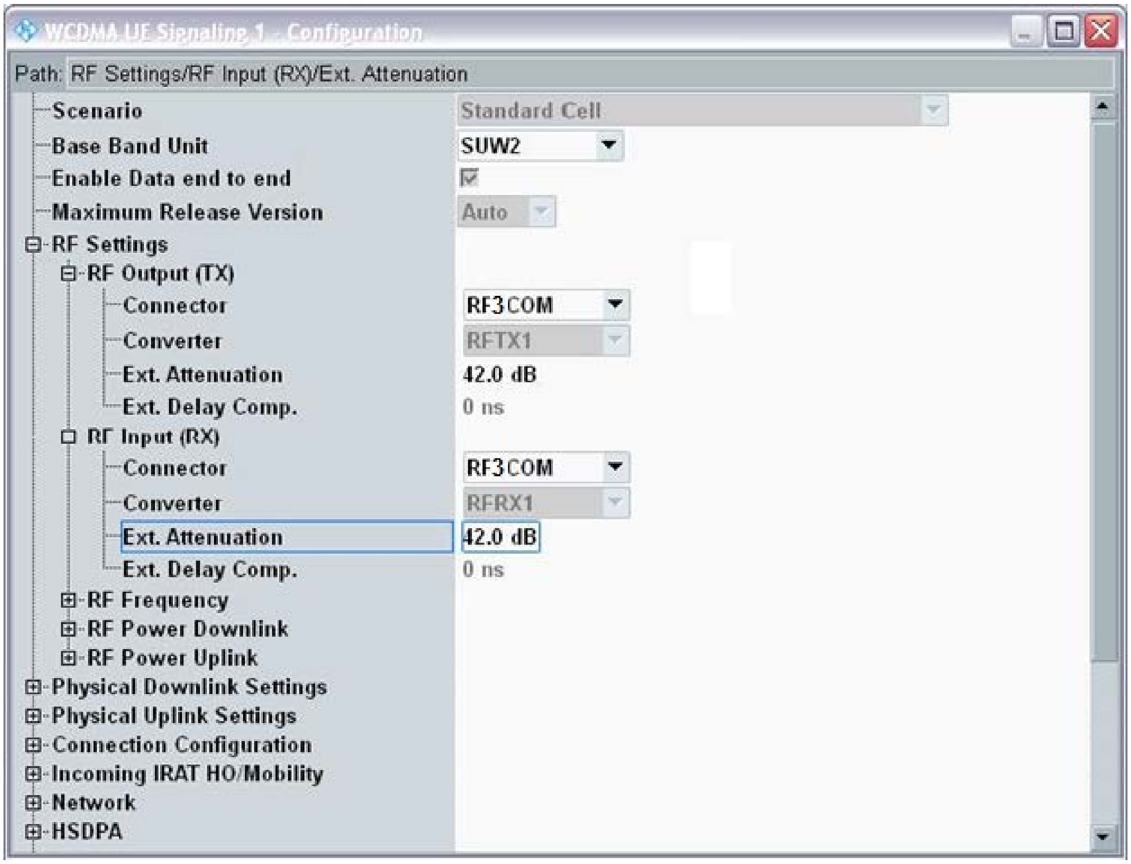
Setup LTE on Signaling 1 (LTE Sig1); Setup WCDMA on Signaling 1 (WCDMA Sig1).



