Qualcomm Technologies, Inc.

Samsung CPE (FCC ID: A3LSMH204V) RF Exposure Compliance Test Report

(Part 2: Test Under Dynamic Transmission Condition)

80-W5681-12 Rev. B

August 20, 2020

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

Revision history

Revision	Date	Description
A	August 14, 2020	Initial release
B	August 20, 2020	Corrected typos throughout the document, remove the test sequences from Appendix A and added list of test equipment in Appendix A

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5775 Morehouse Dr.
San Diego CA 92121

Overview

Test Report Reference:	80-W5681-12
Responsible Engineer:	Lin Lu / Jagadish Nadakuduti / Nandhini Srinivasan
Signature:	
Test Engineer:	Sushant Kadimdivan
Signature:	
Date(s) of lab activity:	13 August 2020 – 14 August 2020
Date of issue:	20 August 2020
Test Location	Qualcomm Incorporated 5665 Morehouse Dr Building QRC, Room 513. San Diego CA 92121 (General Telephone) 1 858 845 7428
Temperature Range	16-25 °C (21.1°C actual)
Humidity Range	25-75% (54% actual)
Customer:	SAMSUNG ELECTRONICS CO., LTD 40th floor Samsung Electronics Building, 11, Seocho-daero 74-Gil, Seocho District, Seoul, South Korea (Head office telephone) +91 124 488 1234
FCC ID:	A3LSMH204V
Test Specification Standard(s):	FCC 47 CFR §1.1310 and §2.1091

Results:	Passed

1 Introduction

The EUT is Samsung CPE (FCC ID: A3LSMH204V) which contains the Qualcomm® SDX55 modem supporting ≤ 4G technologies and mmW 5G NR bands. Both of these modems are enabled in Qualcomm Smart Transmit Feature to control and manage transmitting power in real time and to ensure at all times the averaged RF exposure is in compliance with FCC requirements

The purpose of this document is to demonstrate the validity of the Smart Transmit feature implemented in the SDX55 modems inside Samsung CPE (Qualcomm CPE), which is part of the overall RF exposure compliance application.

In this document, the maximum time averaged transmit power limits for all supported technologies, bands, and antennas used for Qualcomm Smart Transmit are derived from Part 0 report (Ref # 1).

Part1 report for frequenciea <6GHz (Ref # 2) and Part1 report report for frequenciea >6GHz (Ref # 3) submitted to FCC demonstrates that the equipment under test (EUT) complies with FCC RF exposure limits at the maximum time averaged power limits.

1.1 References

Table 1-1 lists related documentation.

Table 1-1 References

Ref#	Document	DCN / URL
[1]	*A3LSMH204V RF Exposure Part 0 Test Report*	1M2004140062-20
[2]	*Part1 MPE Assessment for frequencies <6GHz*	1M2004140062-01
[3]	*Part1 MPE Assessment for frequencies >6GHz*	1M2004140062-18
[4]	*RF Exposure Summary Report*	1M2004140062-19

1.2 Acronyms

Table 1-2 provides definitions for the acronyms used in this document.

Table 1-2 Acronyms

Acronym	Description
EUT	Equipment under test
FDD	Frequency division duplex
EFS	Embedded file system
NR	New radio
mmW	Millimeter wave

Acronym	Description
PD	Power density
CPE	Customer Premise Equipment
Tx	Transmitter

2 Qualcomm CPE Input Parameters

Table 2-1 and Table 2-2 list Qualcommm CPE input parameters entered via EFS for Smart Transmit to operate. Both P_{limit} and *input.power.limit* are determined in Part 0 report (Ref # 1).

Table 2-1 EFS input parameters for Smart Transmit for LTE radio

Reserver_power_margin(dB)	**1.2**	
Tech/Band/Antenna	**P_{limit} (dBm)**	***Maximum tune up target power****
LTE Band 2	29.7	23.5
LTE Band 4	29.8	23.5
LTE Band 5	32.4	24.0
LTE Band 13	30.7	23.95
LTE Band 48	30.3	23.0
LTE Band 66	29.3	23.5
NR5G Band 2	29.7	23.0
NR5G Band 5	32.4	23.5
NR5G Band 66	29.3	23.0

* Maximum tune up target power, Pmax, is configured in NV settings in EUT to limit maximum transmitting power. This power is converted into peak power in NV settings for TDD schemes. The EUT maximum allowed output power is equal to Pmax + 1dB device uncertainty.

Table 2-2 EFS input parameters for Smart Transmit for mmW NR Band n260

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		0	12.0
260		1	12.2
260		2	12.3
260		3	12.3
260		4	12.2
260		5	12.3
260		6	12.3
260		7	12.6
260		8	12.8
260		9	13.1
260		10	13.1
260		11	13.1
260		12	12.8
260		13	12.8
260		14	13.0
260		15	13.1
260		16	13.0
260		17	12.8
260		18	12.7
260		19	-5.7
260		20	-5.6
260		21	-5.6
260		22	-5.6
260		23	-5.6
260		24	-5.6
260		25	-5.7
260		26	-5.4
260		27	-5.4
260		28	-5.3
260		29	-5.4
260		30	-5.4
260		31	-5.4
260		32	-5.4
260		33	-5.3

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		34	-5.4
260		35	-5.4
260		36	-5.5
260		37	-5.5
260		38	-5.0
260		39	-4.9
260		40	-4.9
260		41	-4.9
260		42	-4.9
260		43	-5.0
260		44	-5.0
260		45	-5.1
260		46	-5.0
260		47	-5.0
260		48	-4.9
260		49	-4.9
260		50	-4.9
260		51	-4.9
260		52	-5.0
260		53	-5.1
260		54	-5.2
260		55	-5.1
260		56	-4.3
260		57	-4.2
260		58	-4.2
260		59	-4.1
260		60	-4.2
260		61	-4.2
260		62	-4.3
260		63	-4.4
260		64	-4.5
260		65	-4.6
260		66	-4.6
260		67	-4.5

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		68	-4.4
260		69	-4.3
260		70	-4.2
260		71	-4.2
260		72	-4.2
260		73	-4.2
260		74	-4.4
260		75	-4.6
260		76	-4.7
260		77	-4.7
260		78	-4.6
260		79	-4.5
260		80	-3.4
260		81	-3.3
260		82	-3.2
260		83	-3.2
260		84	-3.2
260		85	-3.2
260		86	-3.3
260		87	-3.4
260		88	-3.5
260		89	-3.7
260		90	-3.9
260		91	-4.0
260		92	-4.0
260		93	-4.0
260		94	-3.8
260		95	-3.6
260		96	-3.5
260		97	-3.4
260		98	-3.3
260		99	-3.2
260		100	-3.2
260		101	-3.3

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		102	-3.4
260		103	-3.6
260		104	-3.9
260		105	-4.1
260		106	-4.2
260		107	-4.1
260		108	-3.9
260		109	-3.7
260		128	11.8
260		129	12.0
260		130	12.0
260		131	12.0
260		132	12.0
260		133	12.0
260		134	12.1
260		135	12.6
260		136	12.5
260		137	12.6
260		138	12.9
260		139	12.8
260		140	12.8
260		141	12.5
260		142	12.5
260		143	12.6
260		144	12.8
260		145	12.8
260		146	12.7
260		147	-5.8
260		148	-5.7
260		149	-5.8
260		150	-5.8
260		151	-5.8
260		152	-5.8
260		153	-5.8

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		154	-5.5
260		155	-5.5
260		156	-5.5
260		157	-5.5
260		158	-5.5
260		159	-5.5
260		160	-5.5
260		161	-5.6
260		162	-5.6
260		163	-5.5
260		164	-5.5
260		165	-5.5
260		166	-5.1
260		167	-5.2
260		168	-5.2
260		169	-5.2
260		170	-5.1
260		171	-5.0
260		172	-5.0
260		173	-5.0
260		174	-5.0
260		175	-5.1
260		176	-5.2
260		177	-5.3
260		178	-5.3
260		179	-5.2
260		180	-5.1
260		181	-5.0
260		182	-5.0
260		183	-5.0
260		184	-4.5
260		185	-4.6
260		186	-4.7
260		187	-4.7

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		188	-4.7
260		189	-4.6
260		190	-4.5
260		191	-4.4
260		192	-4.3
260		193	-4.3
260		194	-4.3
260		195	-4.4
260		196	-4.5
260		197	-4.6
260		198	-4.8
260		199	-4.8
260		200	-4.8
260		201	-4.7
260		202	-4.5
260		203	-4.4
260		204	-4.3
260		205	-4.3
260		206	-4.3
260		207	-4.4
260		208	-3.7
260		209	-3.9
260		210	-4.1
260		211	-4.2
260		212	-4.2
260		213	-4.0
260		214	-3.9
260		215	-3.7
260		216	-3.5
260		217	-3.4
260		218	-3.3
260		219	-3.3
260		220	-3.3
260		221	-3.3

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260		222	-3.4
260		223	-3.6
260		224	-3.8
260		225	-4.0
260		226	-4.3
260		227	-4.3
260		228	-4.2
260		229	-4.0
260		230	-3.8
260		231	-3.5
260		232	-3.4
260		233	-3.3
260		234	-3.3
260		235	-3.3
260		236	-3.5
260		237	-3.6
260	128	0	8.8
260	129	1	9.0
260	130	2	9.1
260	131	3	9.1
260	132	4	9.0
260	133	5	9.1
260	134	6	9.1
260	135	7	9.5
260	136	8	9.6
260	137	9	9.8
260	138	10	9.9
260	139	11	9.9
260	140	12	9.7
260	141	13	9.6
260	142	14	9.7
260	143	15	9.8
260	144	16	9.8
260	145	17	9.7

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260	146	18	9.6
260	147	19	-8.8
260	148	20	-8.7
260	149	21	-8.8
260	150	22	-8.8
260	151	23	-8.8
260	152	24	-8.8
260	153	25	-8.8
260	154	26	-8.5
260	155	27	-8.5
260	156	28	-8.5
260	157	29	-8.5
260	158	30	-8.5
260	159	31	-8.5
260	160	32	-8.5
260	161	33	-8.5
260	162	34	-8.6
260	163	35	-8.5
260	164	36	-8.6
260	165	37	-8.6
260	166	38	-8.1
260	167	39	-8.1
260	168	40	-8.1
260	169	41	-8.1
260	170	42	-8.1
260	171	43	-8.1
260	172	44	-8.1
260	173	45	-8.1
260	174	46	-8.1
260	175	47	-8.1
260	176	48	-8.1
260	177	49	-8.2
260	178	50	-8.2
260	179	51	-8.1

