Qualcomm Technologies, Inc.

Netgear 5G MHS Travel Router (FCC ID: PY319100441) RF Exposure Compliance Test Report

(Part 2: Test Under Dynamic Transmission Scenario)

80-W5669-2 Rev. B

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Revision history

Revision	Date	Description
A	May 07, 2019	Initial release
B	May 14, 2019	Correction in SAR tables

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1 Introduction

The equipment under test (EUT) is Netgear 5G MHS Travel Router (FCC ID: PY319100441), it contains the Qualcomm® SM8150 modem supporting 2G/3G/4G technologies and SDX50 modem supporting mmW 5G NR bands. Both of these modems are enabled with Qualcomm Smart Transmit feature to control and manage transmitting power in real time and to ensure at all times the time-averaged RF exposure is in compliance with the FCC requirement.

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 Netgear 5G MHS Travel Router (FCC ID: PY319100441).

The P_{limit} and *input.power.limit* used in this Part 2 report is determined and listed in Part 0 report.

Refer to Compliance summary report for EUT description and terminology used in this report.

2 Tx Varying Transmission Test Cases and Test Proposal

In general, to validate power enforcement by Smart Transmit and demonstrate the compliance in Tx varying transmission conditions, the following test cases are proposed and agreed by FCC:

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 disconnect and reestablish scenario in 2G/3G/4G technology: To prove that the Smart Transmit algorithm accounts for history of past Tx power transmissions accurately.
3. During technology/band handover within 2G/3G/4G technology: To prove that the Smart Transmit algorithm functions correctly during transitions in technology/band.
4. During antenna (or beam) switch: To prove that the Smart Transmit algorithm functions correctly during transitions in antenna (such as AsDiv scenario) or beams (different antenna array configurations).
5. SAR vs. PD exposure switching during sub-6+mmW transmission: To prove that the Smart Transmit algorithm functions correctly and ensures total RF exposure compliance during transitions in SAR only exposure, SAR+PD exposure, and PD only exposure scenarios.

As shown in Table 4-1 of Section 4.1 Part 1 report, since maximum time-averaged power level $P_{limit} \geq P_{max}$ (maximum RF tune-up output power) for all sub-6 radios supported for this EUT, the power limiting will not be enforced from Smart Transmit when only sub-6 radio is active. Hence, the validation for sub-6 radio is not required for this EUT when only sub-6 radio is active.

The test case 1, 4 and 5 are performed in this Part 2 report for 5G mmW NR band 260 with LTE B2 as anchor.

For a SAR-and PD-characterized wireless device, RF exposure is proportional to the Tx power. Thus, algorithm validation in Part 2 can be effectively performed through conducted (for f < 6GHz) and radiated (for f ≥ 6GHz) power measurement. Therefore, the validation is done in power measurement setup for test cases 1, 4 and 5.

To add confidence in the algorithm validation, the time-averaged SAR and PD measurements are also performed, but they are only performed for test case 1 to avoid the complexity in SAR/PD measurement.

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

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC’s SAR and PD limits, through <u>time-averaged power</u> measurements
  - Measure conducted Tx power (for f < 6GHz) versus time, and radiated Tx power (EIRP for f > 6GHz) versus time.
  - Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
  - Perform running time-averaging over FCC defined time windows.

- Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios (i.e., test case 1, 4, and 5) at all times.

  Mathematical expression:

  For LTE+mmW transmission:

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

$$4cm^2PD(t) = \frac{radiated\_Tx\_power(t)}{radiated\_Tx\_power\_input.power.limit} * 4cm^2PD\_input.power.limit \quad (1b)$$

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

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}. 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*. Both P_{limit} and *input.power.limit* are the parameters pre-defined in Part 0 report and entered through EFS. T_{SAR} is the time window for sub-6 radio defined by FCC; T_{PD} is the time window for mmW radio defined by FCC.

NOTE: If $P_{limit} \geq P_{max}$, 1gSAR or 10gSAR measured at P_{limit} shall be replaced with 1gSAR or 10gSAR measured at P_{max}.

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged PD measurements. Note as mentioned earlier, this measurement is performed for test case 1 only.
  - 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 get normalized exposure versus time.
  - Perform time averaging over FCC defined time windows.
  - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for test case 1 at all times.

    Mathematical expression:

    For LTE+mmW transmission:

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

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

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

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured 1gSAR or 10gSAR values at P_{limit}. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous E-field, E-field measured at *input.power.limit*, and $4cm^2$PD value measured at *input.power.limit*.

NOTE: If $P_{limit} \geq P_{max}$, 1gSAR or 10gSAR measured at P_{limit} shall be replaced with 1gSAR or 10gSAR measured at P_{max}.

NOTE: cDASY6 system measures relative E-field, and provides ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time. See Appendix B for time-averaged PD measurement details.

3 PD Time Averaging Validation Test Procedures

This section 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 a sub-6 LTE link as anchor.

3.1 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.

3.2 Test configuration selection criteria for validating smart transmit algorithm

3.2.1 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/beam per technology is sufficient.

3.2.2 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.

3.2.3 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.

3.3 Test procedures for radiated power measurements

The test procedures for performing 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 are described in this section.

3.3.1 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. (1a), (1b) & (1c) in Section 2).

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. Test condition to measure conducted P_{limit} and radiated *input.power.limit* is:
2. 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.
3. 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.
4. Set *Reserve_power_margin* to actual value (i.e., 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/beam, perform the following steps:
    a. Establish LTE (sub-6) and mmW NR connection. 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 $P_{limit} < P_{max}$, then the RF exposure margin (to mmW NR) gradually run out of (due to high SAR exposure), the 5G NR mmW transmission power should be gradually reduced accordingly and eventually seized when LTE goes to $P_{reserve}$ level.
        ii If $P_{limit} \geq P_{max}$, then the 5G NR mmW transmission averaged power should gradually reduce but the mmW NR connection can sustain all the time (assuming TxAGC uncertainty = 0dB).
    c. Record the conducted Tx power of LTE and radiated Tx power of mmW NR for the full duration of this test of ~ 300s or longer.
5. 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 value using Eq. (1a) and P_{limit} measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR to obtain instantaneous normalized 1gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time as illustrated in Figure 5-1.

NOTE: In Eq.(1a), instantaneous Tx power is converted into instantaneous 1gSAR value by applying the worst-case 1gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

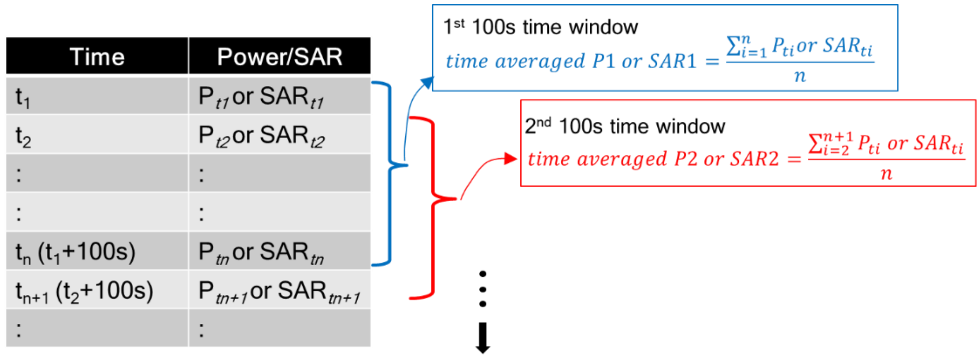


Figure 3-1: Running time averaging illustration

6. Similarly, convert the radiated Tx power for mmW NR into $4cm^2$PD value using Eq. (1b) and the radiated Tx power limit (i.e., radiated Tx power measured 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.(1b), instantaneous radiated Tx power is converted into instantaneous $4cm^2$PD by applying the corresponding worst-case $4cm^2$PD value measured at *input.power.limit* for the selected band/beam in Part 1 report.

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

The validation criteria is, 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. (1c)).