<u>*LTE Config settings.*</u>

Base Band Unit: SUW1

RF Input/Output: RF1COM

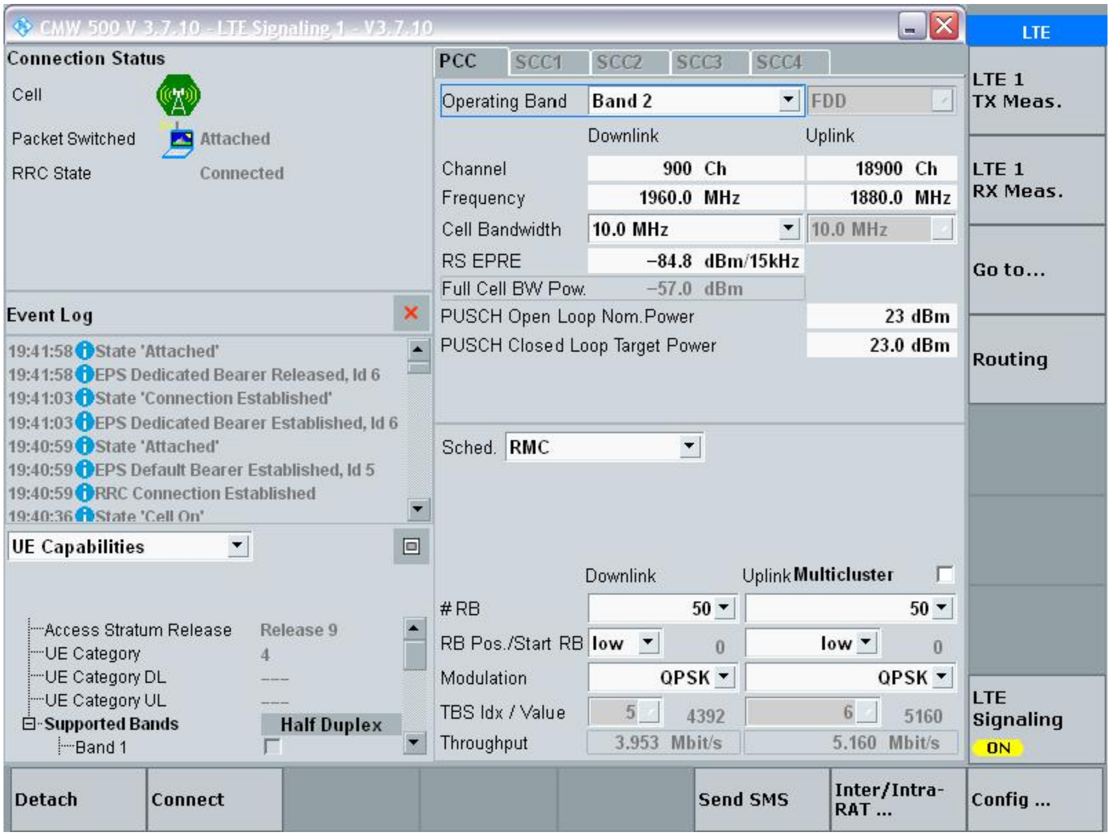


WCDMA Config settings

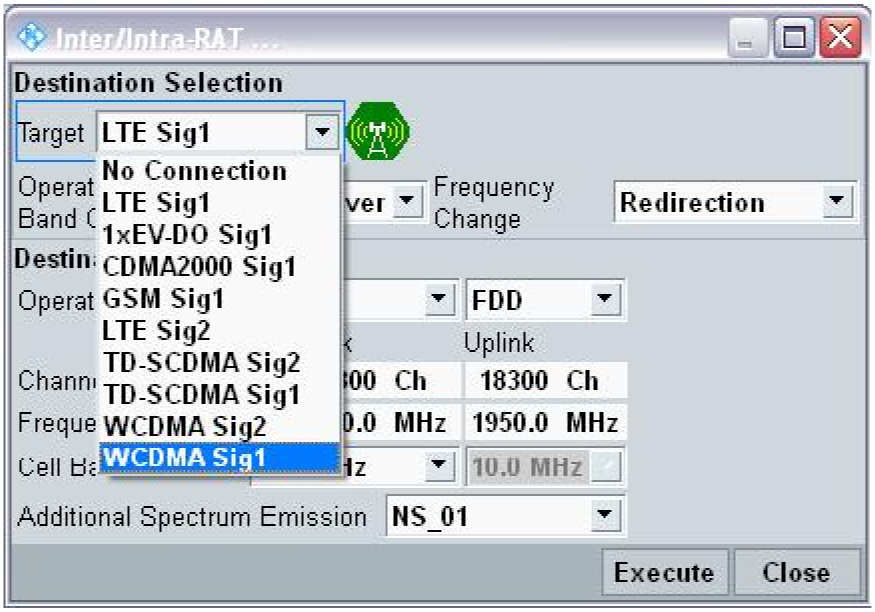
Base Band Unit: SUW2

RF Input/Output: RF3COM

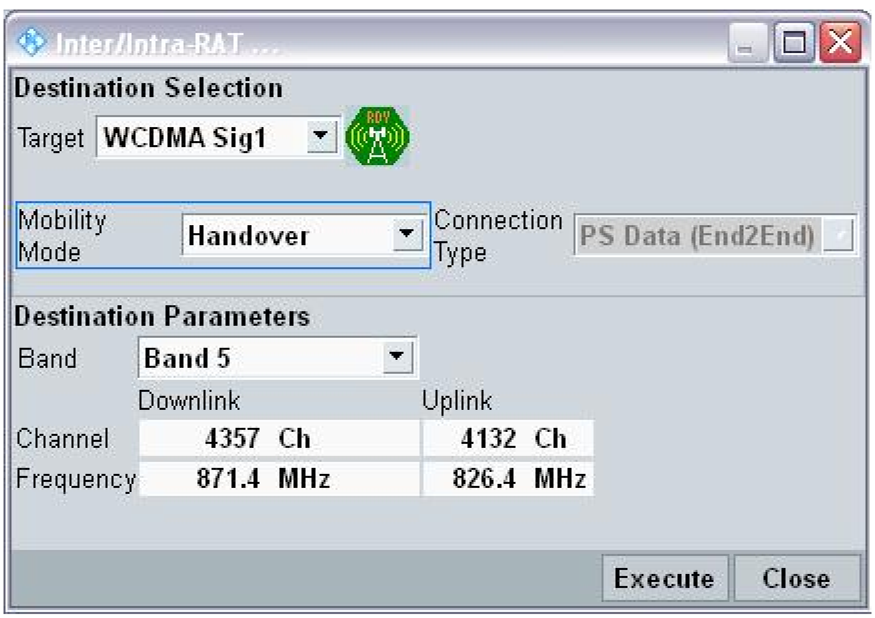
Step 2: Register the EUT in LTE Band 2, and click “Connect” at the bottom of the screen (see below screenshot) to establish LTE Band 2 call with Rohde & Schwarz CMW500 callbox. Measure and record EUT Tx power, and when needed to switch to WCDMA, follow Step 3.



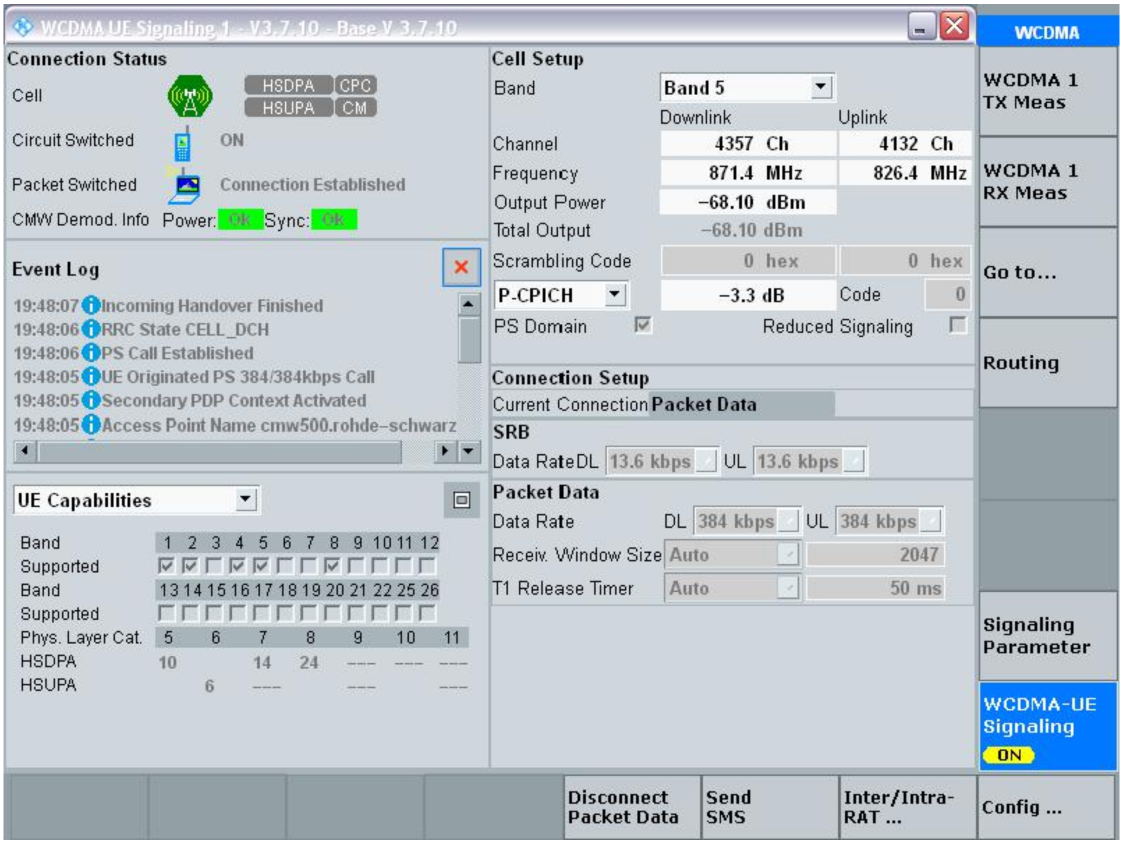
Step 3: To start WCDMA handover, select "Inter/Intra-RAT …" at the bottom of the screen and follow settings in below screenshots:



Target: Select WCDMA Sig1. It will take several seconds to setup WCDMA Sig1.



Select Handover. Connection Type: PS Data (End2End)
Select Execute



LTE B2 to WCDMA B5 handover completed. WCDMA B5 call established.

Step 4: Continue measuring the Tx power of EUT at the corresponding WCDMA Band 5 antenna port versus time.

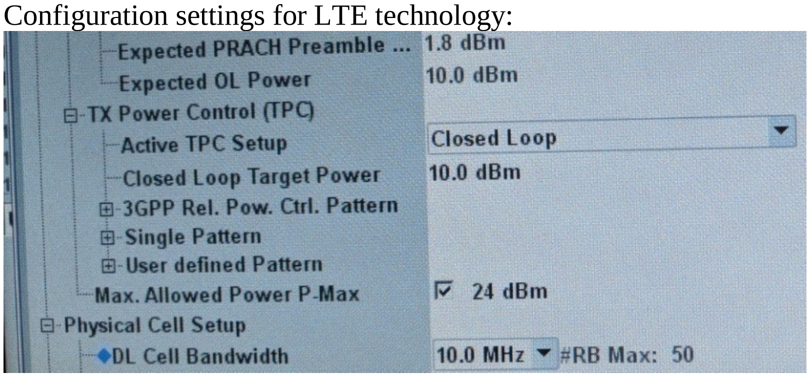
C Test Procedure for Calibrating Setup Loss Between Callbox and EUT Positioned Against Flat Section of SAM Phantom

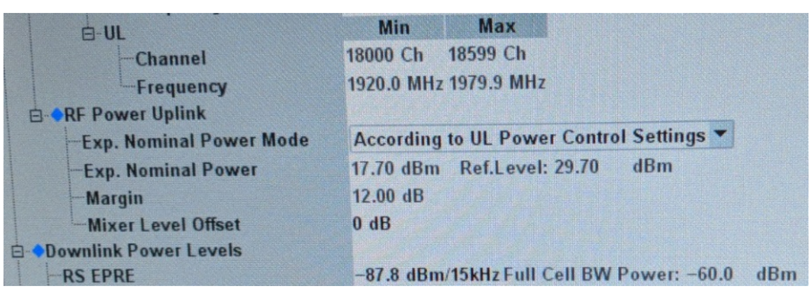
Path loss estimation and callbox setup for time-averaged SAR measurement is described in this appendix.

The purpose for this setup is to have enough dynamic range for time-averaging SAR measurement, otherwise if path loss between callbox and EUT is set too low (or too high) on the callbox, EUT will transmit at maximum power (or low power) most of time (or all the time) in the time averaging measurement regardless of various Tx power level requests from callbox. Note that the path loss determined here is not for the purpose of Tx power measurement, but to vary the Tx power of EUT corresponding to callbox requests in a radiated call. Therefore, the absolute accuracy of path loss in this estimation is not a concern as long as the estimated path loss setting in the callbox results in varying EUT's Tx power upon request from the callbox.

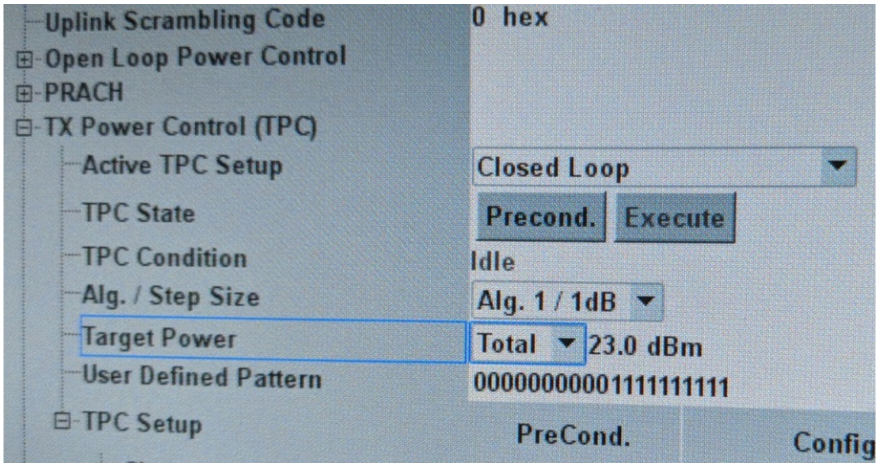
Prior to estimating the path loss, the EUT should be in call with the callbox in "close loop power control" mode. If using Rohde & Schwarz's CMW500 callbox, below are some screen shots to show settings for closed loop power control:

Configuration settings for LTE technology:

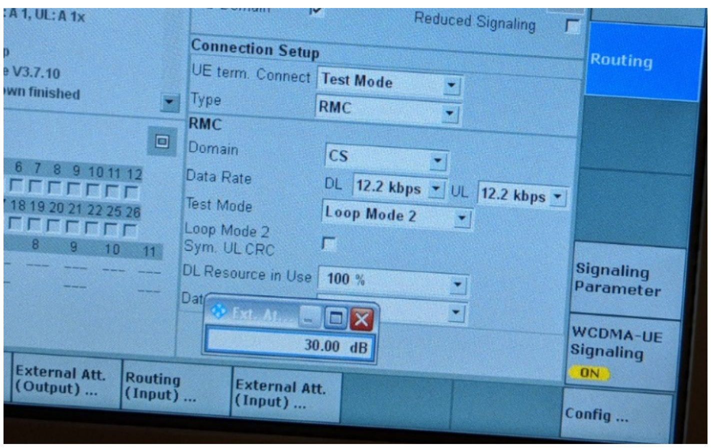




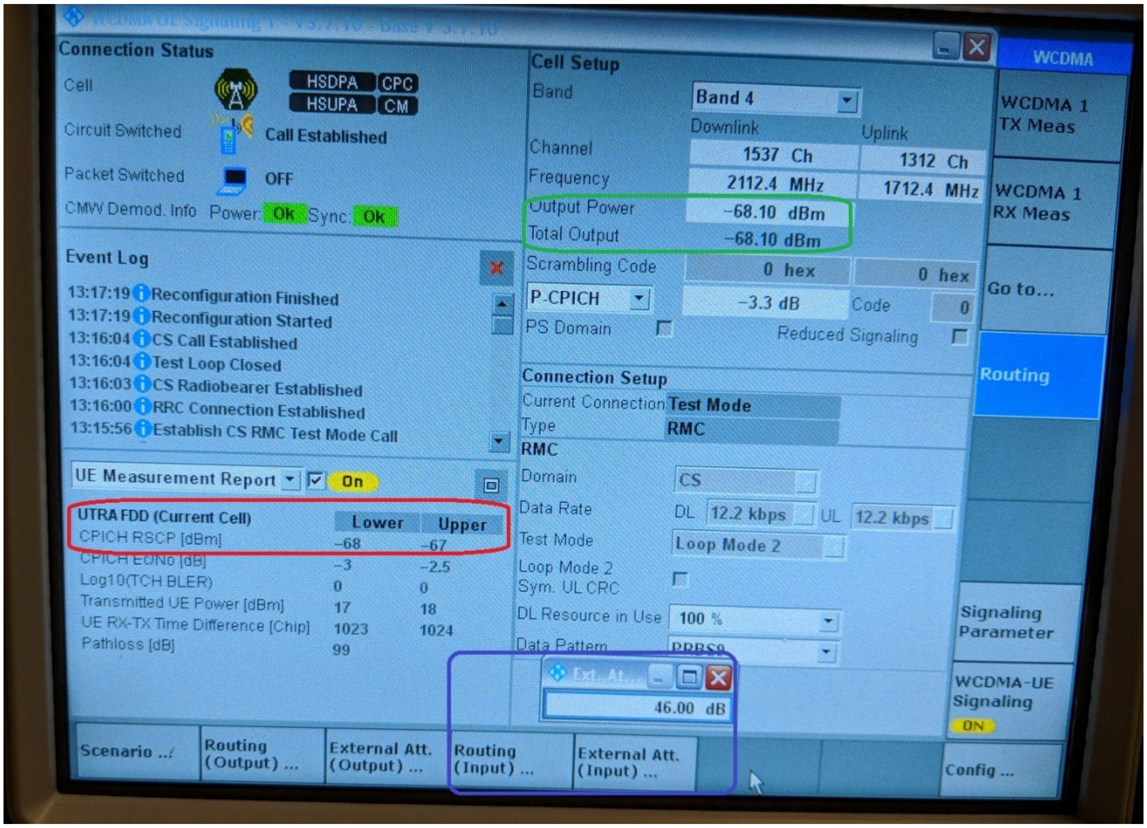
Configuration setting for WCDMA technology:



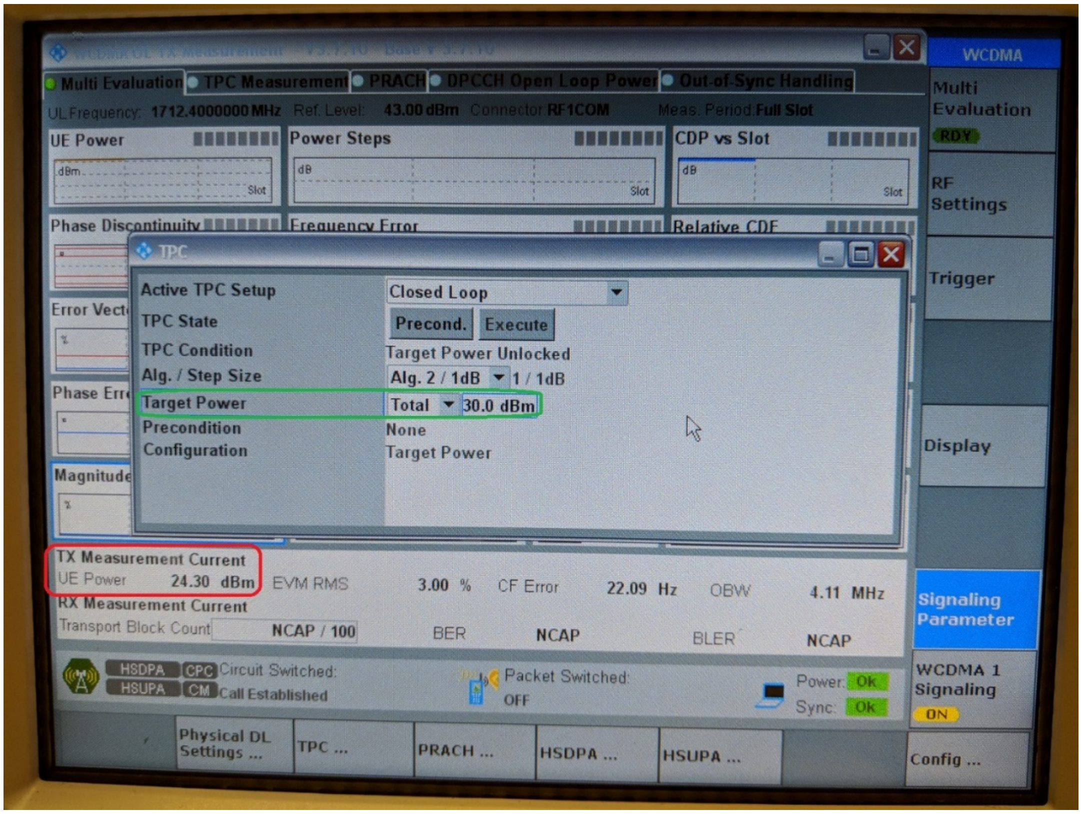
Path loss between callbox and EUT (positioned against flat section of the SAM Twin phantom during SAR test) is estimated by adjusting the path loss setting on callbox (for Rohde & Schwarz CMW500, this setting can be found under “Routing -> External Attenuation” as shown below, where both “External Attenuation (Input)” and “External Attenuation (Output)” settings must be set to the same number).