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260	180	52	-8.1
260	181	53	-8.1
260	182	54	-8.2
260	183	55	-8.1
260	184	56	-7.5
260	185	57	-7.5
260	186	58	-7.5
260	187	59	-7.5
260	188	60	-7.5
260	189	61	-7.5
260	190	62	-7.5
260	191	63	-7.5
260	192	64	-7.5
260	193	65	-7.5
260	194	66	-7.5
260	195	67	-7.5
260	196	68	-7.5
260	197	69	-7.5
260	198	70	-7.6
260	199	71	-7.6
260	200	72	-7.6
260	201	73	-7.5
260	202	74	-7.5
260	203	75	-7.6
260	204	76	-7.6
260	205	77	-7.6
260	206	78	-7.5
260	207	79	-7.5
260	208	80	-6.6
260	209	81	-6.7
260	210	82	-6.7
260	211	83	-6.8
260	212	84	-6.8
260	213	85	-6.7

Band	Paired With ID	Beam ID	Input Power Limit (dBm)
260	214	86	-6.7
260	215	87	-6.6
260	216	88	-6.6
260	217	89	-6.6
260	218	90	-6.7
260	219	91	-6.7
260	220	92	-6.7
260	221	93	-6.7
260	222	94	-6.7
260	223	95	-6.7
260	224	96	-6.7
260	225	97	-6.8
260	226	98	-6.9
260	227	99	-6.8
260	228	100	-6.8
260	229	101	-6.7
260	230	102	-6.7
260	231	103	-6.6
260	232	104	-6.7
260	233	105	-6.8
260	234	106	-6.8
260	235	107	-6.8
260	236	108	-6.8
260	237	109	-6.7

Table 2-3 EFS input parameters for Smart Transmit for mmW NR Band n261

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		0	15.6
261		1	15.8
261		2	15.8
261		3	15.7
261		4	15.7
261		5	15.9
261		6	15.9
261		7	16.2
261		8	16.3
261		9	16.4
261		10	16.4
261		11	16.2
261		12	16.1
261		13	16.0
261		14	16.3
261		15	16.5
261		16	16.6
261		17	16.5
261		18	16.3
261		19	-2.3
261		20	-2.2
261		21	-2.3
261		22	-2.3
261		23	-2.3
261		24	-2.3
261		25	-2.2
261		26	-2.0
261		27	-2.0
261		28	-2.0
261		29	-2.1
261		30	-2.2
261		31	-2.2
261		32	-2.1

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		33	-2.1
261		34	-2.0
261		35	-2.0
261		36	-2.0
261		37	-2.0
261		38	-1.6
261		39	-1.6
261		40	-1.6
261		41	-1.6
261		42	-1.7
261		43	-1.8
261		44	-1.9
261		45	-1.9
261		46	-1.9
261		47	-1.8
261		48	-1.7
261		49	-1.7
261		50	-1.6
261		51	-1.6
261		52	-1.6
261		53	-1.7
261		54	-1.7
261		55	-1.7
261		56	-1.1
261		57	-1.0
261		58	-1.0
261		59	-1.0
261		60	-1.0
261		61	-1.1
261		62	-1.3
261		63	-1.4
261		64	-1.5
261		65	-1.5

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		69	-1.2
261		70	-1.1
261		71	-1.0
261		72	-1.0
261		73	-1.0
261		74	-1.1
261		75	-1.1
261		76	-1.2
261		77	-1.2
261		78	-1.2
261		79	-1.2
261		80	-0.4
261		81	-0.3
261		82	-0.2
261		83	-0.1
261		84	-0.1
261		85	-0.2
261		86	-0.4
261		87	-0.5
261		88	-0.7
261		89	-0.8
261		90	-1.0
261		91	-1.0
261		92	-1.0
261		93	-1.0
261		94	-0.8
261		95	-0.7
261		96	-0.5
261		97	-0.4
261		98	-0.3
261		99	-0.2
261		100	-0.2
261		101	-0.2

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		102	-0.3
261		103	-0.4
261		104	-0.5
261		105	-0.6
261		106	-0.6
261		107	-0.7
261		108	-0.6
261		109	-0.5
261		128	15.7
261		129	15.8
261		130	15.8
261		131	15.9
261		132	15.9
261		133	15.9
261		134	15.9
261		135	16.2
261		136	16.1
261		137	16.3
261		138	16.5
261		139	16.5
261		140	16.3
261		141	16.1
261		142	16.2
261		143	16.4
261		144	16.6
261		145	16.6
261		146	16.3
261		147	-2.4
261		148	-2.3
261		149	-2.3
261		150	-2.3
261		151	-2.2
261		152	-2.2

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		153	-2.3
261		154	-2.1
261		155	-2.2
261		156	-2.2
261		157	-2.1
261		158	-2.0
261		159	-2.0
261		160	-2.0
261		161	-2.0
261		162	-2.0
261		163	-2.0
261		164	-2.0
261		165	-2.1
261		166	-1.8
261		167	-1.9
261		168	-1.9
261		169	-1.9
261		170	-1.8
261		171	-1.7
261		172	-1.6
261		173	-1.6
261		174	-1.6
261		175	-1.6
261		176	-1.7
261		177	-1.7
261		178	-1.7
261		179	-1.7
261		180	-1.6
261		181	-1.6
261		182	-1.7
261		183	-1.8
261		184	-1.4
261		185	-1.5

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		187	-1.5
261		188	-1.5
261		189	-1.4
261		190	-1.3
261		191	-1.1
261		192	-1.0
261		193	-1.0
261		194	-1.0
261		195	-1.1
261		196	-1.1
261		197	-1.2
261		198	-1.2
261		199	-1.2
261		200	-1.2
261		201	-1.2
261		202	-1.1
261		203	-1.1
261		204	-1.0
261		205	-1.1
261		206	-1.1
261		207	-1.2
261		208	-0.7
261		209	-0.9
261		210	-1.0
261		211	-1.0
261		212	-1.0
261		213	-1.0
261		214	-0.9
261		215	-0.7
261		216	-0.5
261		217	-0.4
261		218	-0.2
261		219	-0.2

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261		220	-0.2
261		221	-0.2
261		222	-0.3
261		223	-0.4
261		224	-0.5
261		225	-0.6
261		226	-0.7
261		227	-0.6
261		228	-0.6
261		229	-0.5
261		230	-0.5
261		231	-0.3
261		232	-0.3
261		233	-0.2
261		234	-0.2
261		235	-0.3
261		236	-0.4
261		237	-0.6
261	128	0	12.7
261	129	1	12.8
261	130	2	12.8
261	131	3	12.8
261	132	4	12.8
261	133	5	12.9
261	134	6	12.9
261	135	7	13.2
261	136	8	13.2
261	137	9	13.4
261	138	10	13.5
261	139	11	13.4
261	140	12	13.2
261	141	13	13.1
261	142	14	13.3

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261	143	15	13.5
261	144	16	13.6
261	145	17	13.6
261	146	18	13.3
261	147	19	-5.3
261	148	20	-5.2
261	149	21	-5.3
261	150	22	-5.3
261	151	23	-5.2
261	152	24	-5.2
261	153	25	-5.2
261	154	26	-5.0
261	155	27	-5.1
261	156	28	-5.1
261	157	29	-5.1
261	158	30	-5.1
261	159	31	-5.1
261	160	32	-5.0
261	161	33	-5.0
261	162	34	-5.0
261	163	35	-5.0
261	164	36	-5.0
261	165	37	-5.0
261	166	38	-4.7
261	167	39	-4.7
261	168	40	-4.7
261	169	41	-4.7
261	170	42	-4.7
261	171	43	-4.7
261	172	44	-4.7
261	173	45	-4.7
261	174	46	-4.7
261	175	47	-4.7

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261	176	48	-4.7
261	177	49	-4.7
261	178	50	-4.6
261	179	51	-4.6
261	180	52	-4.6
261	181	53	-4.6
261	182	54	-4.7
261	183	55	-4.7
261	184	56	-4.2
261	185	57	-4.2
261	186	58	-4.2
261	187	59	-4.2
261	188	60	-4.2
261	189	61	-4.2
261	190	62	-4.3
261	191	63	-4.2
261	192	64	-4.2
261	193	65	-4.2
261	194	66	-4.2
261	195	67	-4.3
261	196	68	-4.2
261	197	69	-4.2
261	198	70	-4.1
261	199	71	-4.1
261	200	72	-4.1
261	201	73	-4.1
261	202	74	-4.1
261	203	75	-4.1
261	204	76	-4.1
261	205	77	-4.1
261	206	78	-4.1
261	207	79	-4.2
261	208	80	-3.5

Band	Paired With ID (For Beam Pair)	Beam ID	Input Power Limit (dBm)
261	209	81	-3.6
261	210	82	-3.6
261	211	83	-3.5
261	212	84	-3.5
261	213	85	-3.6
261	214	86	-3.6
261	215	87	-3.6
261	216	88	-3.6
261	217	89	-3.6
261	218	90	-3.6
261	219	91	-3.6
261	220	92	-3.6
261	221	93	-3.6
261	222	94	-3.5
261	223	95	-3.5
261	224	96	-3.5
261	225	97	-3.5
261	226	98	-3.5
261	227	99	-3.4
261	228	100	-3.4
261	229	101	-3.3
261	230	102	-3.4
261	231	103	-3.3
261	232	104	-3.4
261	233	105	-3.4
261	234	106	-3.4
261	235	107	-3.5
261	236	108	-3.5
261	237	109	-3.5

3 Tx Varying Transmission Test Cases and Test Proposal

To demonstrate CPE in compliance with the FCC time-averaged RF exposure limit (as shown in Table 3-1), perform time-averaging validation with the Smart Transmit enabled and show:

- For Tx frequency < 3GHz: 100s-averaged PD < FCC PD limit
- For 3GHz ≤ Tx frequency < 6GHz 60s-averaged PD < FCC PD limit
- For 24GHz < Tx frequency < 42GHz: 4s-averaged $4cm^2$PD < $10W/m^2$ FCC PD limit
- For total RF exposure in case of simultaneous PD exposures:

$$\frac{\frac{1}{T_{sub6.PD}}\int_{t-T_{sub6.PD}}^{t} sub6.PD(t)dt}{FCC\ sub6.PD_{limit}} + \frac{\frac{1}{T_{mmW.PD}}\int_{t-T_{mmW.PD}}^{t} mmW.PD(t)dt}{FCC\ mmW.PD_{limit}} \leq 1 \qquad (1)$$

where $T_{sub6.PD}$ is the time window for f < 6 GHz radio defined by regulator (for FCC, 100 seconds for f < 3 GHz; 60 seconds for $f \geq 3$ GHz); $T_{mmW.PD}$ is the time window for $f \geq 6$ GHz radio defined by regulatory (4 seconds for FCC for 24 GHz < f < 42 GHz). $FCC\ sub6.PD_{limit}$ and $FCC\ mmW.PD_{limit}$ are FCC PD limits for f < 6 GHz and $f \geq 6$ GHz as shown in Table 3-1.