3.3.2 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 only, SAR+PD, and PD only 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/channel/DSI, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW

band/channel/beam. Test condition to measure conducted P_{limit} and radiated *input.power.limit* is:

2. 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 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.
3. 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.
4. Set *Reserve_power_margin* to actual value (intended value) and reset power in EUT, With EUT setup for LTE (sub-6) + mmW NR call, perform the following steps:
5. Establish LTE (sub-6) and mmW NR connection with callbox.
6. 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).
7. After 120s, request LTE to go all-up bits, mmW transmission should gradually run out of RF exposure margin if $P_{limit} < P_{max}$ and seize mmW transmission (SAR only scenario); or mmW transmission should gradually reduce in Tx power if $P_{limit} > P_{max}$ and will sustain the connection, in this case there will be no SAR exposure only scenario when the EUT is in EN-DC mode.
8. After 75s, request LTE to go all-down bits, mmW transmission should start getting RF exposure margin and gradually transmit at high averaged power again.
9. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of ~300s or longer.
10. 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 value using Eq. (1a) and P_{limit} measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR to obtain instantaneous normalized 1gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time.

NOTE: In Eq.(1a), instantaneous Tx power is converted into instantaneous 1gSAR value by applying the corresponding worst-case 1gSAR value measured at P_{limit} for the technology/band/antenna/DSI reported in Part 1 report.

11. Similarly, convert the radiated Tx power for mmW NR into $4cm^2$PD value using Eq. (1b) and the radiated Tx power limit (i.e., radiated Tx power measured 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.(2b), instantaneous radiated Tx power is converted into instantaneous $4cm^2$PD by applying the corresponding worst-case $4cm^2$PD value measured at *input.power.limit* for the selected band/beam in Part 1 report.

12. 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, respectively.

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

The validation criteria is, 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. (1c)).

3.3.3 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. (1a), (1b) and (1c) in Section 2 are written as below for transmission scenario having change in beam,

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (3a)$$

$$4cm^2PD_1(t) = \frac{radiated\_Tx\_power\_1(t)}{radiated\_Tx\_power\_input.power.limit\_1} * 4cm^2PD\_input.power.limit\_1 \quad (3b)$$

$$4cm^2PD_2(t) = \frac{radiated\_Tx\_power\_2(t)}{radiated\_Tx\_power\_input.power.limit\_2} * 4cm^2PD\_input.power.limit\_2 \quad (3c)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\left[\int_{t-T_{PD}}^{t_1} 4cm^2\mathrm{PD}_1(t)dt + \int_{t_1}^{t} 4cm^2\mathrm{PD}_2(t)dt\right]}{FCC\ 4cm^2PD\ limit} \leq 1 \quad (3d)$$

where, *radiated_Tx_power_1(t)*, *radiated_Tx_power_input.power.limit_1*, and *$4cm^2$PD_input.power.limit_1* correspond to the instantaneous radiated Tx power, radiated Tx power measured at *input.power.limit*, and *$4cm^2$PD* measured at *input.power.limit* of beam 1; *radiated_Tx_power_2(t)*, *radiated_Tx_power_input.power.limit_2*, and *$4cm^2$PD_input.power.limit_2* correspond to the instantaneous radiated Tx power, radiated Tx power measured at *input.power.limit*, and *$4cm^2$PD* measured at *input.power.limit* of beam 2.

NOTE: If $P_{limit} \geq P_{max}$, 1gSAR measured at P_{limit} shall be replaced with 1gSAR measured at P_{max}.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for LTE in selected band/channel/DSI, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW

band/channel/beam. Test condition to measure conducted P_{limit} and radiated *input.power.limit* is:

2. Measure radiated power corresponding to mmW *input.power.limit* by setting up the EUT to transmit in desired band/channel for beam 1 at *input.power.limit* in FTM. 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.
3. 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.
4. Set *Reserve_power_margin* to actual value (intended value) and reset power in EUT, With EUT setup for LTE (sub-6) + mmW connection, perform the following steps:
5. Establish LTE (sub-6) and mmW NR connection in beam1. 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.
6. 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.
7. 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 value using the similar approach described in Step 3 of Section 3.3.2. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time.
9. Similarly, convert the radiated Tx power for mmW NR into $4cm^2$PD value using Eq. (3b), (3c) and the radiated Tx power limits (i.e., radiated Tx power measured at *input.power.limit*) measured in Step 1.a for beam 1 and beam 2, respectively, and then divide the resulted PD values by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time for beam 1 and beam 2. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

NOTE: In Eq.(3b) and (3c), instantaneous radiated Tx power of beam 1 and beam 2 is converted into instantaneous $4cm^2$PD by applying the corresponding worst-case $4cm^2$PD value measured at the *input.power.limit* of beam 1 and beam 2 in Part 1 report.

10. Since the measured radiated powers for beam1 and beam2 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 instantaneous radiated power recorded in Step 2.c by the delta of radiated power measured in Step 5 and radiated power obtained in Step 1.a.
11. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time as measured in Step 2, (b) instantaneous radiated Tx power for mmW versus time as obtained in Step 5, (c) computed 4s-averaged radiated Tx power for mmW (using 6.b) versus time and (d) time-averaged radiated Tx power limits for beam 1 and beam 2.
12. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged $4cm^2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (sum of steps (6.a) and (6.b)) versus time.

The validation criteria is, 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., (3d)).

3.4 Test procedure for PD measurements

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

1. Place the EUT on the DASY platform to perform PD measurement in the worst-case position/surface for the selected mmW band/beam/DSI. In PD measurement, the callbox is set to request maximum mmW 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/channel/DSI, and measure point E-field corresponding to *input.power.limit* in desired mmW band/channel/beam. Test condition to measure conducted P_{limit} and PD (i.e., E-field) at *input.power.limit* is:
3. 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.
4. 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 DASY probe.
   a. 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 call, as soon as the mmW 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. Record the conducted Tx power of LTE and point relative E-field (i.e., ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$) of mmW at peak location identified in Step 2.a.ii for the entire duration of this test of ~300s.
   b. Once the measurement is done, extract instantaneous Tx power versus time for LTE and $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time from DASY system for mmW. Convert the conducted Tx power for LTE into 1gSAR value using Eq. (2a) and P_{limit} measured in Step 2.a.i, and then divide this by FCC limit of 1.6 W/kg for 1gSAR to obtain instantaneous normalized 1gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time.

NOTE: In Eq.(2a), instantaneous Tx power is converted into instantaneous 1gSAR value by applying the worst-case 1gSAR value measured at P_{limit} for the corresponding technology/band reported in Part 1 report.

   c. Similarly, convert the $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ for mmW into 4cm^{2}PD value using Eq. (2b) and radiated power limit measured in Step 2.a.ii, and 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.(2b), the instantaneous relative E-field (i.e., ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$) is converted into instantaneous $4cm^2$PD by applying the corresponding worst-case $4cm^2$PD value measured at the *input.power.limit* of beam 1 and beam 2 in Part 1 report.

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

The validation criteria is, 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. (2c)).

4 Test Configurations

4.1 LTE + mmW NR transmission

Based on the selection criteria described in Section 3.2, the selections for LTE and mmW NR validation test are listed in Table 4-1. The radio configurations used in this test is listed in Table 4-2.

