APPENDIX E: MULTI-TX AND ANTENNA SAR CONSIDERATIONS

1 Introduction

The following procedures adopted from FCC KDB Publication 447498 D04v01 are applicable to devices with built in unlicensed transmitters such as 802.11 and Bluetooth devices which may simultaneously transmit with the licensed transmitter."

2 Simultaneous Transmission Procedures

This device contains transmitters that may operate simultaneously. Therefore, simultaneous transmission analysis is required. Per FCC KDB Publication 447498 D04v01 and IEEE 1528-2013 Section 6.3.4.1.2, simultaneous transmission SAR test exclusion may be applied when the sum of the 1g SAR for all the simultaneous transmitting antennas in a specific a physical test configuration is ≤1.6 W/kg. The different test positions in an exposure condition may be considered collectively to determine SAR test exclusion according to the sum of 1g or 10g SAR.

This device is enabled with Qualcomm® FastConnect with pre-defined sub6 antenna groups (AG0 and AG1) for WLAN and Qualcomm® Smart Transmit Gen2 with 1 Antenna Group for WWAN. Simultaneous transmission analysis is performed per antenna groups. Below analysis demonstrates the mutually exclusive operation of AG0 and AG1 and the compliance between each antenna group, WWAN, and BT

When operating in the same antenna group, Qualcomm Smart Transmit algorithm in WWAN directly adds the time-averaged RF exposure from 4G and time-averaged RF exposure from 5G NR. Smart Transmit algorithm controls the total RF exposure from both 4G and 5G NR to not exceed FCC limit and FastConnect algorithm controls the total RF exposure from WLAN to not exceed FCC limit. Therefore, simultaneous transmission compliance between 4G+5G operations and WLAN operations within an antenna group is demonstrated in the Part 2 Report during algorithm validation.

3 Sub6 Antenna Groups

The 2nd generation of Smart Transmit (GEN2) operates based on pre-defined sub6 antenna groups (AG). Sub6 Tx antennas in the device are grouped based on spatial variation of RF exposure distributions, where the RF exposure of one AG is mutually exclusive from other AG. This is accomplished by demonstrating either of below conditions for all exposure scenarios:

a) Sum of SAR of one antenna from each of the sub6 AGs and the RF exposure from radios outside Smart Transmit is less than regulatory limits. This condition must be demonstrated for all antenna combinations of sub6 AGs.

(or)

b) Every antenna from each sub6 AG meets SPLSR criteria (Section 4.3.2(c) in FCC KDB 447498 D04) with every antenna from another sub6 AG. This criteria must be demonstrated for all antenna combinations for each pair of AGs.

This device supports one WWAN AG having 6 antennas (1, 2, 3, 4, 5, 6) using Qualcomm's Smart Transmit, two WLAN AG: AG0 and AG1, with AG0 having 1 antenna (Chain 0) and AG1 having 1 antenna (Chain 1) using Qualcomm's FastConnect, and two BT antennas outside of TAS. The conditions are verified through the following criteria:

i) (SAR1 + SAR2 criteria): If SPLSR criteria is not used, then the highest reported SAR at P_{limit} (or P_{max} when $P_{limit} > P_{max}$) for each antenna should be obtained out of all supported technologies and frequency bands for each DSI. Demonstrate that the sum of reported SAR of one antenna from each of the sub6 AGs and the sum of RF exposure from all supported radios outside of Smart Transmit should be less than the regulatory limit as given below for each DSI.

1. Obtain the worst-case reported SAR for each antenna group (i.e., maximum reported SAR at Plimit (or Pmax when Plimit > Pmax) out of all supported technologies, frequency bands and antennas in AG0 and AG1), denoted as max.SAR.AG0, max.SAR.AG1, and max.SAR.WWAN, and obtain the worst-case RF exposure for each external radio, and demonstrate that the sum of these RF exposures meets: { [max.SAR.AG0 + max.SAR.AG1] + max.SAR.WWAN + BT Ant 1 + BT Ant 2} ≤ 1.6 (for 1g).

ii) (SPLSR criteria): For each antenna, obtain the highest reported SAR value at P_{limit} out of all supported technologies for each frequency band. Using these values, demonstrate for a given DSI that every antenna from one sub6 AG meets SPLSR criteria with every antenna in another sub6 AG for all frequency bands. This criteria must be demonstrated for all antenna pair combinations irrespective of supported simultaneous transmission scenarios as given below for each DSI:

- SPLSR criteria should be met for all antenna pair combinations of AG0 and AG1: {Chain 0 in AG0; Chain 1 in AG1. As it can be seen, these include all combinations of antenna groups, antennas, and frequency bands.

iii) (combination of SPLSR & SAR1+SAR2 criteria): If SPLSR criteria for all the combinations of sub6 antenna groups in (i) is demonstrated to show that each AG is mutually exclusive from other AGs, and if the WWAN and BT antennas do not meet SPLSR criteria, then the condition in (ii) reduces to: {max.SAR.AG0 + max.SAR.WWAN + BT Ant 1 + BT Ant 2} ≤ 1.6 and {max.SAR.AG1 + max.SAR.WWAN + BT Ant 1 + BT Ant 2} ≤ 1.6 for compliance demonstration (for 1g).

If SPLSR criteria evaluation and analysis is needed to determine compliance for a certain DSI configuration, SPLSR is performed by taking the highest reported SAR for each of the supported technologies and bands per antenna, along with the peak SAR locations. Peak locations are documented in the Highest Report SAR and Hotspot Location Section below for each DSI configuration.

The following formula is used to calculate the SPLSR between Top Set and Bottom Set for each exposure configuration:

$$\boldsymbol{SPLSR} = \frac{(\boldsymbol{Max\ SAR\ Top\ Set} + \boldsymbol{Max\ SAR\ Bottom\ Set})^{\mathbf{1.5}}}{|\boldsymbol{Y_{max}} - \boldsymbol{Y_{min}}|}$$

4 No motion - SAR Antenna Group Analysis

For this device configuration:

- DSI = 3 (No Motion) for WWAN
- Pmax (No Motion) for WLAN

Table 1
WLAN AG0 Highest Reported SAR

AG0 SAR (W/kg)			
Body SAR	Configuration	Chain 0	Max
	Bottom	0.845	0.845

Table 2
WLAN AG1 Highest Reported SAR

AG1 SAR (W/kg)			
Body SAR	Configuration	Chain 1	Max
	Bottom	1.032	1.032

Table 3
Simultaneous Combinations with Bluetooth

Configuration	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 2.4 GHz Bluetooth Chain 1 SAR (W/kg)	BT Worst-case Combination SAR (W/kg)
Bottom	0.243	0.109	0.352	0.352

Table 4
WWAN Highest Reported SAR

WWAN SAR (W/kg)								
Body SAR	Configuration	1	2	3	4	5	6	Max
	Front	-	0.999	-	-	0.998	-	0.999
	Top	1.054	0.992	0.997	0.986	0.997	1.198	1.198
	Right	-	-	-	-	-	0.993	0.993
	Left	0.998	-	-	-	-	-	0.998

Table 5
No Motion Simultaneous Analysis

	Configuration	WWAN SAR (W/kg)	AG0 SAR (W/kg)	AG1 SAR (W/kg)	BT Worst-case Combination SAR (W/kg)	WWAN + AG0 + AG1 + BT SAR (W/kg)
Body SAR	Front	0.999	-	-	-	0.999
	Top	1.198	-	-	-	1.198
	Bottom	-	0.845	1.032	0.352	See Table Below
	Right	0.993	-	-	-	0.993
	Left	0.998	-	-	-	0.998

Table 6
Bottom Edge Sum and SPLSR

Antenna Pair		Standalone Values		Standalone Sum	Peak Separation Distance (mm)	SPLS Ratio
		SAR (W/kg)	SAR (W/kg)			
Ant "a"	Ant "b"	a	b	a+b	D_{a-b}	$(a+b)^{1.5}/D_{a-b}$
WLAN + BT Co-Located Ant Chain 0	WLAN + BT Co-Located Ant Chain 1	1.088	1.141	2.229	175.76	0.02

Note:

1. Per KDB Workshop Notes, if the sum of two overlapping SAR is <1.6, those antennas can be determined to be co-located. In SPLSR analysis, the sum of the two SAR values will be used with the worst-case coordinate. WLAN + BT Co-Located Chain 0 value in the table above is from AG0 WLAN SAR + 2.4GHz Bluetooth Chain 0, and WLAN + BT Co-Located Chain 1 value in the table above is from AG1 WLAN SAR + 2.4 GHz Bluetooth Chain 1.
2. No evaluation was performed to determine the aggregate 1g SAR for these configurations as the SPLS ratio between the antenna pairs was not greater than 0.04 per FCC KDB 447498 D04v01. Please see the Highest Reported SAR and Hotspot Location Section for peak coordinate locations.