This path loss setting in the callbox is adjusted (highlighted in blue box in below image) such that the RSSI (received signal strength indicator) by the EUT (found under “UE measurement report” setting in Rohde & Schwarz CMW500 callbox as shown inside red box in below image) is similar to the requested setting in the callbox (indicated by green box in below image).



By following this procedure thus far, gives a reasonable estimate for path loss. Additional fine tuning of path loss needs to be done to ensure that EUT's maximum power indicated on the callbox matches with maximum conducted power (P_{max}). Callbox should be set to request maximum power from EUT (in this case, it was set to 30dBm*, as shown in green box in below image). The path loss setting (under Routing>External attenuation in Rohde & Schwarz CMW500 callbox) should be further adjusted such that the EUT's power shown on the callbox matches with measured maximum conducted power (meas. P_{max}) for this tech/band. The EUT's power can be found against "UE Tx power" level under "Tx Measurement" tab (as shown in red box in below image) in Rohde & Schwarz CMW500 callbox:



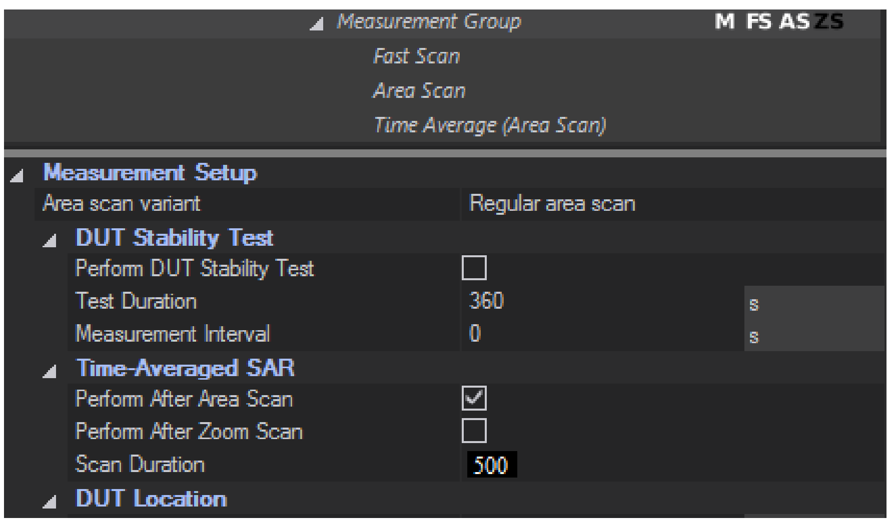
*Note that during path loss calibration, 30dBm, was intentionally requested in the callbox setting instead of maximum conducted power (P_{max}). This is because the initial estimation of path loss from matching RSSI could still be off by few dB so the EUT might not transmit at maximum power even if indicated so by the UE Tx measurement report in the callbox. Requesting higher power than EUT capable of transmitting (in this case, 30dBm) during fine tuning of path loss calibration confirms the calibration is accurate if the UE Tx measurement report in callbox corresponds to P_{max} of EUT. Otherwise, UE Tx measurement report will indicate lower reading (if path loss setting is too low) or higher reading than P_{max} (if path loss setting is too high).

D Test Procedure for Time-Averaged SAR Validation Using cDASY6

Test procedures for time-averaged SAR algorithm validation with cDASY6 system:

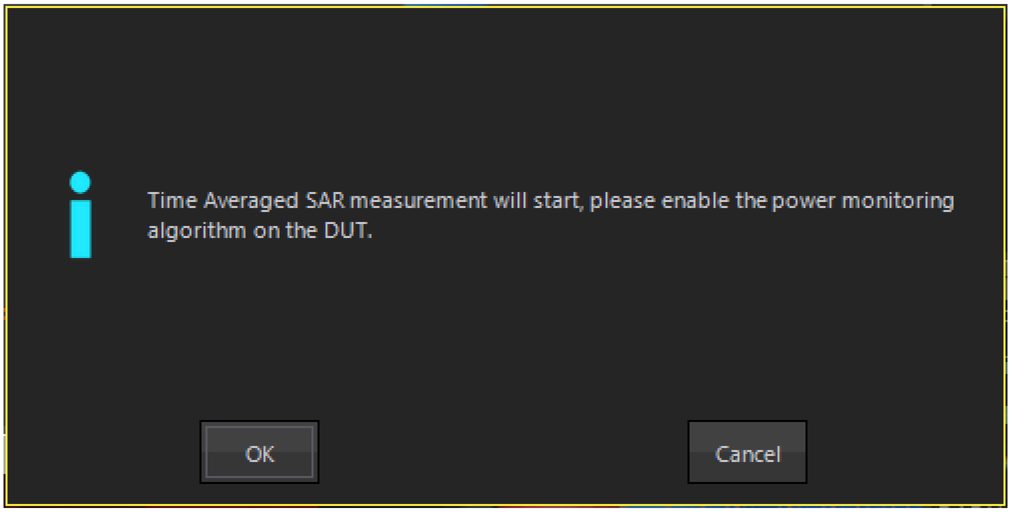
D.1. With Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, establish radio link with a callbox in desired operational technology, band and channel

D.2. In cDASY6, enable checkbox for time-averaged SAR measurement option (this is equivalent to multimeter option in DASY5) after Area Scan in Measurement Setup settings (see screen capture below), and set the duration of the scan to 500s (greater than duration of test sequence in the "Scan Duration" field).