Table 4-1 Selections for LTE + mmW NR validation measurements

Transmission Scenario	Test	Technology and Band	mmW Beam
Time-varying Tx power test	Cond. & Rad. Power meas. PD meas.	LTE Band 2 and n260	Beam ID 171
Switch in SAR vs. PD	Cond. & Rad. Power meas.	LTE Band 2 and n260	Beam ID 171
Beam switch test	Cond. & Rad. Power meas.	LTE Band 2 and n260	Beam ID 158 to Beam ID 131

Table 4-2: Test configuration for LTE + mmW NR validation

Tech	Band	DSI	Channel	RB/offset	Freq (MHz)	Mode	UL Duty Cycle
LTE	B2	15	18900	50	1880	QPSK	100%
mmW NR	n260	--	2254147	28	38499	CP-OFDM, BPSK	75.6%

5 Radiated Power Test Results for mmW Smart Transmit Algorithm Validation

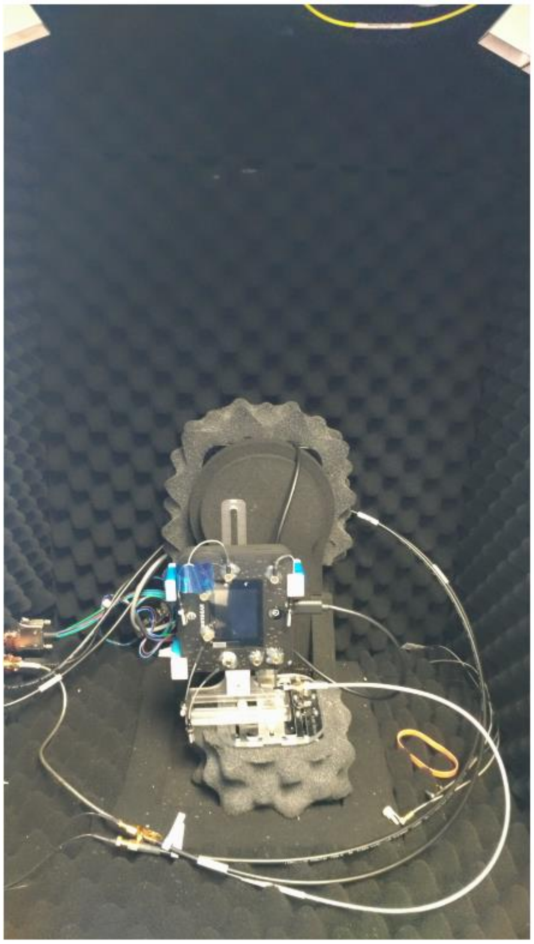
5.1 WWAN (sub-6) transmission

As discussed in Section 2, since maximum time-averaged power level $P_{limit} \geq P_{max}$ (maximum RF tune-up output power) for all supported 4G WWAN technologies/bands/DSI for this EUT, there is no power limiting required if only 4G radio is active. Hence, the Tx varying transmission scenario tests listed in Section 2 are performed for EN-DC, i.e., mmW NR + LTE radio, only in this Part 2 report for Netgear 5G MHS Travel Router (FCC ID: PY319100441).

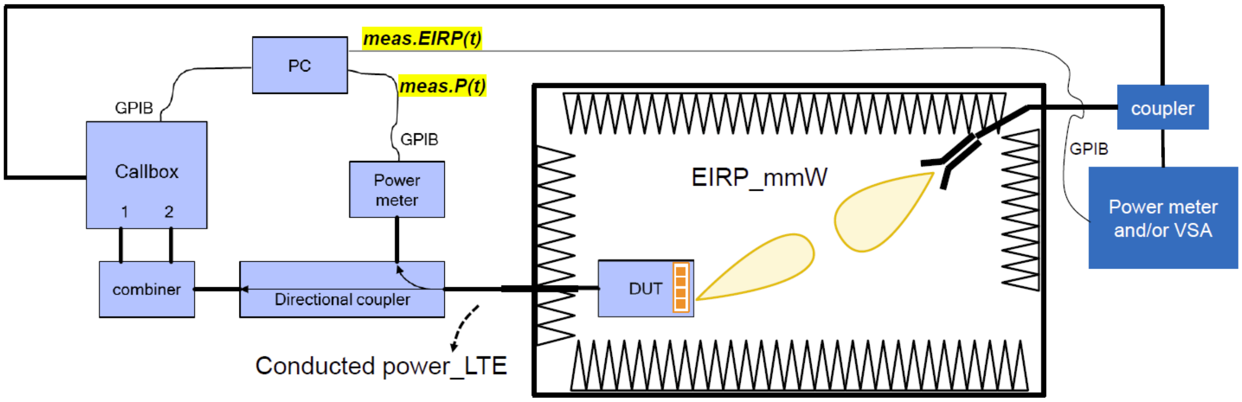
5.2 Measurement Setup

The Keysight Technologies E7515B UXM callbox is used in this test. The test setup is shown in Figure 5-1a and the schematic of the setup is shown in Figure 5-1b. 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 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 5-1. 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 NR8S 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.

Setup in Figure 5-1 is used for the test scenario 1, 4 and 5 described in Section 2. The test procedures described in Section 3 are followed. The path losses from the EUT to the power meters are calibrated and used as offset in the power meter.



(a)



(b)

Figure 5-1 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. Immediately after the mmW link is established, test script is programmed to set LTE Tx power to all-down bits on the callbox 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.

5.3 Radiated power test results

To demonstrate the compliance, the conducted Tx power of LTE B2 is converted to worst-case exposure 1gSAR by applying the worst-case 1gSAR value of 0.9 W/kg @ 23.5dBm for LTE B2 as reported in Table 4-2 of Part 1 report.

Similarly, following Step 4 in Section 3.3.1, radiated Tx power of mmW n260 for the beams tested is converted by applying the corresponding worst-case 4cm^{2}PD values as reported in Table 4-3 of Part 1 report.

Both worst-case 1gSAR and 4cm2PD values used in this section are listed in Table 5-1.

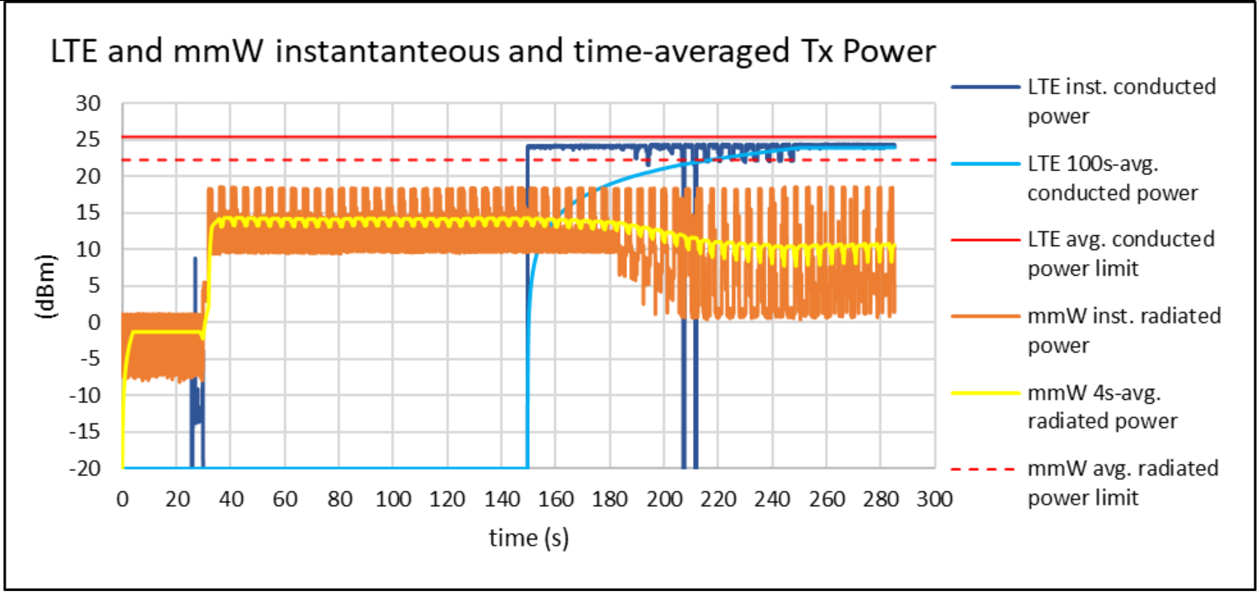
Table 5-1: Worst-case 1gSAR, 4cm^2 avg. PD and EIRP measured at *input.power.limit* of the selected configurations

					meas. 4cm2PD		
Tech	Band	Module ID	Beam ID	input.power.limit (dBm)	at input.power.limit (W/m2)	configuration	meas. EIRP at input.power.limit (dBm)
mmW NR	n260	0	171	2.3	2.69	right	16.5
		0	158	5.7	2.11	right	14.4
		0	131	6.5*	1.12	right	10.2
*input.power.limit is 7.4dBm, but Pmax is 6.5dBm so all measurements correspond to Pmax							
					1gSAR		
				Plimit (dBm)	at Pmax (W/kg)	configuration	Pmax max. tune-up power (dBm)
LTE	B2	--	--	24.1	1.16	front	24.0