Table 3-1 Applicable FCC PD limits

Frequency (GHz)	PD limit (W/m^2)
0.3 GHz ≤ f ≤ 1.5 GHz	$10 * f / 1.5$
f > 1.5 GHz	10

f is in GHz.

The following scenarios cover validation of time-averaging algorithm.

1. During a time-varying Tx power transmission: To prove that the Smart Transmit feature accounts for Tx power variations in time accurately.
2. During a call disconnect and re-establish scenario: To prove that the Smart Transmit feature accounts for history of past Tx power transmissions accurately.
3. During technology/band handover: To prove that the Smart Transmit feature functions correctly during transitions in technology/band.
4. During antenna (or mmW beam) switch: To prove that the Smart Transmit feature functions correctly during transitions in antenna (AsDiv scenario) or beams (different antenna array excitation configurations).

5. During time window switch: To prove that the Smart Transmit feature correctly handles the transition from one time window to another specified by FCC, and maintains the normalized time-averaged RF exposure to be less than FCC limit of 1.0 at all times.
6. PD exposure switching between two active radios (radio1 and radio2): To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance when exposure varies among PD_radio1 only, PD_radio1 + PD_radio2, and PD_radio2 only scenarios.

As described in Part 0 report (Ref # 1), the power density RF exposure is proportional to the conducted and/or radiated power for a PD-characterized wireless device. Thus, time-averaging algorithm validation can be effectively performed through conducted/radiated power measurement. The strategy for the validation in power measurement is outlined as follows:

<u>Conducted power / Radiated power measurement</u>:

- Measure conducted Tx power for f < 6GHz and radiated Tx power (EIRP) for f > 10GHz
- Convert it into RF exposure and divide by respective FCC limits to get normalized exposure
- Perform time-averaging over predefined time windows
- Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios 1~6;
  - For f < 6 GHz transmission only:

$$sub6.PD(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * sub6.PD\_P_{limit} \qquad (2a)$$

$$\frac{\frac{1}{T_{sub6.PD}}\int_{t-T_{sub6.PD}}^{t} PD(t)dt}{FCC\ sub6.PD_{limit}} \le 1 \qquad (2b)$$

  - For f < 6 GHz+mmW transmission:

$$sub6.PD(t) = \boxed{\frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}}} * sub6.PD\_P_{limit} \qquad (3a)$$

$$mmW.PD(t) = \boxed{\frac{radiated\_Tx\_power(t)}{radiated\_Tx\_power\_input.power.limit}} * mmW.PD\_input.power.limit \qquad (3b)$$

$$\frac{\frac{1}{T_{sub6.PD}}\int_{t-T_{sub6.PD}}^{t} PD(t)dt}{FCC\ sub6.PD_{limit}} + \frac{\frac{1}{T_{mmW.PD}}\int_{t-T_{mmW.PD}}^{t} PD(t)dt}{FCC\ mmW.PD_{limit}} \le 1 \qquad (3c)$$

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $sub6.PD\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and calculated *sub6.PD* value (based on measured P_{limit} and antenna gain) at P_{limit} for the worst-case f < 6 GHz radio configuration within the technology/band/antenna tested. Similarly, $radiated\_Tx\_power(t)$, $radiated\_Tx\_power\_input.power.limit$, and $mmW.PD\_input.power.limit$ correspond to the measured instantaneous radiated Tx power, measured radiated Tx power at *input.power.limit*, and calculated *mmW.PD* value (based on measured EIRP) at *input.power.limit*. Note all PD values in equations 1~3 are referring to point PD values. $T_{Sub6.PD}$ is the time window for f < 6 GHz radio defined by FCC; $T_{mmW.PD}$ is the time window for $f \ge 6$ GHz radio defined by FCC.

NOTE: All the PD values in equation 2 and 3 are calculated using Friis equation.

NOTE: Part 1 and Part 2 testing can be performed in parallel. The ratio circled in red square is obtained from the measurement on the radio configuration selected in this Part 2 report, while the $sub6.PD\_P_{limit}$ must be the PD at P_{limit} measured/calculated from the worst-case radio configuration within the seleted technology/band/Antenna, and *mmW.PD_input.power.limit* must be the PD value measured at *input.power.limit* under static transmission scenario.

NOTE: For CPE, typically the $f < 6$ GHz radios have P_{limit} higher than their respective P_{max} (the maximum power entered in NV) by 2.2dB. In that case, the test scenarios 1~6 can be excluded for $f < 6$ GHz radios as no power enforcement is required.

4 mmW Validation Test Plan

This chapter provides the test plan for validating Qualcomm Smart Transmit feature for mmW transmission. This EUT only supports mmW NR transmission in non-standalone mode, i.e., it requires a LTE link as anchor. For CPE that supports both non-standalone mode (NSA) and standalone mode (SA), if the validation test is performed in NSA mode, the validation for SA mode is not required as the validity of time-averaging operation described in Section 4.2.1, 4.2.2 and 4.2.3 covers the SA exposure scenario.

mmW NR callbox UL duty cycle should be configured to the highest UL duty cycle that the callbox suppports for all LTE+mmW NR Part 2 tests.

The 100 seconds time window for operating $f < 3$GHz is used as an example to detail the test procedures, the similar applies to 60 seconds time window for anchor radio operating at 3GHz $\leq f < 6$GHz.

4.1 Test sequence determination for validation

Maximum power tests are performed with the callbox requesting EUT to transmit in mmW NR 5G at maximum power all the time.

4.2 Test configuration selection criteria for validating Smart Transmit feature

4.2.1 Test configuration selection for time-varying Tx power transmission

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

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

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

4.2.3 Test configuration selection for PD exposure switch during transmission

The Smart Transmit time averaging operation is independent of the nature of exposure (PD1 vs PD2) and ensures total time-averaged RF exposure compliance. Hence, validation of Smart Transmit in any one band/mode/channel/beam for mmW + f < 6GHz (LTE) transmission is sufficient, where the exposure varies among LTE PD only, LTE PD + mmW NR PD, and mmW NR PD only scenarios.

4.3 Test procedures for radiated power measurements

This section provides general power measurement procedures to perform compliance tests under dynamic transmission scenarios selected Section 4.2. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

4.3.1 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 regulatory limit at all times (see Eq. (3a), (3b) & (3c)). Maximum power tests are performed with the callbox requesting EUT to transmit in mmW NR 5G at maximum power all the time.

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:
   a. Measure peak radiated power (i.e., peak EIRP) corresponding to mmW *input.power.limit* by setting up the CPE to transmit in desired band/channel/beam at *input.power.limit* in Factory Test Mode and rotating the CPE to the peak position. Do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.
   b. Measure conducted Tx power corresponding to LTE P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value, with EUT setup for LTE (f < 6GHz) + mmW call. First, establish LTE (f < 6GHz) connection with the callbox, and then mmW connection is added with callbox requesting CPE to transmit at maximum mmW power. 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 mmW NR PD exposure scenario (as LTE PD exposure is negligible from all-down bits). After 120s, request LTE to go all-up bits, to test the scenario where callbox is requesting CPE to transmit at maximum power on both radios (LTE and mmW NR). Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of ~300s.
3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into PD value (see Eq. (3a)) using Step 1.b result, and then divide this by regulatory PD limit (note for f < 1.5 GHz radio, low channel frequency of the band tested should be used to derive FCC PD limit) to obtain instantaneous normalized PD versus time. Perform 100s running average to determine normalized 100s-averaged PD versus time as illustrated in below Figure 4-1. Note that in Eq.(3a), instantaneous Tx power is converted into instantaneous PD value by applying the

worst-case PD value of the technology/band at P_{limit} as obtained from measured conducted power in Part 1 report (Ref # 2 for frequecies <6GHz and Ref # 3 for frequecies >6GHz).

Time	Power
t_1	p_{t1}
t_2	p_{t2}
:	:
:	:
t_n (t_1+100s)	p_{tn}
t_{n+1} (t_2+100s)	p_{tn+1}
:	:

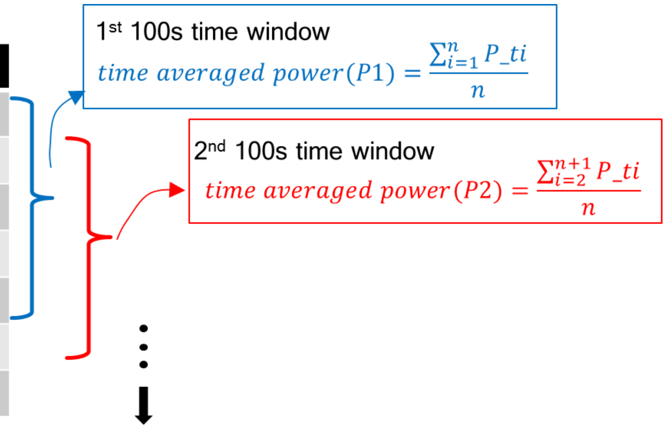


Figure 4-1 100s running average illustration

4. Similarly, convert the radiated Tx power for mmW into PD value (see Eq. (3b)) using Step 1.a result, and then divide this by FCC PD limit of 10W/m^2 to obtain instantaneous normalized PD versus time. Perform 4s running average to determine normalized 4s-averaged PD versus time as illustrated in Figure 4-1. Note that in Eq.(3b), instantaneous Tx power is converted into instantaneous PD by applying the calculated point PD value (based on peak EIRP measured in Step 1.a) for the selected band/beam at *input.power.limit*.
5. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, and (b) instantaneous radiated Tx power for mmW versus time, as measured in Step 2.
6. Make another plot containing: (a) instantaneous normalized PD for LTE versus time determined in Step 3, (b) computed normalized 100s-averaged PD versus time determined in Step 3, (c) instantaneous normalized PD for mmW versus time determined in Step 4, (d) computed normalized 4s-averaged PD versus time determined in Step 4, and (e) corresponding total normalized time-averaged RF exposure (sum of steps (b) and (d)) versus time.