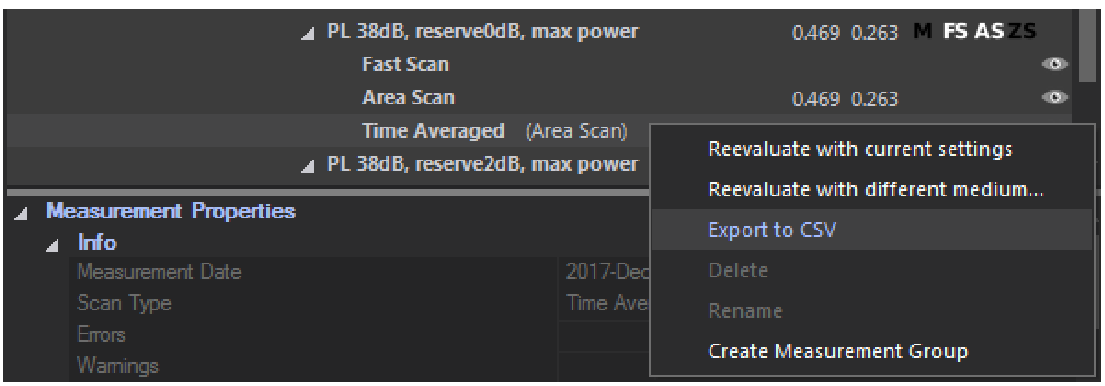


D.3. Perform path loss calibration as described in Appendix C.

D.4. Request EUT to transmit at maximum power and perform the area scan. After the area scan, cDASY6 will pause for time-averaged SAR measurement (this is equivalent to multimeter option in DASY5) as shown in below screen shot:



Without changing the *Reserve power margin* setting, continue with performing pointSAR measurements versus time (under "Time-averaged SAR" measurement label in cDASY6) with callbox requesting max power. Wireless device will transmit at P_{limit}, and measured pointSAR versus time can be extracted as shown below. Average of extracted data indicates the pointSAR value corresponding to measured P_{limit}. This value is scaled to $reported\_P_{limit}$ level and is used as the $pointSAR_{reported\_Plimit}$ for time-averaging validation.



D.5. To measure time-average SAR for test sequences: First, set *Reserve_power_margin* to the actual (intended) value (see Table 3-2) without disturbing the wireless device position relative to the flat section of the SAM Twin phantom. Perform the 2nd Area Scan (settings similar to Step D.2) with callbox requesting EUT to transmit at $P_{reserve}$-1dB* (i.e., few dB below P_{limit}) so that EUT Tx power is constant during area scan (otherwise, Smart Transmit algorithm will enforce power limiting if max power was requested during area scan). When SAR measurement pauses for the readiness of time-averaged SAR measurement, resume pointSAR measurement with callbox requesting DUT to transmit Test Sequence1 described in Appendix A. Extract this data, and perform running average to determine time-averaged pointSAR data corresponding to Test Sequence 1. For Smart Transmit validation, this time-averaged pointSAR should be less than $pointSAR_{reported\_Plimit}$ determined in Step D.4 at all times.

*Note that this power level is used only to identify the peak SAR location for probe placement to perform pointSAR measurements. Therefore, the exact power level is not important, as long as it is lower than P_{limit} so that EUT Tx power is constant during area scan.

D.6. Repeat Step D.5 for the algorithm validation with Test sequence 2 described in Appendix A.

D.7. Repeat Steps D.1~D.6 to complete the validation for all the selected technologies/bands.

Note that during the time-averaging SAR measurements, the entire lab environment surrounding cDASY6 system should be motionless (including the operator) as it would significantly affect the estimated path loss which will result in different DUT response. Since these tests are performed in uncalibrated and uncontrolled wireless environment, the time variation of SAR measurement may not be repeatable. However, Smart Transmit ensures that the time averaged SAR will always comply.

E SAR Measurement Plots

Date: 2018/4/10

LTE Band 4 (20MHz)_Body_Back side_CH 20175_QPSK_100-0_0mm

Communication System: LTE; Frequency: 1732.5 MHz; Duty Cycle: 1:1

Medium parameters used: f = 1732.5 MHz; σ = 1.45 S/m; ε_r = 51.9; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

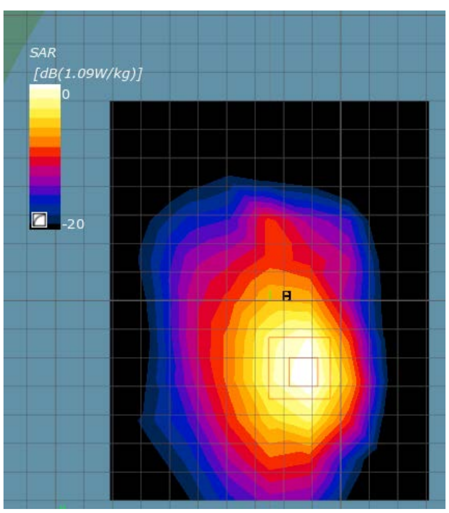
- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Body/Area Scan (113x141x1): Interpolated grid: dx=14 mm, dy=14 mm

Reference Value = 0.897 W/kg; Power Drift = -0.26 dB

Estimated SAR(1 g) = 0.894 W/kg; Estimated SAR(10 g) = 0.474 W/kg

Maximum value of SAR (measured) = 1.09 W/kg



Date: 2018/4/20

LTE Band 5 (10MHz)_Body_Back side_CH 20600_QPSK_25-25_0mm

Communication System: LTE; Frequency: 844 MHz; Duty Cycle: 1:1

Medium parameters used: f = 844 MHz; σ = 1.00 S/m; ε_r = 53.5; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