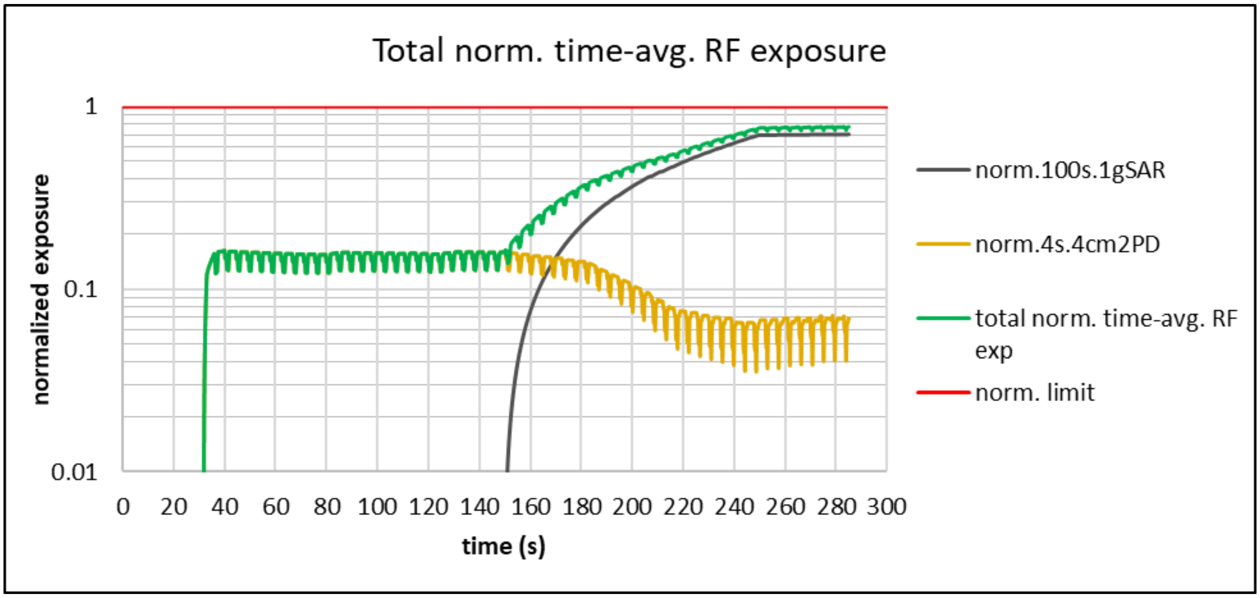
5.3.1 Maximum transmit power test results for n260

This test was measured with LTE B2 (DSI = 15) and mmW Band n260 Beam ID 171, by following the detailed test procedure described in Section 3.3.1.

Instantaneous and 100s-averaged conducted LTE Tx power versus time, instantaneous and 4s-averaged radiated mmW Tx power versus time, time-averaged conducted LTE Tx power limit and time-averaged radiated mmW Tx power limit:



Above instantaneous conducted Tx power for LTE B2 is converted into instantaneous 1gSAR using Equation (1a)), which is divided by FCC 1gSAR limit of 1.6 W/kg to obtain normalized SAR exposure versus time. Similarly, instantaneous radiated Tx power for 5G mmW NR is converted into instantaneous $4cm^2$PD using Equation (1b), which is divided by FCC $4cm^2$PD limit of 10 W/m^2 to obtain normalized PD exposure versus time. Time-averaged normalized exposures versus time are obtained using Equation (1c). Below plot shows (a) normalized time-averaged 1gSAR versus time, (b) normalized time-averaged 4cm2-avg.PD versus time, (c) sum of normalized time-averaged 1gSAR and normalized time-averaged $4cm^2$-avg.PD.



FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.775
Validated	

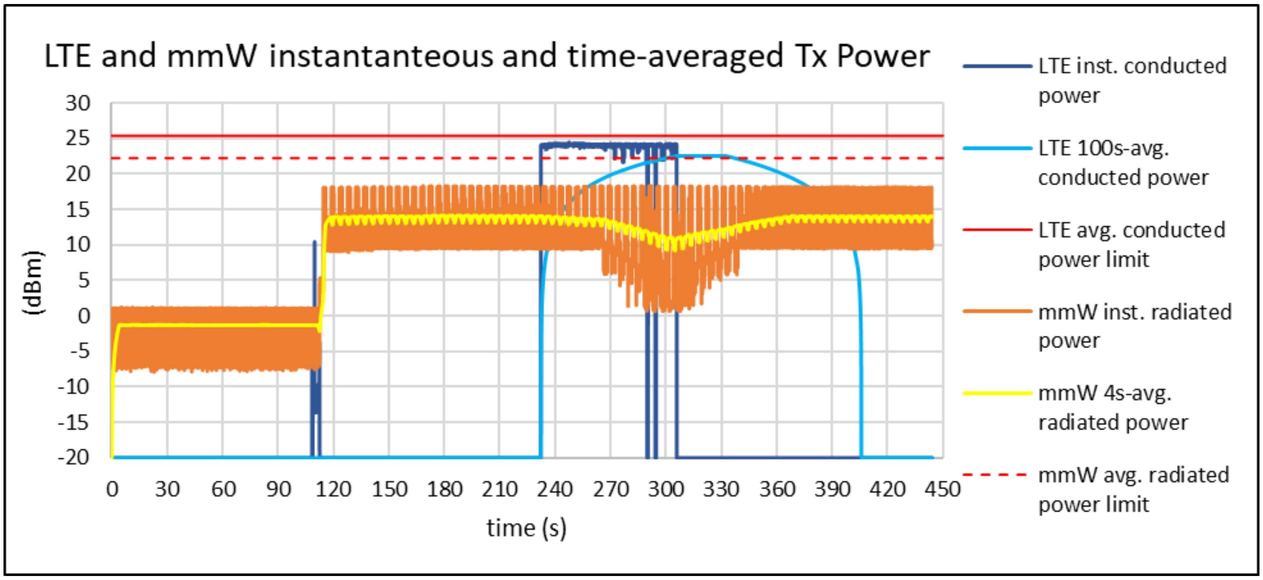
Plot notes: 5G mmW NR call was established at ~30s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 30s~150s, mmW exposure is the dominant contributor. Here, Smart Transmit algorithm allocates a maximum of 75% for mmW (i.e., at least 25% is allocated to 4G LTE anchor to maintain the link) based on the 3dB of the reserve settings in Table 3-1 of Part 1 report. From Table 5-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 171 of (75% * 2.69 W/m^2)/(10 W/m^2) = 20% ± 2.8dB device related uncertainty (see orange curve between 30s~150s). At 150s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of test, LTE is the dominant contributor towards RF exposure, i.e., corresponding normalized 1gSAR exposure value of (100% * 1.16 W/kg)/(1.6 W/kg) = 72.5% ± 1dB design related uncertainty (see black curves approaching this level towards end of the test).