The validation criteria is, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.e shall not exceed the normalized limit of 1.0.

NOTE: In this section, point PD should be used in all the conversions.

4.3.2 Switch in PD exposure during transmission

This test is to demonstrate that Smart Transmit feature is independent of the nature of exposure (PD vs. PD), accurately accounts for switching in exposures among LTE PD only, LTE PD + mmW NR PD, and mmW NR PD only scenarios, and ensures total time-averaged RF exposure compliance (see Eq. (3a), (3b) & (3c).

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:

   a. Measure peak radiated power (i.e., peak EIRP) corresponding to mmW *input.power.limit* by setting up the CPE to transmit in desired band/channel/beam at *input.power.limit* in Factory Test Mode and rotating the CPE to the peak position. Do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.
   b. Measure conducted Tx power corresponding to LTE P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value, with EUT setup for LTE (f < 6GHz) + mmW call. First, establish LTE (f < 6GHz) connection with the callbox, and then mmW connection is added with callbox requesting CPE to transmit at maximum mmW power. 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 mmW NR PD exposure scenario (as LTE PD exposure is negligible from all-down bits). After 120s, request LTE to go all-up bits, to test the scenario where callbox is requesting maximum power on both radios (LTE and mmW NR). After 100s, request LTE to go all-down bits, to resume predominantly mmW exposure scenario. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of ~300s.
3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into PD value (see Eq. (3a)) using Step 1.b result, and then divide this by regulatory PD limit (for this band) to obtain instantaneous normalized PD versus time. Perform 100s running average to determine normalized 100s-averaged PD versus time as illustrated in Figure 4-1. Note that in Eq.(3a), instantaneous Tx power is converted into instantaneous PD value by applying the worst-case PD value of the technology/band at P_{limit} as obtained from measured conducted power in Part 1 report (Ref # 2 for frequecies <6GHz and Ref # 3 for frequecies >6GHz).
4. Similarly, convert the radiated Tx power for mmW into PD value (see Eq. (3b)) using Step 1.a result, and then divide this by regulatory PD limit of $10W/m^2$ to obtain instantaneous normalized PD versus time. Perform 4s running average to determine normalized 4s-averaged PD versus time as illustrated in Figure 4-1. Note that in Eq.(3b), instantaneous Tx power is converted into instantaneous PD by applying the calculated point PD value (based on peak EIRP measured in Step 1.a) for the selected band/beam at *input.power.limit*.
5. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, and (b) instantaneous radiated Tx power for mmW versus time, as measured in Step 2.
6. Make another plot containing: (a) instantaneous normalized PD for LTE versus time determined in Step 3, (b) computed normalized 100s-averaged PD for LTE versus time determined in Step 3, (c) instantaneous PD for mmW versus time determined in Step 4, (d) computed normalized 4s-averaged PD for mmW NR versus time determined in Step 4, and (e) corresponding total normalized time-averaged RF exposure (sum of steps (b) and (d)) versus time.

The validation criteria is, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.e shall not exceed the normalized limit of 1.0.

NOTE: In this section, point PD should be used in all the conversions.

4.3.3 Change in antenna configuration/beam

This test is to demonstrate the correct power control by Smart Transmit during changes in antenna configuration/beam. As described in Section 2, the *input.power.limit* varies with beam within a given mmW band, the instantaneous Tx power for a given beam could be converted into PD exposure using Eq. (3b). Thus, the equation (3) in Section 3 can be written as below for transmission scenario having change in beam,

$$LTE.PD(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * LTE.PD\_P_{limit} \tag{4a}$$

$$mmW.PD_1(t) = \frac{radiated\_Tx\_power\_1(t)}{radiated\_Tx\_power\_input.power.limit\_1} * mmW.PD\_input.power.limit\_1 \tag{4b}$$

$$mmW.PD_2(t) = \frac{radiated\_Tx\_power\_2(t)}{radiated\_Tx\_power\_input.power.limit\_2} * mmW.PD\_input.power.limit\_2 \tag{4c}$$

$$\frac{\frac{1}{T_{PD\_LTE}}\int_{t-T_{PD\_LTE}}^{t} LTE.PD(t)dt}{LTE\_PD_{limit}} + \frac{\frac{1}{T_{PD\_mmW}}\left[\int_{t-T_{PD\_mmW}}^{t_1} mmW.PD_1(t)dt + \int_{t-T_{PD\_mmW}}^{t} mmW.PD_2(t)dt\right]}{mmW\_PD_{limit}} \leq 1 \tag{4d}$$

where, *radiated_Tx_power_1(t)*, *radiated_Tx_power_input.power.limit_1(t)*, and *mmW.PD_input.power.limit_1* correspond to the measured instantaneous radiated Tx power, measured radiated Tx power at *input.power.limit* and calculated *mmW.PD* value (based on measured EIRP) of beam1 at *input.power.limit_1*; *radiated_Tx_power_2(t)*, *radiated_Tx_power_input.power.limit_2(t)*, and *mmW.PD_input.power.limit_2* correspond to the measured instantaneous radiated Tx power, measured radiated Tx power at *input.power.limit* and calculated *mmW.PD* value (based on measured EIRP) of beam2 at *input.power.limit_2*. Transition from first beam to the second beam happens at time-instant 't_1'.

Test procedure:

1. Set *Reserve_power_margin* to actual (intended) value, with EUT setup for LTE (f < 6GHz) + mmW call. First, establish LTE (f < 6GHz) connection with the callbox, and then mmW connection in beam 1 is added with callbox requesting CPE to transmit at maximum mmW power. As soon as the mmW connection is established, request all-down bits on LTE link. After 120s, request the CPE to change from beam 1 to beam 2. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of ~300s. Do not disturb the position of the EUT inside the anechoic chamber to perform Step 2.a measurement below.
2. 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 for tested beam 1 and beam 2 in Step 1. Test condition to measure conducted P_{limit} and radiated *input.power.limit* is:
   a. At the tested angle in Step 1, measure radiated power corresponding to mmW *input.power.limit* by setting up the CPE to transmit in desired band/channel/beam_1 at *input.power.limit* in Factory Test Mode. Repeat this step for beam_2.
   b. Rotate the CPE to the peak angle to measure maximum radiated power (i.e., peak EIRP) corresponding to mmW *input.power.limit* by setting up the CPE to transmit in desired band/channel/beam_1 at *input.power.limit* in Factory Test Mode. This value corresponds to $radiated\_Tx\_power\_input.power.limit\_1$ in Eq.(4b). Repeat this Step for beam_2 as well.
   c. Based on this peak EIRP value in Step 2.b, calulate mmW point PD value $mmW.PD\_input.power.limit\_1$ for beam_1. Repeat this Step for beam_2 as well.

d. 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.

3. From the measurement in Step 1, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into PD value (see Eq. (4a)) using Step 2.d result, and then divide this by regulatory PD limit (for this frequency band) to obtain instantaneous normalized PD versus time. Perform 100s running average to determine normalized 100s-averaged PD versus time as illustrated in Figure 4-1. Note that in Eq.(4a), instantaneous Tx power is converted into instantaneous PD value by applying the worst-case PD value of the technology/band at P_{limit} as obtained in Part 1 report (Ref # 2 for frequecies <6GHz and Ref # 3 for frequecies >6GHz).

4. Similarly, convert instantaneous radiated Tx power versus time for beam_1 in Step 1 at tested angle into peak angle by dividing with measured value in Step 2.a and multiplying by value in Step 2.b corresponding to beam_1 to determine "$radiated\_Tx\_power\_1(t)$" versus time. Similarly, repeat this Step for beam_2 to determine "$radiated\_Tx\_power\_2(t)$"

5. Convert the $radiated\_Tx\_power(t)$ for beam_1 and beam_2 in Step 4 into PD value (see Eq. (4b) & (4c)) using the corresponding Step 2.b results and calculated mmW PD value at input.power.limit obtained in Step 2.c, and then divide this by regulatory PD limit of $10W/m^2$ to obtain instantaneous normalized PD versus time. Perform 4s running average to determine normalized 4s-averaged PD versus time as illustrated in Figure 4-1.

6. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time as measured in Step 1, and (b) instantaneous radiated Tx power for mmW versus time, as computed in Step 4.

7. Make another plot containing: (a) instantaneous normalized PD for LTE versus time determined in Step 3, (b) computed normalized 100s-averaged PD for LTE versus time determined in Step 3, (c) instantaneous normalized PD for mmW versus time determined in Step 5, (d) computed normalized 4s-averaged PD for mmW versus time determined in Step 5, and (e) corresponding total normalized time-averaged RF exposure (sum of steps (b) and (d)) versus time.

The validation criteria is, at all times, the total normalized time-averaged RF exposure versus time determined in Step 7.e shall not exceed the normalized limit of 1.0.

NOTE: In this section, point PD should be used in all the conversions.

5 Test Configurations

5.1 Sub-6 transmission

Based on Part 0 report (Ref # 1) and Part 1 report (Ref# 2) , as indicated in Table 2-1, this EUT has the P_{limit} higher than P_{max} by 5.8dB or more for all f < 6GHz radios. Therefore the validation for *f* < 6GHz radios is not required.

5.2 *f* < 6GHz radio + mmW NR transmission

Based on the selection criteria described in Section 4.2, the selections for validation test are listed in Table 5-1, and the test configuration is listed in Table 5-2.