5 Motion - SAR Antenna Group Analysis

For this device configuration:

- DSI = 6 (Motion) for WWAN
- DSI = 1 (Motion) for WLAN

Table 7
WLAN AG0 Highest Reported SAR

AG0 SAR (W/kg)			
Body SAR	Configuration	Chain 0	Max
	Bottom	1.123	1.123

Table 8
WLAN AG1 Highest Reported SAR

AG1 SAR (W/kg)			
Body SAR	Configuration	Chain 1	Max
	Bottom	1.169	1.169

Table 9
WWAN Highest Reported SAR

WWAN SAR (W/kg)								
Body SAR	Configuration	1	2	3	4	5	6	Max
	Bottom	1.197	1.008	0.647	0.827	0.985	1.179	1.197

Table 10
Bluetooth Simultaneous Scenarios

Configuration	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 2.4 GHz Bluetooth Chain 1 SAR (W/kg)	BT Worst-case Combination SAR (W/kg)
Bottom	0.243	0.109	0.352	0.352

Table 11
DSI=6 AG Verification with WLAN

Body SAR	Configuration	WWAN SAR (W/kg)	AG0 SAR (W/kg)	AG1 SAR (W/kg)	BT Worst-case Combination SAR (W/kg)	WWAN + AG0 + AG1 + BT SAR (W/kg)
	Bottom	1.197	1.123	1.169	0.352	See Table Below

Table 12
Bottom Edge Sum and SPLSR

Antenna Pair		Standalone Values		Standalone Sum	Peak Separation Distance (mm)	SPLS Ratio
		SAR (W/kg)	SAR (W/kg)			
Ant "a"	Ant "b"	a	b	a+b	D_{a-b}	$(a+b)^{1.5}/D_{a-b}$
WWAN Ant 1	WLAN + BT Co-Located Ant Chain 0	1.197	1.366	2.563	159.81	0.03
WWAN Ant 2	WLAN + BT Co-Located Ant Chain 0	1.008	1.366	2.374	214.48	0.02
WWAN Ant 3	WLAN + BT Co-Located Ant Chain 0	0.647	1.366	2.013	209.34	0.01
WWAN Ant 4	WLAN + BT Co-Located Ant Chain 0	0.827	1.366	2.193	265.56	0.01
WWAN Ant 5	WLAN + BT Co-Located Ant Chain 0	0.985	1.366	2.351	307.30	0.01
WWAN Ant 6	WLAN + BT Co-Located Ant Chain 0	1.179	1.366	2.545	278.42	0.01
WWAN Ant 1	WLAN + BT Co-Located Ant Chain 1	1.197	1.278	2.475	279.74	0.01
WWAN Ant 2	WLAN + BT Co-Located Ant Chain 1	1.008	1.278	2.286	312.12	0.01
WWAN Ant 3	WLAN + BT Co-Located Ant Chain 1	0.647	1.278	1.925	266.14	0.01
WWAN Ant 4	WLAN + BT Co-Located Ant Chain 1	0.827	1.278	2.105	206.42	0.01
WWAN Ant 5	WLAN + BT Co-Located Ant Chain 1	0.985	1.278	2.263	218.34	0.02
WWAN Ant 6	WLAN + BT Co-Located Ant Chain 1	1.179	1.278	2.457	158.50	0.02
WLAN + BT Co-Located Ant Chain 0	WLAN + BT Co-Located Ant Chain 1	1.366	1.278	2.644	175.76	0.02

Note:

1. Per KDB Workshop Notes, if the sum of two overlapping SAR is <1.6, those antennas can be determined to be co-located. In SPLSR analysis, the sum of the two SAR values will be used with the worst-case coordinate. WLAN + BT Co-Located Chain 0 value in the table above is from AG0 WLAN SAR + 2.4GHz Bluetooth Chain 0, and WLAN + BT Co-Located Chain 1 value in the table above is from AG1 WLAN SAR + 2.4 GHz Bluetooth Chain 1.
2. No evaluation was performed to determine the aggregate 1g SAR for these configurations as the SPLS ratio between the antenna pairs was not greater than 0.04 per FCC KDB 447498 D04v01. Please see the Highest Reported SAR and Hotspot Location Section for peak coordinate locations.