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging algorithm is validated

5.3.2 Switch in SAR vs. PD exposure test results for n260

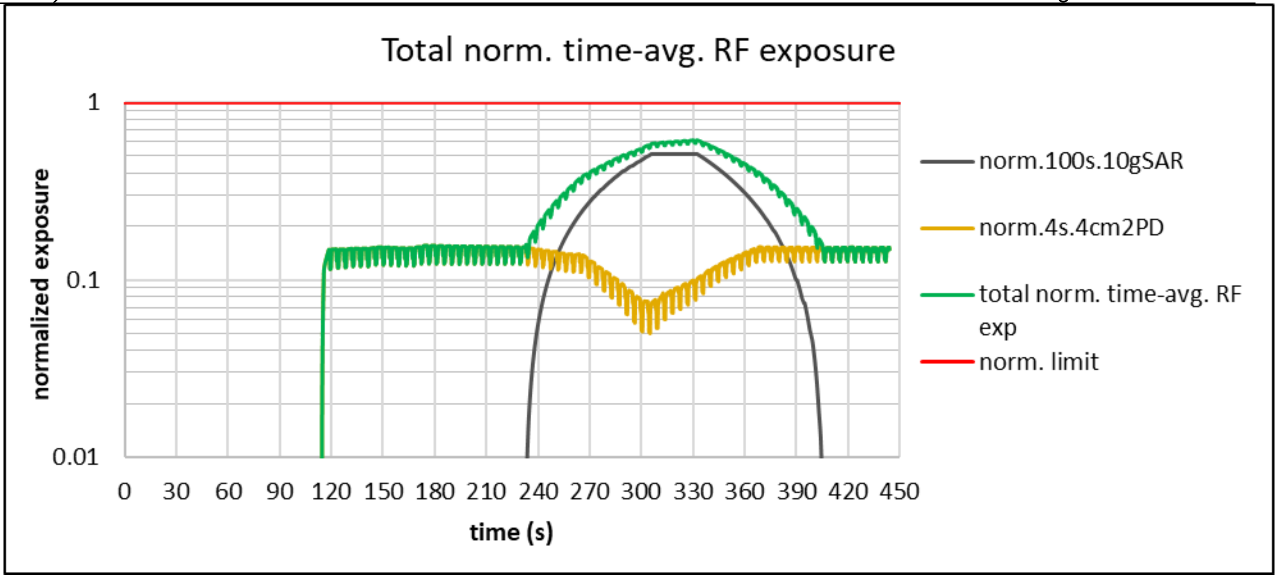
This test was measured with LTE Band 2 (DSI = 15) and mmW Band n260 Beam ID 171, by following the detailed test procedure is described in Section 3.3.2.

Instantaneous and 100s-averaged conducted LTE Tx power versus time, instantaneous and 4s-averaged radiated mmW Tx power versus time, time-averaged conducted LTE Tx power limit and time-averaged radiated mmW Tx power limit:



From the above plot, it can be seen that between 110s ~ 230s, it is predominantly instantaneous PD exposure, between 230s ~ 310s, it is instantaneous SAR+PD exposure, and above 310s, it is predominantly instantaneous PD exposure.

Normalized time-averaged exposures for LTE (1gSAR) and mmW (4cm^{2}PD), as well as total normalized time-averaged exposure versus time:



FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.614
Validated	

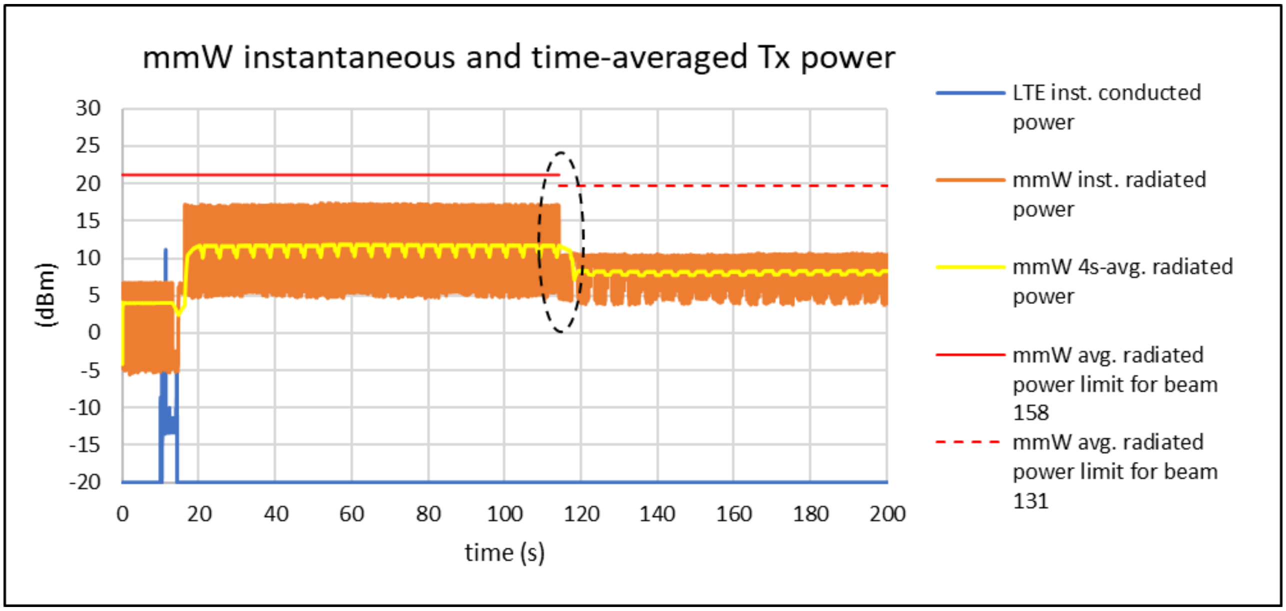
Plot notes: 5G mmW NR call was established at ~110s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 110s~230s, mmW exposure is the dominant contributor. Here, Smart Transmit algorithm allocates a maximum of 75% for mmW (i.e., at least 25% is allocated to 4G LTE anchor to maintain the link) based on 3dB of the reserve settings in Table 3-1 of Part 1 report. From Table 5-1, this corresponds to a normalized $4cm^2$PD exposure value for Beam ID 171 of (75% * 2.69 W/m^2)/(10 W/m^2) = 20% ± 2.8dB device related uncertainty (see orange curve between 110s~230s). At 230s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually (orange curve for mmW exposure goes down while black curve for LTE exposure goes up). At 310s time mark, LTE is set to all-down bits, which results in mmW getting back RF margin slowly as seen by gradual increase in mmW exposure (orange curve for mmW exposure goes up while black curve for LTE exposure goes down). The calculated maximum RF exposure from LTE corresponds to normalized 1gSAR exposure value of (100% * 1.16 W/kg)/(1.6 W/kg) = 72.5% ± 1dB design related uncertainty (note that this level will be achieved by green and black curves if LTE remains in all-up bits for longer time duration which was already demonstrated in maximum transmit power test in Section 5.3.2). Total normalized time-averaged exposure (green curve) for this test should be within the calculated range between 20% ± 2.8dB device related uncertainty (only PD exposure) and 72.5% ± 1dB design related uncertainty (only SAR exposure).

As can be seen, the power limiting enforcement is effective during transmission when SAR and PD exposures are switched, and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging algorithm is validated.

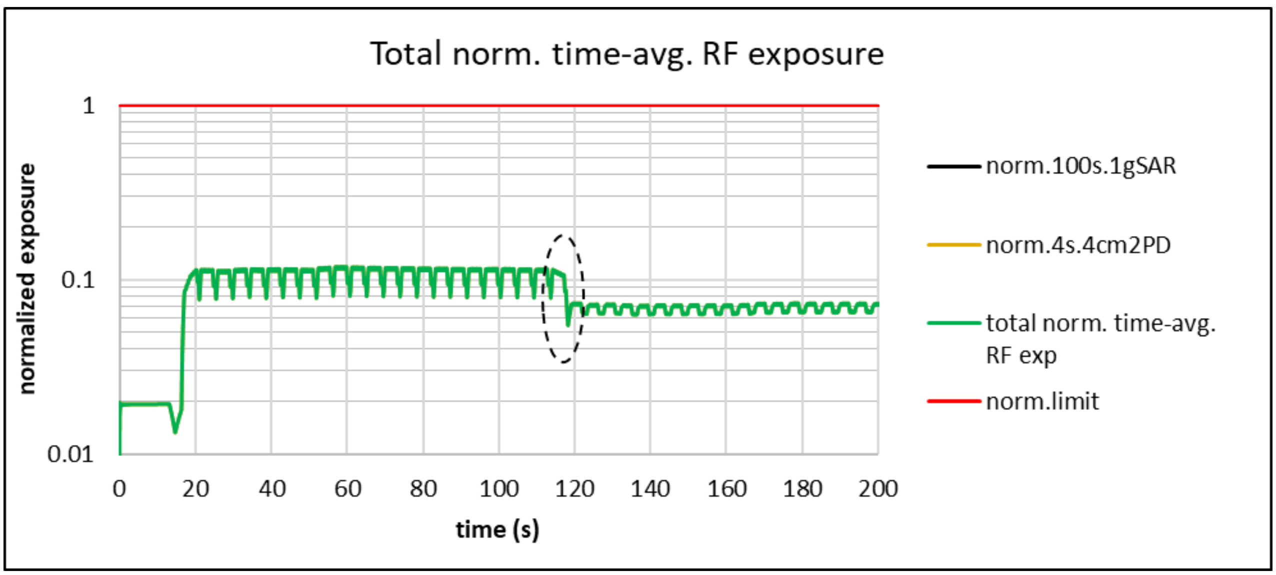
5.3.3 Change in Beam test results for n260

This test was measured with LTE Band 2 (DSI = 15) and mmW Band n260, with beam switch from Beam ID 158 to Beam ID 131, by following the test procedure is described in Section 3.3.3.