Table 5-1 Selections for sub-6+mmW validation measurements

Transmission Scenario	Test	Technology and Band	mmW Beam
Time-varying power test	Cond. & Rad. Power meas.	LTE Band 2 and mmW band n261	Beam ID 21
Switch in PD exposure	Cond. & Rad. Power meas.		Beam ID 21
Antenna beam switch test	Cond. & Rad. Power meas.		Beam ID 21 to Beam ID 0
Time-varying power test	Cond. & Rad. Power meas.	LTE Band 2 and mmW band n260	Beam ID 21
Switch in PD exposure	Cond. & Rad. Power meas.		Beam ID 21
Antenna beam switch test	Cond. & Rad. Power meas.		Beam ID 21 to Beam ID 2

Table 5-2 Test configuration for LTE + mmW NR validation

Tech	Band	Waveform	Channel	RB/Offset	Freq (MHz)	Mode	Bandwidth (MHz)	UL Duty Cycle
LTE	B2	--	18900	12/12	1880	QPSK	10	100%
mmW NR	N261	CP-OFDM	2077891	22/22	27924	QPSK	100	66%
mmW NR	N260	CP-OFDM	2254147	22/22	38499	QPSK	100	66%

6 Radiated Power Measurement for mmW Smart Transmit Feature Validation

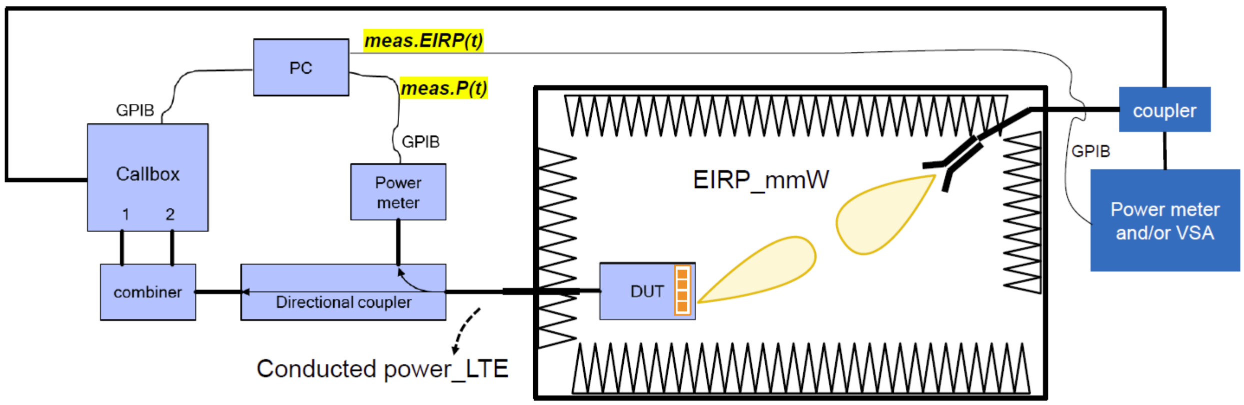
6.1 Measurement Setup

The Keysight Technologies E7515B UXM 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 EUT (CPE MTP) is shown in Figure 6-1b (see Appendix B for missing figures). 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. 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 6-1a. 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 6-1 is used for time-averaging validation test scenarios in Sections 4.2.1, 4.2.2 and 4.2.3. All the path losses from the EUT to the power meters are calibrated (listed in Table 6-1) and used as offset in the power meter.

FIGURE

(a)



(b)

Figure 6-1 Radiated power measurement setup

Table 6-1 Path loss in conducted power measurement setup

Frequency (GHz)	Power Meter Path Loss (dB)
1.88	14.3 dB
28	67.4 dB
39	71.4 dB

Both the callbox and power meters are connected to the PC using USB cables. Test scripts are custom made for automation of establishing mmW call (with LTE in all-up bits), for LTE conducted Tx power recording and for mmW radiated Tx power recording. These tests are manually stopped after desired time duration. Once the mmW link is established, LTE Tx power is manually toggled between all-up and all-down bits on the callbox, and also beam switch command is sent manually to the EUT via USB connection. For all the tests, the callbox is set to request maximum Tx power from EUT all the time.

Power meter readings are periodically recorded every 10ms on both NR8S and NR50S power sensors. A running average of this measured conducted Tx power over 100 seconds (i.e., 10000 data points collected with 10ms sampling rate) is performed in the post-data processing to determine the 100s-time averaged power for LTE. Similarly, a running average of radiated Tx power over 4 seconds (i.e., 400 data points collected with 10ms sampling rate) is performed in the post-data processing to determine the 4s-time averaged power for mmW.

Test configurations for this validation are listed in Table 5-1. Test procedures are described in Sections 4.3.1, 4.3.2 and 4.3.3. Conducted Tx power of LTE B2 is converted by applying the worst-case PD value for LTE Band 2 based on conducted power measurements at P_{limit} as obtained in Table 3-2 of Part 1 report (Ref # 2 for frequecies <6GHz and Ref # 3 for frequecies >6GHz) and copied in Table 6-2 below.

Table 6-2 Worst-case PD exposure for LTE Band 2

Tech	Band	Measured worst-case P_{limit} * (dBm)	Worst-case PD (W/m^2)	FCC limit (W/m^2)
LTE	Band 2	23dBm	1.02 (calculated using 4.1dB antenna gain listed in Ref # 1)	10

* This value corresponds to measured worst-case P_{max} if $P_{limit} > P_{max}$.

** FCC PD limit for f < 1.5 GHz radio = 10**f*/1.5, where f is in GHz and the low channel frequency of the band should be used for conservativeness.

Similarly, peak radiated power (i.e., peak EIRP) of mmW Band n261 is converted into maximum point PD, $pointPD_{max}$, at *input.power.limit*, and listed in Table 6-3.

Table 6-3 Worst-case PD exposure for mmW Band n261

Tech	Band	Beam ID	*input.power.limit* (dBm)	Measured EIRP** (dBm) at input.power.limit	Calculated $pointPD_{max}$ (W/m^2)	FCC limit (W/m^2)
mmW NR	N261	21	-2.3	31.5	2.81	10
		0	15.6* (tested at 4.9 dBm maximum input power)	21.7	0.29	10
	N260	21	-5.6	29.7	1.86	10
		2	12.3* (tested at 3.0 dBm maximum input power)	20.3	0.21	10

* This *input.power.limit* > maximum input power of 4.9 dBm (n261) and 3.0 dBm (n260) limited for this CPE by OEM

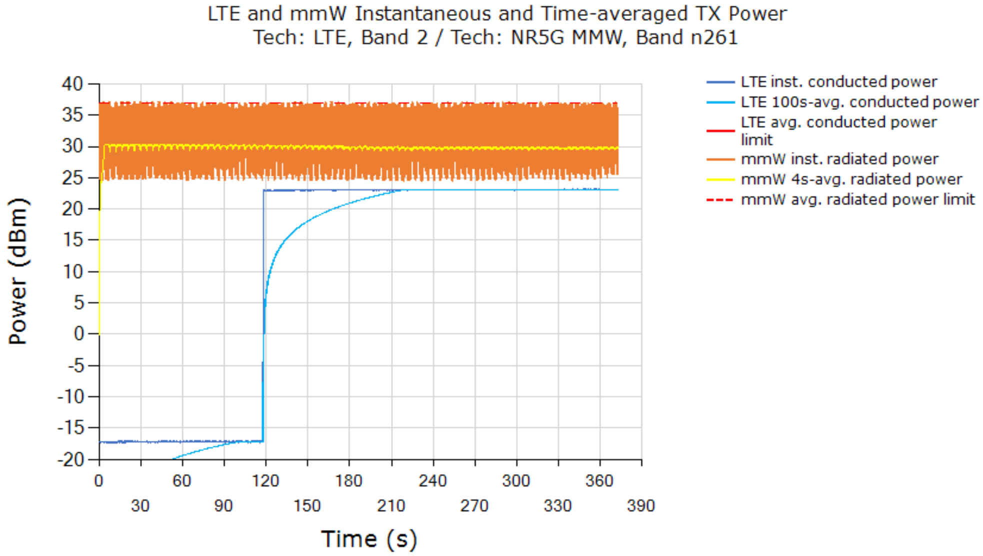
** Measured EIRP theoretically should correspond to "minimum (*input.power.limit*, maximum input power) + array gain" within device uncertainty. However, it can be lower due to thermal reason as prolonged testing of CPE at high power will lower the PA efficiency. Lower measured EIRP will directly result in lower calculated $pointPD_{max}$.

6.2 Maximum transmit power measurement results

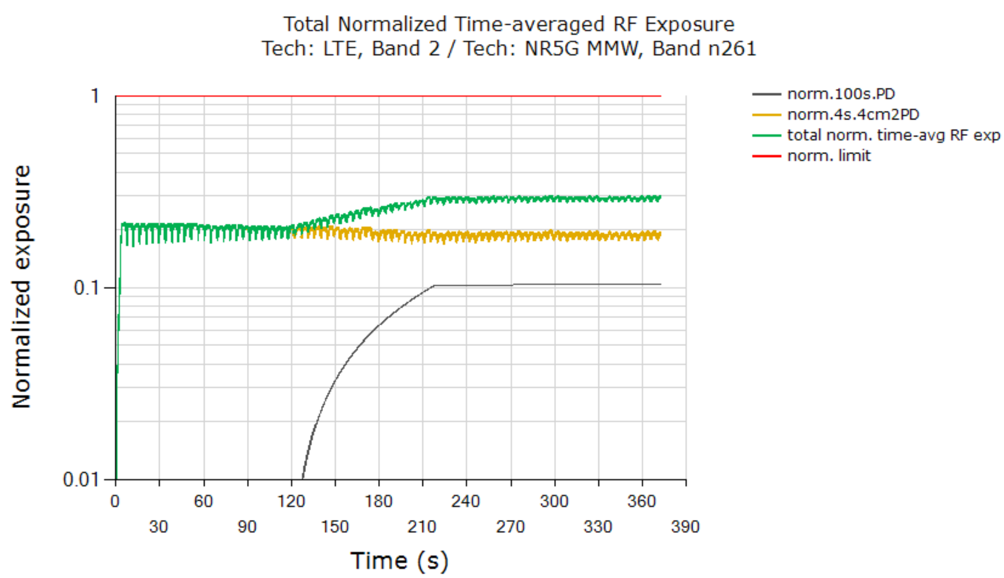
6.2.1 Maximum transmit power measurement results for n261

This test was measured with LTE Band 2 and mmW Band n261 Beam ID 21, by following the detailed test procedure is described in Section 4.3.1. Note that the mmW call was placed with the UXM callbox at 66% UL duty cycle.