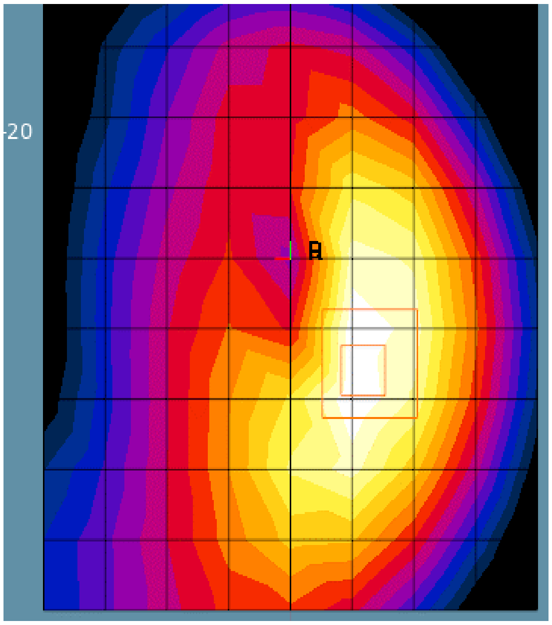
- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Body/Area Scan (113x141x1): Interpolated grid: dx=14 mm, dy=14 mm

Reference Value = 1.05 W/kg; Power Drift = 0.03 dB

Estimated SAR(1 g) = 0.985 W/kg; Estimated SAR(10 g) = 0.602 W/kg

Maximum value of SAR (measured) = 1.13 W/kg



Date: 2018/4/11

WCDMA Band IV_Body_Back side_CH 1312_0mm

Communication System: WCDMA; Frequency: 1712.4 MHz; Duty Cycle: 1:1

Medium parameters used: f = 1712.4 MHz; σ = 1.44 S/m; ε_r = 51.9; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

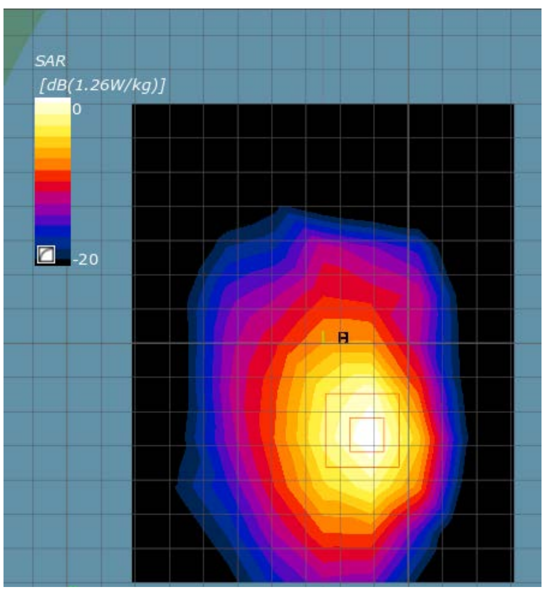
- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Body/Area Scan (113x141x1): Interpolated grid: dx=14 mm, dy=14 mm

Reference Value = 0.861 W/kg; Power Drift = -0.14 dB

Estimated SAR(1 g) = 1.00 W/kg; Estimated SAR(10 g) = 0.519 W/kg

Maximum value of SAR (measured) = 1.26 W/kg



Date: 2018/4/25

WCDMA Band V_Body_Back side_CH 4233_0mm

Communication System: WCDMA; Frequency: 846.6 MHz; Duty Cycle: 1:1

Medium parameters used: f = 847 MHz; σ = 1.00 S/m; ε_r = 53.5; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

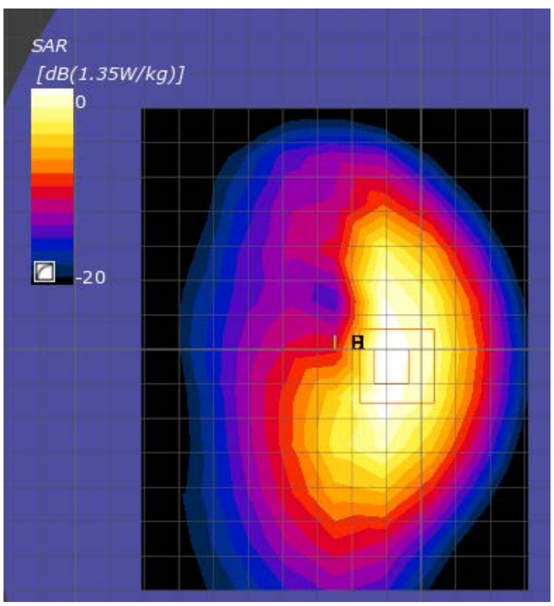
- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Body/Area Scan (131x141x1): Interpolated grid: dx=14 mm, dy=14 mm

Reference Value = 1.34 W/kg; Power Drift = 0.05 dB

Estimated SAR(1 g) = 1.20 W/kg; Estimated SAR(10 g) = 0.720 W/kg

Maximum value of SAR (measured) = 1.35 W/kg



F cDASY6 System Check

F.1 System components

cDASY6 system by Schmid & Partner Engineering AG (SPEAG) was used to validate time-averaged SAR for HP tablet Model HSN-106C. Table F-1 lists all measurement equipment used in this test and their calibration information.