Instantaneous conducted LTE Tx power versus time, instantaneous and 4s-averaged radiated mmW Tx power versus time, time-averaged conducted LTE Tx power limit and time-averaged radiated mmW Tx power limit:



Normalized time-averaged exposures for LTE (1gSAR) and mmW (4cm^{2}PD), as well as total normalized time-averaged exposure versus time:



FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.119
Validated	

Plot notes: 5G mmW NR call was established at ~15s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. For the rest of this test, mmW exposure is the dominant contributor as LTE is left in all-down bits. Here, Smart Transmit algorithm allocates a maximum of 75% for mmW (i.e., at least 25% is allocated to 4G LTE anchor to maintain the link) based on 3dB of the reserve settings in Table 3-1 of Part 1 report. From Table

5-1, exposure between 15s ~110s corresponds to a normalized $4cm^2$PD exposure value for Beam ID 158 of (75% * 2.11 W/m^2)/(10 W/m^2) = 15.8% ± 2.8dB device related uncertainty between 15s~110s). At 110s~120s time mark (shown in black dotted ellipse), beam is switched to Beam ID 131 resulting in a normalized $4cm^2$PD exposure value of (75% * 1.12 W/m^2)/(10 W/m^2) = 8.4% ± 2.8dB device related uncertainty. Additionally, during the switch, the ratio between the averaged radiated powers of the two beams (yellow curve) should correspond to the ratio of EIRPs measured at each corresponding *input.power.limit* (within ±2.8dB device uncertainty) for these beams listed in Table 5-1.

As can be seen, the power limiting enforcement is effective during beam switches and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging algorithm is validated

6 PD Test Results for mmW Smart Transmit Algorithm Validation

6.1 Measurement setup

The measurement setup is similar to normal PD measurements, the EUT is positioned on DASY platform, and is connected with the callbox (conducted for LTE and wirelessly for mmW). Keysight UXM callbox is set to request maximum mmW Tx power from EUT all the time. Hence, “path loss” calibration between callbox antenna and EUT is not needed in this test. 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 NR8S power sensor and NRP2 power meter. Additionally, EUT is connected to the PC via USB connection for toggling between FTM and online mode with Smart Transmit enabled following the test procedures described Section 3.4.

Worst-surface of EUT (for the mmW beam being tested) is positioned facing up for PD measurement with DASY mmW probe as shown in Figure 6-1. Figure 6-2 shows the schematic of this measurement setup.

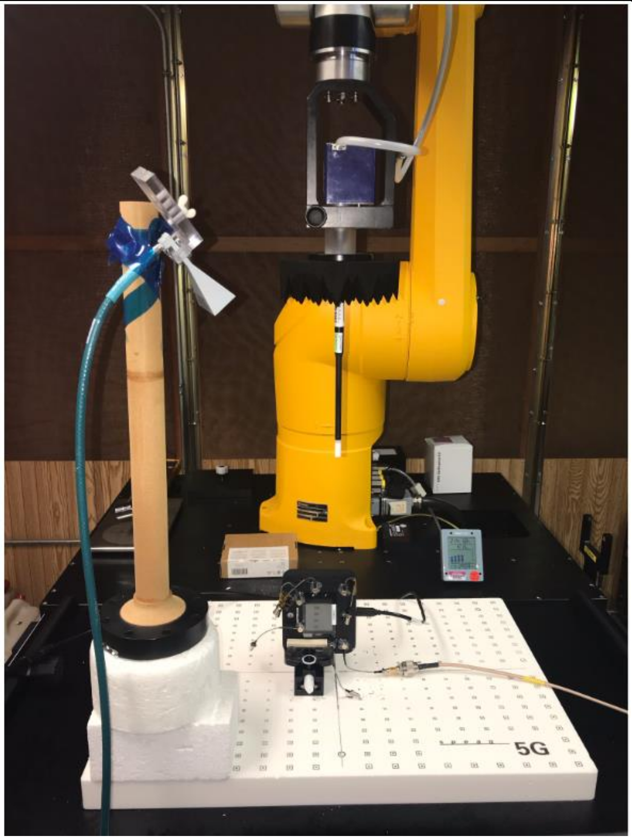


Figure 6-1 Worst-surface of EUT positioned for the mmW beam being tested

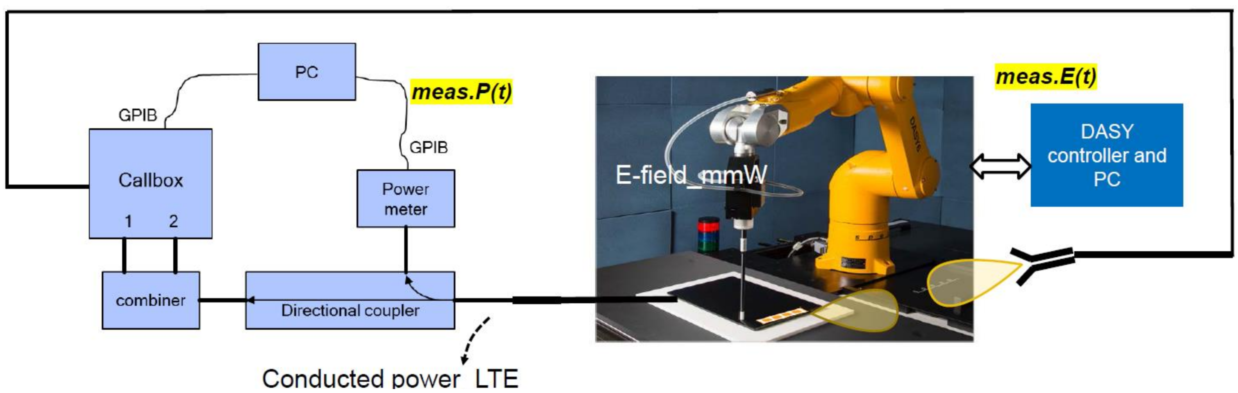


Figure 6-2 PD measurement setup

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. These tests are manually stopped after desired time duration. Once the mmW link is established, LTE Tx power is programmed to toggle between all-up and all-down bits on the callbox. For all the tests, the callbox is set to request maximum Tx power in mmW NR radio from EUT all the time. Therefore, the calibration for the pathloss between the EUT and the horn antenna connected to the remote radio head of the callbox is not required.

Power meter readings are periodically recorded every 10ms on NR8S power sensor for LTE conduced power. Time-averaged E-field measurements are performed using EUmmWV2 mmW probe at peak location of fast area scan. The distance between EUmmWV2 mmW probe tip to EUT surface is ~0.5 mm, and the distance between EUmmWV2 mmW probe sensor to probe tip is 1.5 mm. Appendix B furthermore detailed the steps for performing time-averaged E-field measurements using cDASY6 measurement system used for this validation. cDASY6 records relative point E-field values at mmW frequencies periodically every 0.1s seconds.

6.2 PD measurement results for maximum power transmission scenario

The configuration of LTE Band 2 (DSI =15) and mmW n260 Beam ID 171 was measured by following the detailed test procedure is described in Section 5.4.