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 time-averaged conducted Tx power for LTE B2 and radiated Tx power for mmW NR n261 beam 21are converted into time-averaged PD using (3b) which is divided by FCC corresponding PD limit of 10 W/m^2 to obtain normalized exposures versus time. Below plot shows (a) normalized time-averaged PD_{LTE} versus time, (b) normalized time-averaged PD_{mmW} versus time, (c) sum of normalized time-averaged PD_{LTE} and normalized PD_{mmW} :



FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.305
Validated	

Plot notes: 5G mmW NR call was established at ~0s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, this corresponds to a normalized PD exposure value for Beam ID 21 of (85% * $pointPD_{max}$)/(10 W/m^2) = (85% * 2.81 W/m^2)/(10 W/m^2) = 23.9% ± 2.64dB† device related uncertainty (see green/orange curve between 10s~130s). At ~130s time mark, LTE is set to all-up bits. From Table 6-2, the maximum contribution from LTE (black curve) transmitting at maximum power corresponds to the maximum normalized LTE PD exposure of (1.02 W/m^2)/(10 W/m^2) = 10.2% ± 1.0dB design related uncertainty (see black curve above 210s time mark).

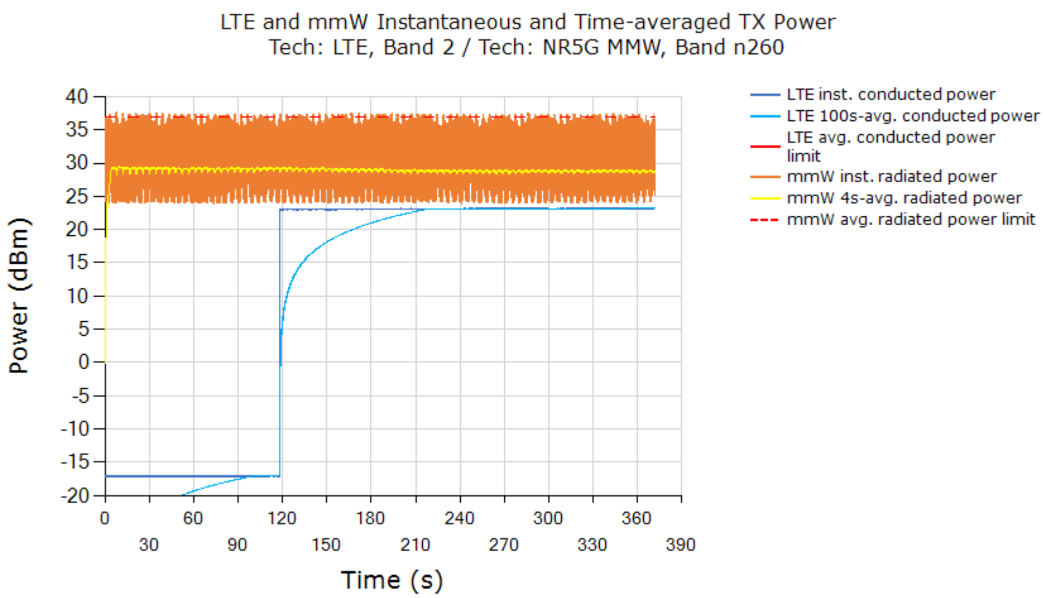
As can be seen, the total normalized time-averaged RF exposure (green curve) does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

† Total uncertainty for n261 (2.5dB module level uncertainty + 1.16dB device level uncertainty) from [Ref #1]

6.2.2 Maximum transmit power measurement results for n260

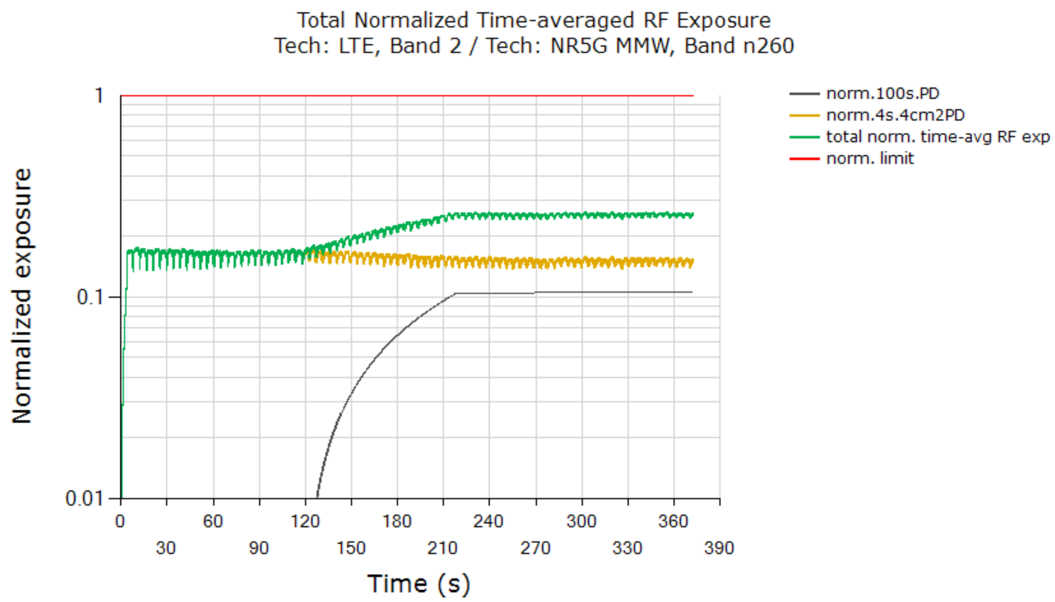
This test was measured with LTE Band 2 and mmW Band n260 Beam ID 21, by following the detailed test procedure is described in Section 4.3.1. Note that the mmW call was placed with the UXM callbox at 66% UL duty cycle.

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 time-averaged conducted Tx power for LTE B2 and radiated Tx power for mmW NR n260 beam 21are converted into time-averaged PD using (3b) which is divided by FCC corresponding PD limit 10 W/m^2 to obtain normalized exposures versus time. Below plot shows

(a) normalized time-averaged PD_{LTE} versus time, (b) normalized time-averaged PD_{mmW} versus time, (c) sum of normalized time-averaged PD_{LTE} and normalized PD_{mmW} :



FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.265
Validated	

Plot notes: 5G mmW NR call was established at ~0s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, this corresponds to a normalized PD exposure value for Beam ID 21 of (85% * $pointPD_{max}$)/(10 W/m^2) = (85% * 1.86 W/m^2)/(10 W/m^2) = 15.8% ± 3.44dB† device related uncertainty (see green/orange curve between 10s~130s). At ~130s time mark, LTE is set to all-up bits. From Table 6-2, the maximum contribution from LTE (black curve) transmitting at maximum power corresponds to the maximum normalized LTE PD exposure of (1.02 W/m^2)/(10 W/m^2) = 10.2% ± 1.0dB design related uncertainty (see black curve above 210s time mark).

As can be seen, the total normalized time-averaged RF exposure (green curve) does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

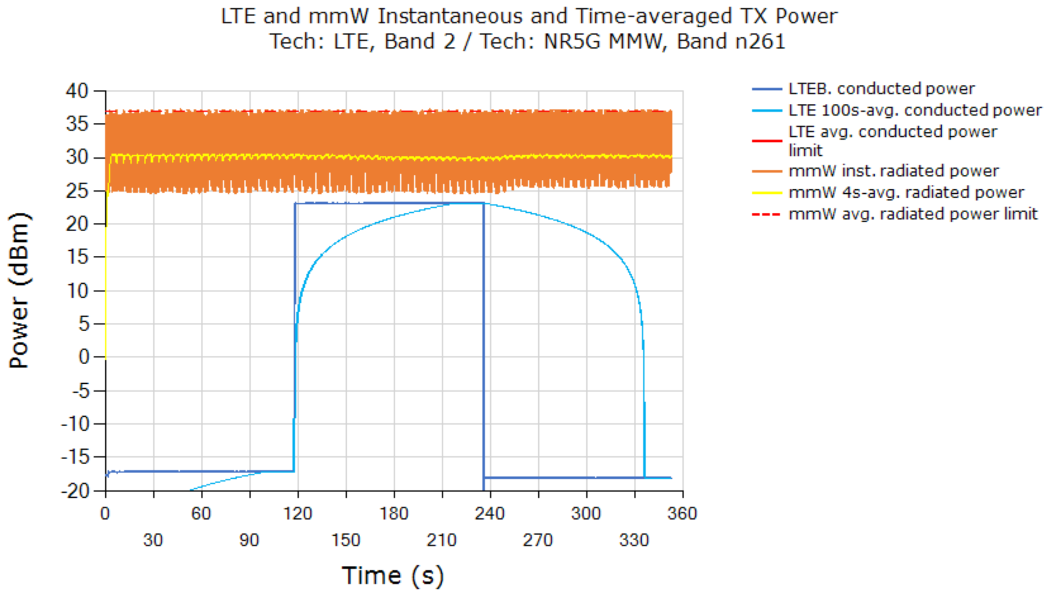
† Total uncertainty for n260 (3.3dB module level uncertainty + 1.46dB device level uncertainty) from [Ref #1]

6.3 Switch in LTE PD vs. mmW PD exposure measurement results

6.3.1 Switch in LTE PD vs. mmW PD exposure measurement results for n261

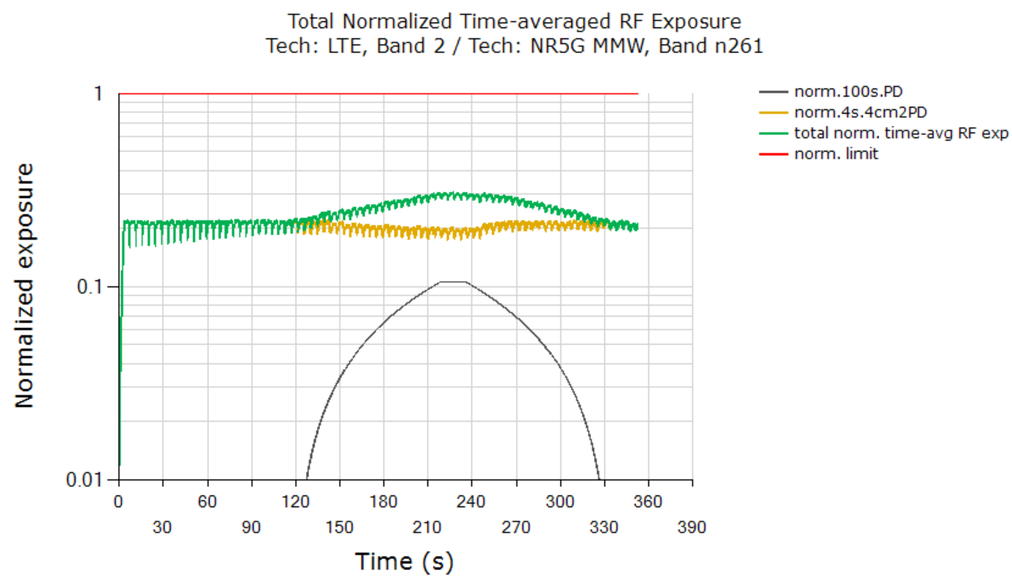
This test was measured with LTE Band 2 and mmW Band n261 Beam ID 21, by following the detailed test procedure is described in Section 4.3.2. Note that the mmW call was placed with the UXM callbox at 66% UL duty cycle.