Table F-1 Measurement equipment

MFR	Model	Description	Quantity	Calibration date
Speag	DASY6	DASY6 system	1	N/A
Speag	ES3DV3	SAR probe	1	02/07/2018
Speag	cDASY6	system software	1	N/A
Speag	DAE3	D/A converter	1	02/06/2018
Rohde & Schwarz	CMW500	Callbox	1	12/19/2017
Rohde & Schwarz	NRP2	Power meter	1	01/09/2018
Rohde & Schwarz	Z21	Power meter sensor	1	01/04/2018
HP	8648C	Signal generator	1	12/08/2017

F.2 SAR system verification

SAR measurement system manufactured by SPEAG (cDASY6 system) was used along with a calibrated dosimetric probe (ES3DV3 model) equipped with an optical surface detector system and data acquisition electronics (DAE3 model). A broadband liquid (0.6 – 6GHz) was used as tissue simulating liquid, whose electrical properties were measured daily as listed below, and are all within ±5% of target values:

Tissue Type	Measurement Date	Measured Frequency (MHz)	Target Dielectric Constant, εr	Target conductivity, σ (S/m)	Measured Dielectric Constant, εr	Measured Conductivity, σ (S/m)	%deviation, εr	%deviation, σ
Body	6-Apr-18	835	55.2	0.97	53.5	1	-3.1%	3.1%
	10-Apr-18	1732	53.5	1.48	51.9	1.45	-3.0%	-2.0%
	11-Apr-18	1712	53.5	1.46	51.9	1.44	-3.0%	-1.4%
	16-Apr-18	1800	53.3	1.52	51.8	1.49	-2.8%	-2.0%
	20-Apr-18	844	55.2	0.98	53.5	1	-3.1%	2.0%
	25-Apr-18	847	55.2	0.98	53.5	1	-3.1%	2.0%

The accuracy of this system was validated by measuring SAR at 835MHz & 1800MHz using calibrated dipoles positioned at 15mm & 10mm distances from the flat section of the SAM Twin phantom, respectively. As can be seen from below results, the SAR measurement system is operating within ±10% of the target values.

Validation Kit	S/N	Frequency (MHz)	1W Target 1gSAR (W/kg)	Measured 1gSAR (W/kg)	Measured 1gSAR normalized to 1W	% deviation	Measured Date
D835V2	466	835	9.9	1.02	10.2	3.0%	6-Apr-18
D1800V2	269	1800	39.5	3.93	39.3	-0.5%	16-Apr-18

F.3 SAR system verification

Date: 2018/04/06

Dipole 835 MHz_SN:466

Communication System: CW; Frequency: 835 MHz

Medium parameters used: f = 835 MHz; σ = 1.00 S/m; ε_r = 53.5; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Pin=100mW/Area Scan (61x91x1): Interpolated grid: dx=15 mm, dy=15 mm

Reference Value = 1.40 W/kg; Power Drift = 0.00 dB

Maximum value of SAR (interpolated) = 1.40 W/kg

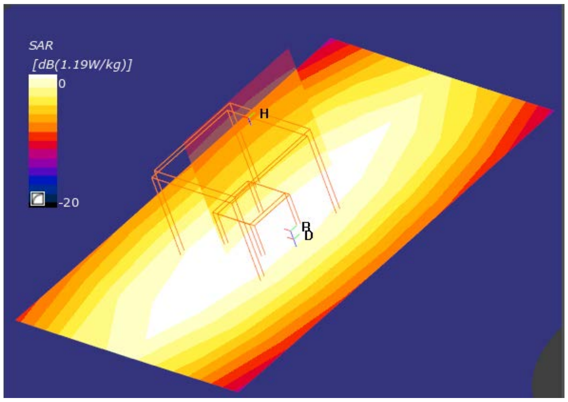
Configuration/Pin=100mW/Zoom Scan (11x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 1.40 W/kg; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 1.54 W/kg

SAR(1 g) = 1.02 W/kg; SAR(10 g) = 0.656 W/kg

Maximum value of SAR (measured) = 1.19 W/kg



Date: 2018/04/16

Dipole 1800 MHz_SN:269

Communication System: CW; Frequency: 1800 MHz

Medium parameters used: f = 1800 MHz; σ = 1.49 S/m; ε_r = 51.8; ρ = 1000 kg/m^3

Phantom section: Flat

cDASY6 Configuration:

- Probe: EX3DV3 – SN3314; Calibrated: 2018/02/07;
- Sensor-Surface: 3mm (Optical Surface Detection)
- Electronics: DAE3 Sn400; Calibrated: 2018/02/06
- Phantom: Twin-SAM V4.0 (30deg probe tilt) – SN1171
- cDASY6 v6.6.0.13816

Configuration/Pin=100mW/Area Scan (57x85x1): Interpolated grid: dx=14 mm, dy=14 mm

Reference Value = 5.41 W/kg; Power Drift = 0.01 dB

Maximum value of SAR (interpolated) = 5.47 W/kg

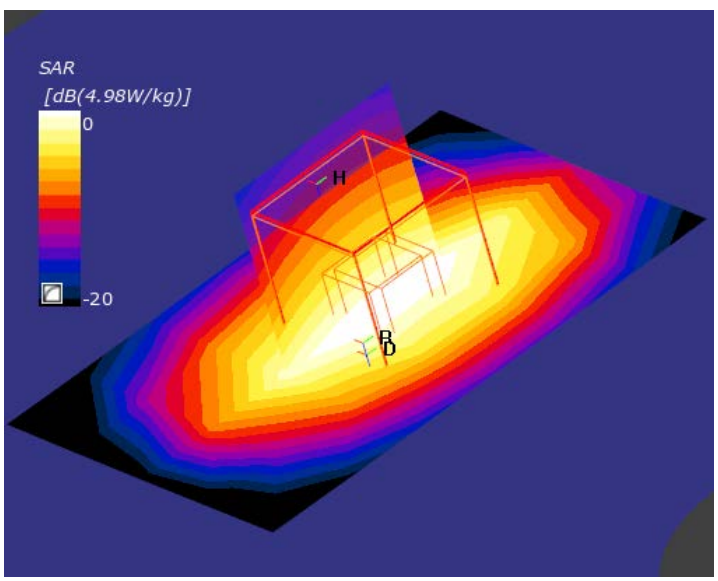
Configuration/Pin=100mW/Zoom Scan (11x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 5.42 W/kg; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 6.92 W/kg

SAR(1 g) = 3.93 W/kg; SAR(10 g) = 2.05 W/kg

Maximum value of SAR (measured) = 4.98 W/kg



G Speag Certificates of SAR Probe, DASY DAE, and Dipoles

Speag Certificates