Similar to the maximum transmit power test described in Section 5.3.1., by applying LTE 1gSAR of 1.16 W/kg at 24.0dBm, $4cm^2$PD at *input.power.limit* of 2.69 W/m^2, the measured conducted Tx power of LTE and ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ of mmW is converted into *1gSAR(t)* and $4cm^2PD(t)$ value, respectively, using Eq. (2a) and (2b), rewritten below:

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

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

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

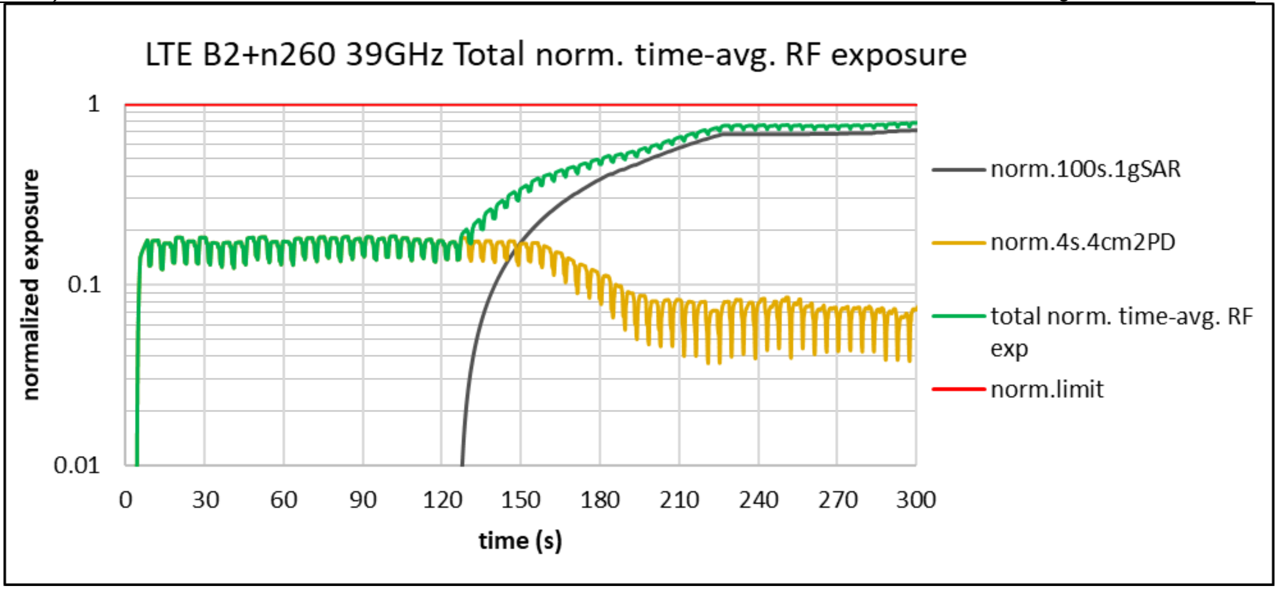
Where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured 1gSAR values at P_{limit}. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm^2PD@input.power.limit$ correspond to the measured instantaneous E-field, E-field at *input.power.limit*, and $4cm^2$PD value at *input.power.limit*.

NOTE: If $P_{limit} \geq P_{max}$, 1gSAR or 10gSAR measured at P_{limit} shall be replaced with 1gSAR or 10gSAR measured at P_{max}.

NOTE: cDASY6 system measures relative E-field, and provides ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time. See Appendix A for measurement details.

6.2.1 PD test results for n260

Step 2.e plot (in Section 5.4) for normalized time-averaged exposures for LTE and mmW n260 beam 23:



FCC limit for total RF exposure	1.0
Max total normalized time-averaged RF exposure (green curve)	0.787
Validated	

Plot notes: LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 10s~130s, mmW exposure is the dominant contributor. Here, Smart Transmit algorithm allocates a maximum of 75% for mmW (i.e., at least 25% is allocated to 4G LTE anchor to maintain the link) based on the reserve settings in Table 3-1 of Part 1 report. From Table 5-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 171 of (75% * 2.69 W/m^2)/(10 W/m^2) = 20% ± 2.8dB device related uncertainty (see orange curve between 10s~130s). Around 130s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of the test, LTE is the dominant contributor towards RF exposure, i.e., corresponding normalized 1gSAR exposure value of (100% * 1.16 W/kg)/(1.6 W/kg) = 72.5% ± 1dB design related uncertainty (see black curves approaching this level towards end of the test).

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging algorithm is validated

7 Conclusions

Qualcomm Smart Transmit feature for managing time-averaging of RF exposure, employed in Netgear 5G MHS Travel Router (FCC ID: PY319100441) has been validated through the conducted/radiated power measurement (as demonstrated in Section 5), as well as PD measurement (as demonstrated in Section 6).

As demonstrated in this report, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0 for all the transmission scenarios described in Section 2.

In conclusion, all transmission scenarios that EUT supports comply with FCC time-averaged RF exposure requirement.

A Appendix A: PD Measurement System Validation

A.1 Test environment

Test location	Qualcomm Incorporated, Inc. 5775 Morehouse Dr., San Diego, CA 92121
Ambient temperature	22±2^{0}C
Tissue simulating liquid	22±2^{0}C
Humidity range	30% ~ 49%

A.2 Power density measurement system

Table A-1 provides the list of calibrated equipment.

Table A-1 List of calibrated equipment

Equipment Manufacturer and Type	Serial number	Last Calibrated	Next Calibration
Rohde & Schwarz NR8S Power Sensor	105485	1/17/2019	1/17/2020
Rohde & Schwarz NR50S Power Sensor	101086	2/18/2019	2/18/2021
Keysight UXM 5G Wireless Test Platform	MY57510551	2/2/2018	N/A
Keysight Input E7770A	GB57330038	11/16/2018	N/A
Keysight mmWave transceiver M1740A	US58230232	12/11/2018	N/A
Keysight mmWave transceiver M1740A	US58230215	12/14/2018	N/A

Appendix D lists the calibration certificates for the measurement equipment used in this report.

The PD measurement system is operated within a shielded screen room manufactured by Lindgren RF Enclosures to provide isolation from external EM fields. The phantom bench is placed on two ferrite panels measuring 2 ft^2 each to minimize reflected energy that would otherwise re-enter the phantom and combine constructively or destructively with the desired results

The power density measurement system is constructed based on the DASY6 platform by SPEAG (see Figure A-1). The DASY6 with EUmmWv2 and 5G software module can measure the electromagnetic exposure (electromagnetic and power density) up to 110GHz as close as 2mm from any transmitter.

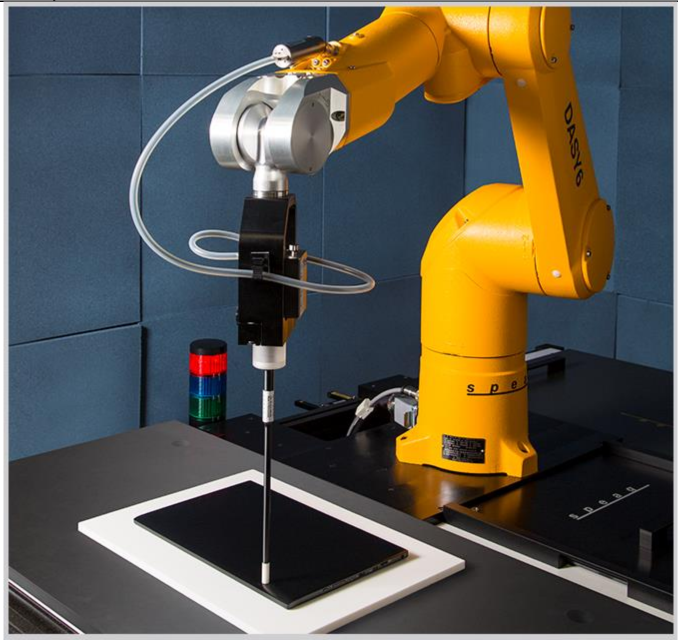


Figure A-1 Power density measurement system

A.2.1 Power density probe

The novel EUmmWV2 probe is used in the power density measurement. It is designed for precise near-field measurements in the mm-wave range by Schmid & Partner Engineering AG of Zurich, Switzerland. The specifications are:

- Frequency range: 0.75 ~ 110 GHz
- Dynamic range: <50 – 3000 V/m (up to 10000 V/m with additional PRE-10 voltage divider)
- Linearity: < ± 0.2 dB
- Supports sensor model calibration (SMC)
- ISO17025 accredited calibration

A.2.2 Power density measurement system verification

The power density system verification is performed using the SPEAG verification device. It consists of a ka-band horn antenna with a corresponding gun oscillator packaged with a cube-shaped housing (see Figure A-2).