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 is predominantly instantaneous mmW PD exposure between 0s ~ 120s, it is instantaneous LTE PD + mmW NR PD exposure between 120s ~ 240s. Since the maximum LTE PD exposure is only 10.2% of total exposure (see Table 6-2, (1.02W/m^2/10 W/m^2)), it is predominantly instantaneous mmW NR exposure above 240s.

Normalized time-averaged exposures for LTE and mmW NR, 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)	0.310
Validated	

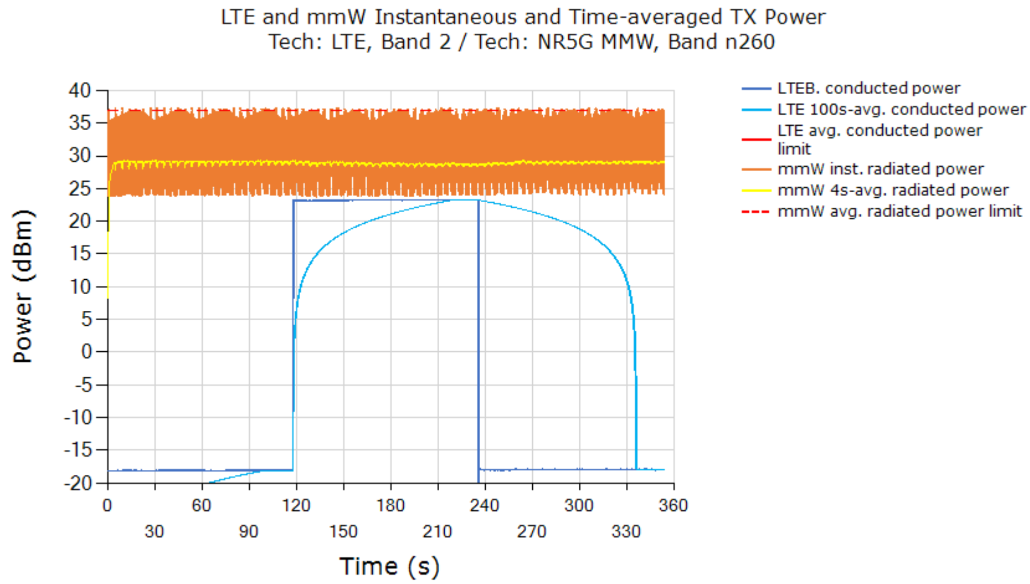
Plot notes: 5G mmW NR call was established at ~0s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, this corresponds to a normalized PD exposure value for Beam ID 21 of (85% * $pointPD_{max}$)/(10 W/m^2) = (85% * 2.81 W/m^2)/(10 W/m^2) = 23.9% ± 2.64dB device related uncertainty (see green/orange curve between 0s~120s). At ~120s time mark, LTE is set to all-up bits, and at ~240s time mark, LTE is set to all-down bits. The calculated maximum RF exposure from LTE (black curve) corresponds to normalized PD exposure value of (100%*1.02W/m^2)/(10 W/m^2) = 10.2% ± 1.0dB design related uncertainty (note that this level will be achieved by black curves if LTE remains in all-up bits for longer time duration which was already demonstrated in maximum Tx power test in Section 6.2).

As can be seen, the total normalized time-averaged RF exposure (green curve) does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging feature is validated.

6.3.2 Switch in LTE PD vs. mmW PD exposure measurement results for n260

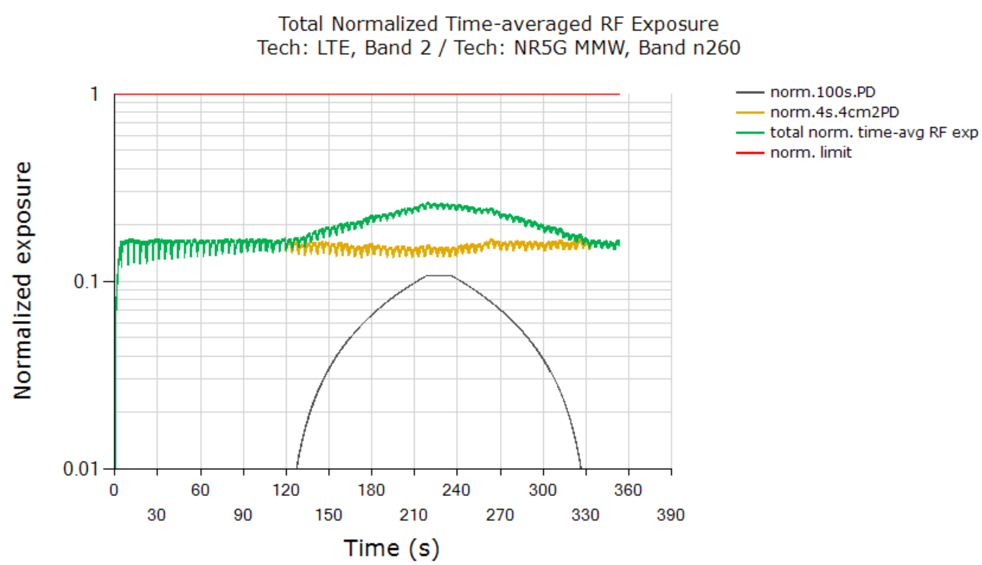
This test was measured with LTE Band 2 and mmW Band n260 Beam ID 21, by following the detailed test procedure is described in Section 4.3.2. Note that the mmW call was placed with the UXM callbox at 66% UL duty cycle.

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 is predominantly instantaneous mmW PD exposure between 0s ~ 120s, it is instantaneous LTE PD + mmW NR PD exposure between 120s ~ 240s. Since the maximum LTE PD exposure is only 10.2% of total exposure (see Table 6-2, (1.02W/m^2/10 W/m^2)), it is predominantly instantaneous mmW NR exposure above 240s.

Normalized time-averaged exposures for LTE and mmW NR, 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)	0.263
Validated	

Plot notes: 5G mmW NR call was established at ~0s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, this corresponds to a normalized PD exposure value for Beam ID 21 of (85% * $pointPD_{max}$)/(10 W/m^2) = (85% * 1.86 W/m^2)/(10 W/m^2) = 15.8% ± 3.44dB device related uncertainty (see green/orange curve between 0s~120s). At ~120s time mark, LTE is set to all-up bits, and at ~240s time mark, LTE is set to all-down bits. The calculated maximum RF exposure from LTE (black curve) corresponds to normalized PD exposure value of (100%*1.02W/m^2)/(10 W/m^2) = 10.2% ± 1.0dB design related uncertainty (note that this level will be achieved by black curves if LTE remains in all-up bits for longer time duration which was already demonstrated in maximum Tx power test in Section 6.2).

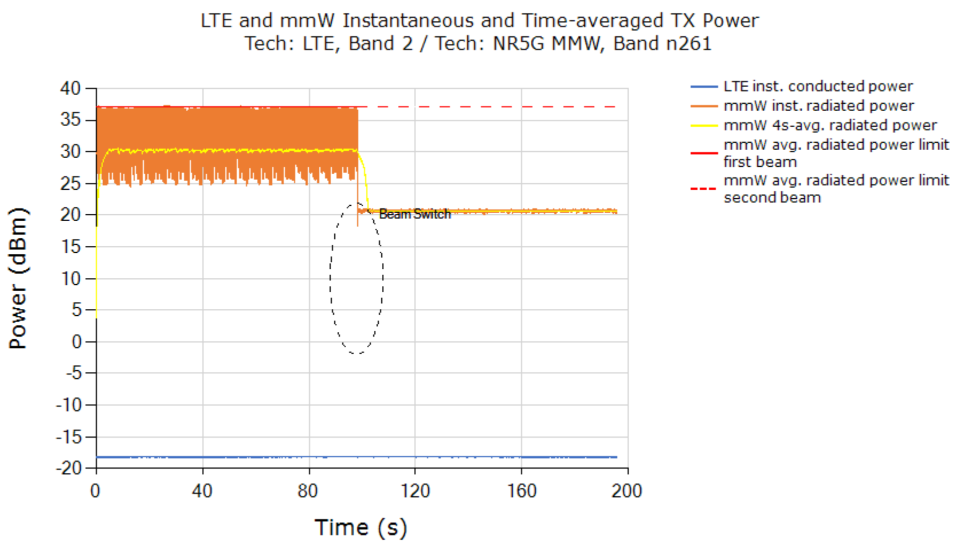
As can be seen, the total normalized time-averaged RF exposure (green curve) does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging feature is validated.