6 Highest Report SAR and SAR Hotspot Locations

Table 13
Bottom Edge at 0mm Peak Y Coordinates

								Chain 0	Chain 1
		WWAN						AG0	AG1
		1	2	3	4	5	6	Chain 0	Chain 1
Mode/Band	Distance	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
UMTS 850	SAR					0.755			
	Y-Axis					-157.600			
UMTS 1750	SAR	1.192							
	Y-Axis	140.800							
UMTS 1900	SAR	1.194							
	Y-Axis	143.000							
LTE Band 71	SAR		0.602			0.884			
	Y-Axis		136.900			-143.800			
LTE Band 12	SAR		0.808			0.592			
	Y-Axis		135.600			-147.100			
LTE Band 13	SAR		0.792			0.654			
	Y-Axis		136.000			-161.000			
LTE Band 14	SAR		0.756			0.613			
	Y-Axis		136.000			-161.100			
LTE Band 26	SAR		0.958			0.963			
	Y-Axis		136.100			-161.100			
LTE Band 5	SAR		1.008			0.970			
	Y-Axis		136.100			-161.100			
LTE Band 66	SAR	1.018							
	Y-Axis	142.400							
LTE Band 25	SAR	1.096							
	Y-Axis	142.500							
LTE Band 2	SAR	1.178							
	Y-Axis	144.000							
LTE Band 30	SAR	0.898							
	Y-Axis	142.700							
LTE Band 41	SAR	1.187					1.169		
	Y-Axis	141.800					-163.600		
LTE Band 48	SAR	1.070					1.155		
	Y-Axis	143.700					-158.500		
NR Band n71	SAR		0.559			0.658			
	Y-Axis		137.500			-158.600			
NR Band n12	SAR		0.701			0.985			
	Y-Axis		137.100			-160.400			
NR Band n14	SAR		0.833			0.686			
	Y-Axis		137.500			-159.100			
NR Band n26	SAR		0.975			0.985			
	Y-Axis		137.600			-159.300			
NR Band n5	SAR		0.957			0.970			
	Y-Axis		137.600			-159.300			
NR Band n66	SAR	1.145							
	Y-Axis	146.300							
NR Band n30	SAR	1.068							
	Y-Axis	145.000							
NR Band n41	SAR	0.947					1.155		
	Y-Axis	144.800					-161.800		
NR Band n48	SAR	0.978		0.570	0.410		1.179		
	Y-Axis	141.500		69.600	-92.400		-160.200		
NR Band n77	SAR	1.197		0.647	0.827		1.027		
	Y-Axis	141.500		66.100	-90.000		-158.100		
2.4 GHz WIFI/a	SAR							0.680	1.060
	Y-Axis							87.100	-98.900
5 GHz WIFI/a	SAR							1.123	1.169
	Y-Axis							85.200	-93.600
6 GHz WIFI/a	SAR							0.513	0.555
	Y-Axis							82.500	-93.200
2.4 GHz Bluetooth/b	SAR							0.243	0.109
	Y-Axis							84.300	-99.600

Table 14
Bottom Edge at 25mm Peak Y Coordinates

		Chain 0	Chain 1
		AG0	AG1
		Chain 0	Chain 1
Mode/Band	Distance	0 mm	0 mm
2.4 GHz WIFI/a	SAR	0.039	0.026
	Y-Axis	87.100	-98.900
5 GHz WIFI/a	SAR	0.845	1.032
	Y-Axis	85.200	-93.600
6 GHz WIFI/a	SAR	0.484	0.301
	Y-Axis	82.500	-93.200
2.4 GHz Bluetooth/b	SAR	0.243	0.109
	Y-Axis	84.300	-99.600

7 Conclusion

The above numerical summed SAR and SPLSR results for all the combinations of antenna groups and external radios are sufficient to show that AG0 is mutually exclusive from AG1 and that simultaneous transmission cases will not exceed the SAR limit and therefore no measured volumetric simultaneous SAR summation is required per FCC KDB Publication 447498 D04v01 and IEEE 1528- 2013 Section 6.3.4.1.