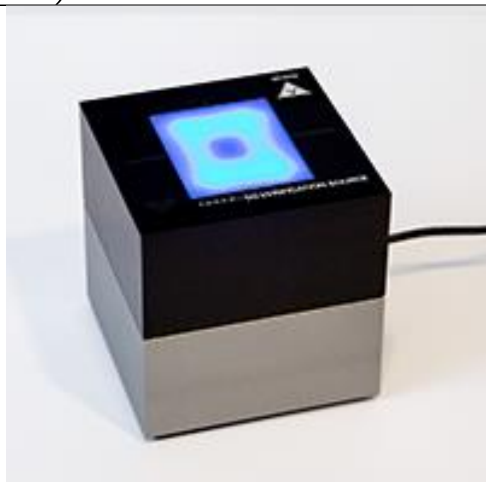


Figure A-2 Ka-band verification device

The specification of the verification device is

- Calibrated frequency: 30 GHz at 10 mm from the case surface
- Frequency accuracy: ± 100 MHz
- E-field polarization: linear
- Harmonics: -20 dBc (typ)
- Total radiated power: 14 dBm (typ)
- Power stability: 0.05 dB
- Power consumption: 5 W (max)
- Size: 100 × 100 × 100 mm
- Weight: 1 kg

Table A-2 shows the verification test results. The measured power density (PD) value is within 0.4dB of target level. Note that the uncertainty of 5G verification source is 1.4dB (k=2).

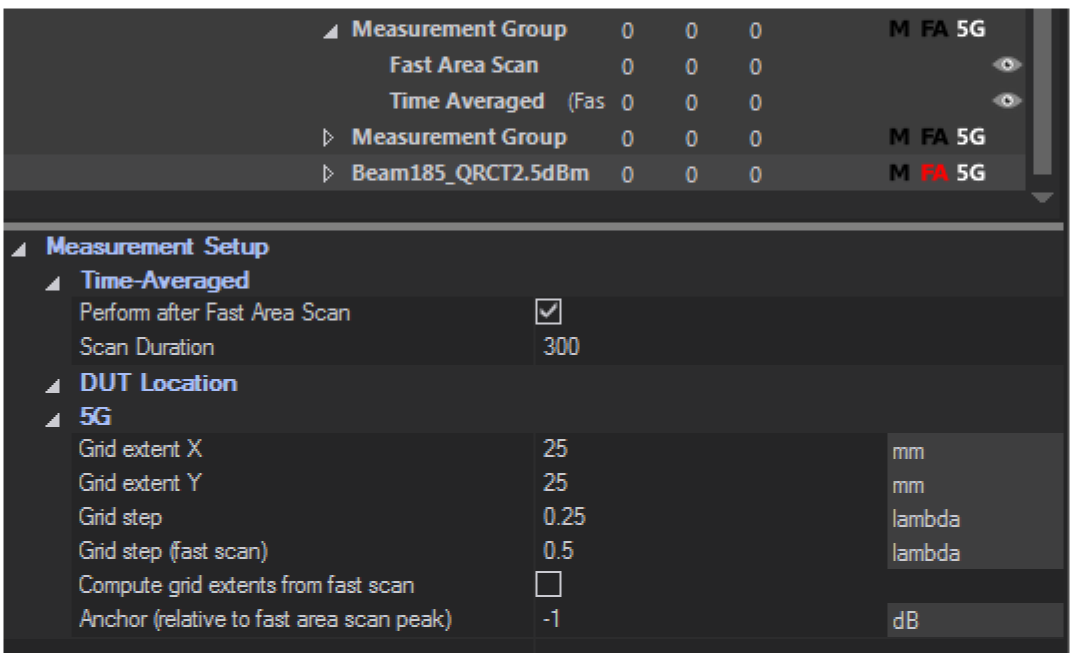
Table A-2 System validation results

Validation kit	S/N	Frequency (GHz)	14dBm Target PD (W/m^2)	14W Meas. PD (W/m^2)	Deviation (dB)	Date
Ka-band source	1012	30	47.9 ($4cm^2$)	51.8($4cm^2$)	0.34dB ($4cm^2$)	4/22/2019

B Test Procedure for Time-Averaged PD Measurement Using cDASY6

Test procedures for time-averaged PD algorithm measurement with cDASY6 system:

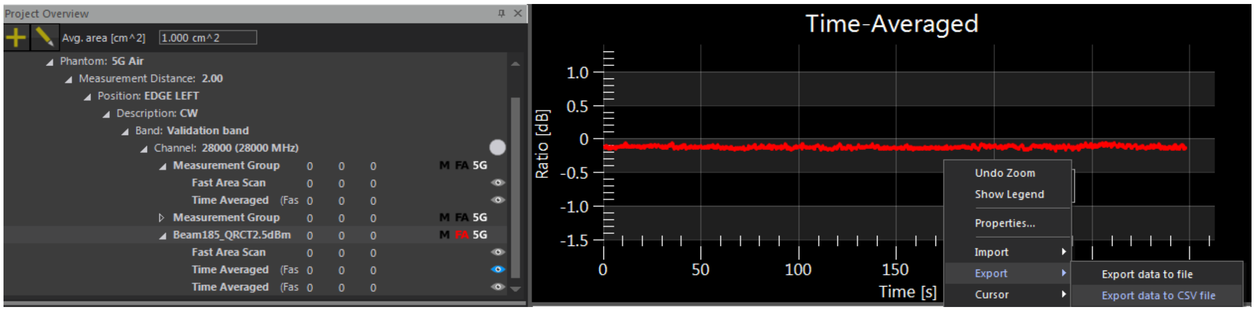
1. Setup the EUT to transmit in the desired band, channel and beam configuration at *input.power.limit*.
2. In cDASY6, enable checkbox for time-averaged measurement option after Fast Area Scan in Measurement Setup settings (see screen capture below), and set the duration of the scan to 300s. Fast area scan quickly scans the area to identify the hotspot location with highest E-field along the polarization of the sensor inside the mmW probe.



3. For tests where the callbox requesting EUT to transmit at maximum power at all times, mmW path loss between EUT and the callbox need not be calibrated.
4. Setup EUT to transmit at *input.power.limit* via Factory Test Mode (FTM) and perform the fast area scan with time-average scan enabled. After the fast area scan, cDASY6 will pause for time-average measurement at the peak location of fast area scan.
5. To measure time-average PD for maximum power test sequences: place EUT in online mode without disturbing the wireless device position relative to the mmW probe. Start the cDASY6

time-averaged measurement with EUT in mmW call and the callbox requesting maximum power in mmW link at all times. After this step, user should click 'no' on the prompt for an additional cDASY time-averaged measurements.

6. Extract recorded data in dB scale (i.e., point E-field data versus time normalized to the E-field at peak location from fast area scan in Step 4) from time-averaged measurement as shown below by first viewing the data in field viewer, and then right-click on the plot to export data in csv format.



7. Exported data is in dB scale, *rel_dB(t)*, indicates the PD value versus time is relative to the 4cm2.PD measured at *input.power.limit* in Table 7-1, as given by below equation, i.e.,

$$4cm2PD(t) = 10^{[rel\_dB(t)/10]} * 4cm2PD\_P_{limit}$$

8. The above equation is represented as equation (2b) in this report re-written below:

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

where, $\frac{[pointE(t)]^2}{[pointE_{input}.power.limit]^2}$ is a ratio between E-field for time-varying mmW Tx power and E-field measured at *input.power.limit*, which is also represented by $10^{[rel\_dB(t)/10]}$.