6.4 Change in Beam measurement results

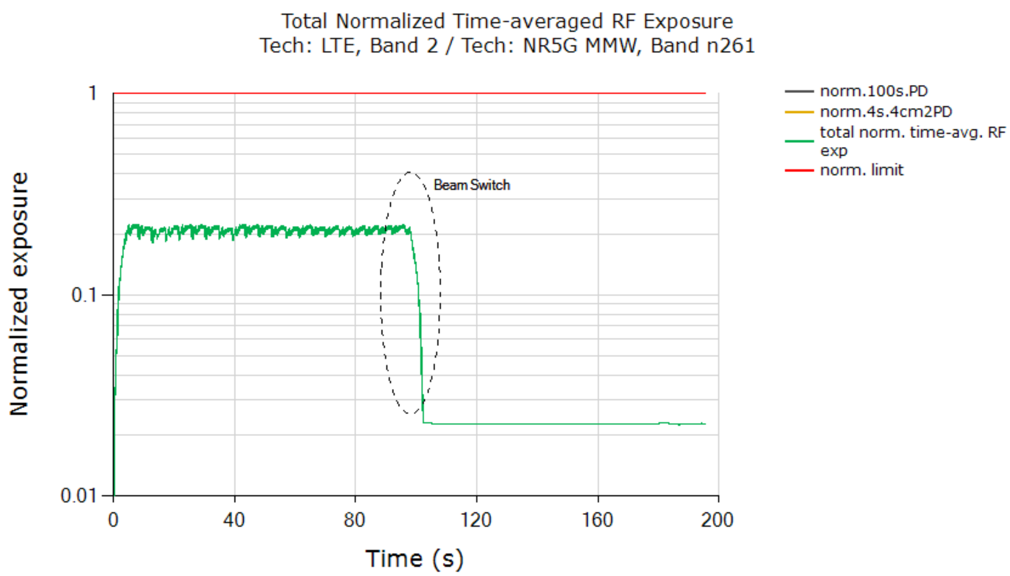
6.4.1 Change in Beam measurement results for n261

This test was measured with LTE Band 2 and mmW Band n261, with beam switch from Beam ID 21 to Beam ID 0, by following the test procedure is described in Section 4.3.3.

Instantaneous conducted LTE Tx power versus time, instantaneous and 4s-averaged radiated mmW Tx power versus time, time-averaged radiated mmW Tx power limits for Beam ID 21 and Beam ID 0:



Normalized time-averaged exposures for LTE and mmW, 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)	0.224
Validated	

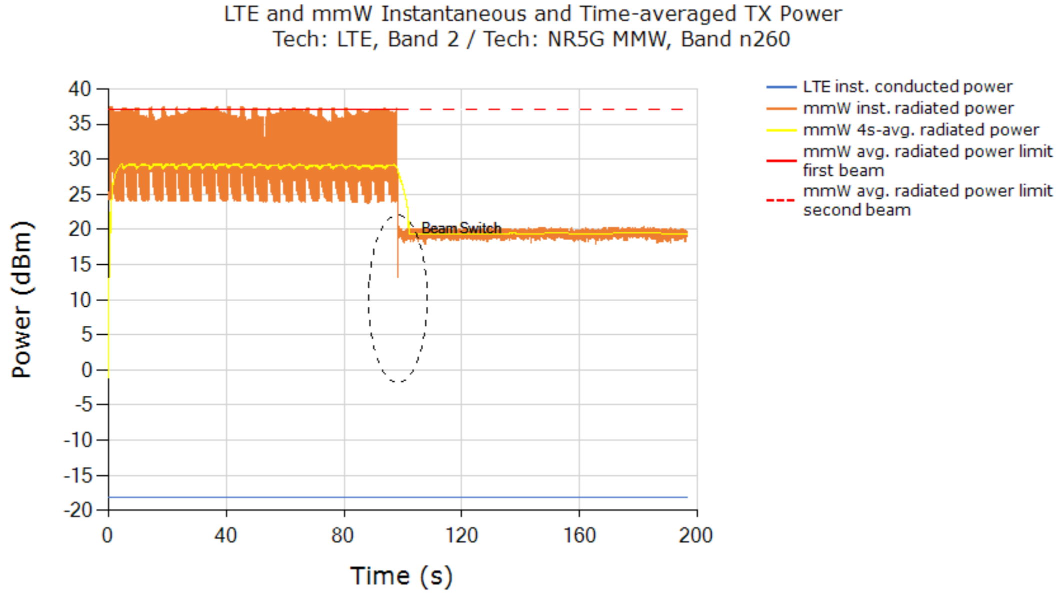
Plot notes: 5G mmW NR call was established at ~0s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. For the rest of this test, mmW exposure is the dominant contributor as LTE is left in all-down bits. Here, Smart Transmit feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, exposure between 0s ~100s corresponds to a normalized PD exposure value for Beam ID 21 of (85% * 2.81 W/m^2)/(10 W/m^2) = 23.9% ± 2.64dB device related uncertainty. At ~100s time mark, beam was switched to Beam ID 0 resulting in a normalized PD exposure value of (66%† * $pointPD_{max}$)/(10 W/m^2)= 1.9% ± 2.64dB device related uncertainty. Additionally, during the switch, the ratio between the averaged radiated powers of the two beams (yellow curve) should correspond to the difference in EIRPs measured at each corresponding *input.power.limit* for these beams listed in Table 6-3, i.e., 9.8dB ± 2.64dB device uncertainty.

† Since *input.power.limit* > maximum input power supported by SDX55/QTM527-1 for this beam (see Table 6-2), RF exposure will be limited to the UL duty cycle of this test, i.e., the mmW call was placed with the UXM callbox at 66% UL duty cycle.

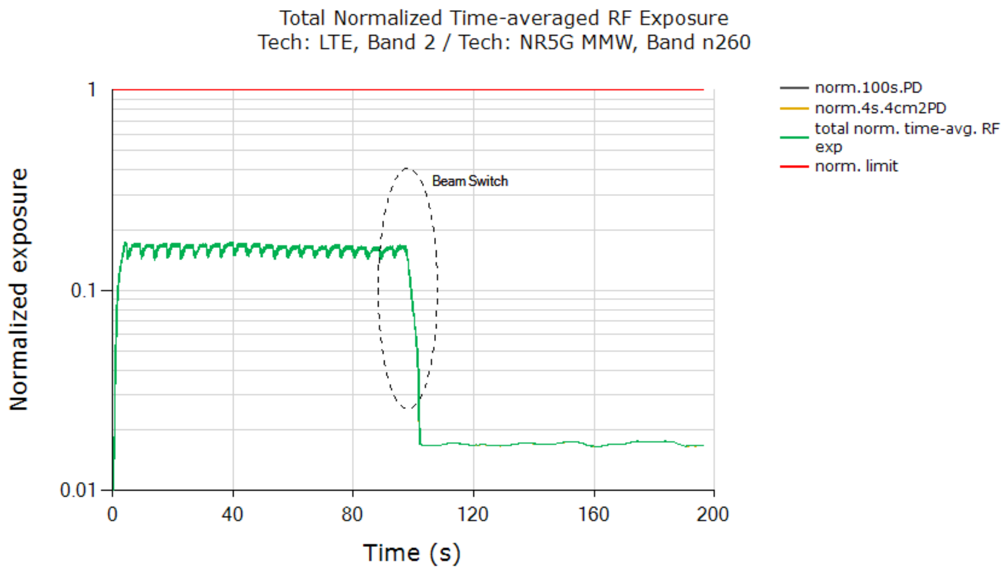
6.4.2 Change in Beam measurement results n260

This test was measured with LTE Band 2 and mmW Band n260, with beam switch from Beam ID 21 to Beam ID 2, by following the test procedure is described in Section 4.3.3.

Instantaneous conducted LTE Tx power versus time, instantaneous and 4s-averaged radiated mmW Tx power versus time, time-averaged radiated mmW Tx power limits for Beam ID 21 and Beam ID 2:



Normalized time-averaged exposures for LTE and mmW, 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)	0.173
Validated	

Plot notes: 5G mmW NR call was established at ~0s 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 feature allocates a maximum of 85% for mmW (based on the EFS settings for this CPE). From Table 6-3, exposure between 0s ~100s corresponds to a normalized PD exposure value for Beam ID 21 of (85% * 1.86 W/m^2)/(10 W/m^2) = 15.8% ± 3.44dB device related uncertainty. At ~100s time mark, beam was switched to Beam ID 2 resulting in a normalized PD exposure value of (66%† *$pointPD_{max}$)/(10 W/m^2)= 1.41% ± 3.44dB device related uncertainty. Additionally, during the switch, the ratio between the averaged radiated powers of the two beams (yellow curve) should correspond to the difference in EIRPs measured at each corresponding *input.power.limit* for these beams listed in Table 6-3, i.e., 9.4dB ± 3.44dB device uncertainty.

† Since *input.power.limit* > maximum input power supported by SDX55/QTM527-1 for this beam (see Table 6-2), RF exposure will be limited to the UL duty cycle of this test, i.e., the mmW call was placed with the UXM callbox at 66% UL duty cycle.

7 Conclusions

Qualcomm Smart Transmit employed in Qualcommm CPE has been validated through the conducted/radiated power measurement as demonstrated in this Part 2 report.

With the combination of Ref # 4 summary report, Part 0 report (Ref # 1), Part 1 report (Ref # 2 for frequecies <6GHz and Ref # 3 for frequecies >6GHz)and this 80-W5681-12 Part 2 report, it can be concluded that the time-averaged RF exposure from Qualcomm CPE is compliant with the FCC limits in all transmission scenarios for all the supported radios.

A Test Equipment

Table A-1 Measurement Equipment

Equipment	S/N	Qualcomm Asset Tag #	Calibration date
Keysight E7760B	US58410105 ATO-11686	UC0137135	NA*
Keysight M1740-A	M1740A MY58270247 ATO-5528	UC0137925	NA*
Keysight CTAR mmW chamber Z2160A-178-430	US59390152	UC0513238	11/20/2019
Horn antenna SAGE WR-28 SAR-2013-282F-E2	15220-10	Part of CATR system	Part of CATR system
Rohde & Schwarz NR-50S Power meter	ID 1419.00087K02-101165-XW	UC0152605	11/26/2019
Rohde & Schwarz NR-50S Power meter	ID 1419.00087K02-101086-qk	UC0137281	1/15/2020

*ISO calibration not available for mmW NR from callbox vendor. Absolute measurement for mmW power was collected using power meter during this testing.

B Test Setup Photos