

APPENDIX F: MULTI-TX AND ANTENNA SAR CONSIDERATIONS

F.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.

F.2 Simultaneous Transmission Procedures

This device contains transmitters that may operate simultaneously. Therefore, simultaneous transmission analysis is required. Per FCC KDB Publication 447498 D04v01 4.3.2 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.

Per FCC KDB Publication 941225 D06v02r01, the devices edges with antennas more than 2.5 cm from edge are not required to be evaluated for SAR (“-“).

(*) For test positions that were not required to be evaluated for WLAN SAR per FCC KDB publication 248227, the worst case WLAN SAR result for the applicable exposure conditions was used for simultaneous transmission analysis.

This device is enabled with Qualcomm® Smart Transmit Gen2 with pre-defined sub6 antenna groups (AG0 and AG1). Simultaneous transmission analysis is performed per antenna groups. Analysis is provided below to show compliance between AG0 with BT/WLAN/NFC and AG1 with BT/WLAN/NFC.

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. Therefore, simultaneous transmission compliance between 4G+5G operations within an antenna group is demonstrated in the Part 2 Report during algorithm validation.

F.3 Sub6 Antenna Groups

The 2nd generation of Smart Transmit (GEN2) operates based on pre-defined sub6 antenna groups (AG) and mmW module groups (MG). 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 D04v01) with every antenna from another sub6 AG. This criteria must be demonstrated for all antenna combinations for each pair of AGs.

This device supports two sub6 AG: AG0 and AG1, with AG0 having 2 antennas (Main 1, Main 2) and AG1 having 2 antennas (Sub, 4th path), and two WIFI/BT antennas outside of Smart Transmit. The conditions are verified through the following criterias:

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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.

2. Obtain the worst-case reported SAR for each antenna group (i.e., maximum reported SAR at P_{limit} (or P_{max} when $P_{limit} > P_{max}$) out of all supported technologies, frequency bands and antennas in AG0 and AG1), denoted as max.SAR.AG0 and max.SAR.AG1, and obtain the worst-case RF exposure for each external radio, and demonstrate that the sum of these RF exposures meets: $\{ [\text{max.SAR.AG0} + \text{max.SAR.AG1}] + \text{WIFI/BT Ant 1} + \text{WIFI/BT Ant 2} \} \leq 1.6$ (for 1g, or 4.0 for 10g).

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: antenna (Main 1, Main 2) in AG0; antenna (Sub, 4th path) 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 WIFI/BT antennas supported outside of Smart Transmit do not meet SPLSR criteria, then the condition in (ii) reduces to: $\{ \text{max.SAR.AG0} + \text{WIFI/BT Ant 1} + \text{WIFI/BT Ant 2} \} \leq 1.6$ and $\{ \text{max.SAR.AG1} + \text{WIFI/BT Ant 1} + \text{WIFI/BT Ant 2} \} \leq 1.6$ for compliance demonstration (for 1g, or 4.0 for 10g).

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. Per Qualcomm guidance, only Y-axis coordinates are recorded in the analysis for calculation simplicity (assumes all 0mm of separation on the x-axis). Peak locations are documented in Section D.7 below for each DSI configuration.

For bottom AG0, Y_{max} coordinate represents the worst case hotspot location that is closest to the top AG1. Similarly, for top AG1, Y_{min} coordinate represents the worst case hotspot location that is closest to the bottom AG0.

The following formula is used to calculate the SPLSR between AG0 and AG1 for each exposure configuration:

$$SPLSR = \frac{(\text{Max SAR AG0} + \text{Max SAR AG1})^{1.5}}{|Y_{max} - Y_{min}|}$$

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F.4 Head (DSI = 2) SAR Antenna Group Analysis

Table F-1
DSI=2 Held-to-ear AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Head SAR	Configuration	Main 1	Main 2	Max
	Right Cheek	0.439	0.197	0.439
	Right Tilt	0.126	0.092	0.126
	Left Cheek	0.422	0.166	0.422
	Left Tilt	0.177	0.117	0.177

Table F-2
DSI=2 Held-to-ear AG1 Highest Reported SAR

AG1 SAR (W/kg)				
Head SAR	Configuration	Sub	4th path	Max
	Right Cheek	0.245	-	0.245
	Right Tilt	0.210	-	0.210
	Left Cheek	0.949	-	0.949
	Left Tilt	0.725	-	0.725

Table F-3
Simultaneous Transmission Scenarios of WLAN/BT (Held to Ear)

Configuration	2.4 GHz WLAN Chain 0 SAR (W/kg)	2.4 GHz WLAN Chain 0 at 11 dBm SAR (W/kg)	2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 SAR (W/kg)	5 GHz WLAN Chain 1 SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)
	1	2	3	4	5	6	7	8
Right Cheek	0.647	0.188	0.000*	0.401	0.000	0.060	0.165	0.000
Right Tilt	0.112	0.188*	0.000*	0.401*	0.000	0.005	0.035	0.000
Left Cheek	0.127	0.042	0.000	0.177	0.001	0.025	0.026	0.000
Left Tilt	0.647*	0.188*	0.000*	0.039	0.000	0.000	0.007	0.000

Configuration	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz WLAN Chain 0 at 11 dBm + 2.4 GHz WLAN Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz WLAN Chain 0 at 11 dBm + 2.4 GHz WLAN Chain 1 + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 1 + 6 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1+3	4+5	2+3+4+5	2+3+6	7	8	7+4+5	8+4+5	7+6	8+6	6	
Right Cheek	0.647	0.401	0.589	0.248	0.165	0.000	0.566	0.401	0.225	0.060	0.060	0.647
Right Tilt	0.112	0.401	0.589	0.193	0.035	0.000	0.436	0.401	0.040	0.005	0.005	0.589
Left Cheek	0.127	0.178	0.220	0.067	0.026	0.000	0.204	0.178	0.051	0.025	0.025	0.220
Left Tilt	0.647	0.039	0.227	0.188	0.007	0.000	0.046	0.039	0.007	0.000	0.000	0.647

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Table F-4
DSI=2 Held-to-ear AG Verification

Head SAR	Configuration	AG0 SAR (W/kg)	AG1 SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)	AG0 + AG1 + WLAN/BT SAR (W/kg)
	Right Cheek	0.439	0.245	0.647	1.331
	Right Tilt	0.126	0.210	0.589	0.925
	Left Cheek	0.422	0.949	0.220	1.591
	Left Tilt	0.177	0.725	0.647	1.549

Notes:

- For all combinations where the sum of AG0+AG1+WLAN/BT is less than 1.6 W/kg, there's no further analysis required for compliance demonstration.

F.5 Body-worn (DSI = 0) SAR Antenna Group Analysis

Table F-5
DSI=0 Body-worn AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Body-Worn SAR	Configuration	Main 1	Main 2	Max
		Back	0.319	0.393

Table F-6
DSI=0 Body-worn AG1 Highest Reported SAR

AG1 SAR (W/kg)				
Body-Worn SAR	Configuration	Sub	4th path	Max
		Back	0.392	0.462

Table F-7
Simultaneous Transmission Scenarios of WLAN/BT (Body-worn at 1.0 cm)

Configuration	2.4 GHz WLAN Chain 0 SAR (W/kg)	2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 SAR (W/kg)	5 GHz WLAN Chain 1 SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)
	1	2	3	4	5	6	7
Back	0.121	0.084	0.065	0.084	0.135	0.036	0.022

Configuration	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth Chain 1 + 6 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1+2	3+4	1+2+3+4	1+2+5	6	7	6+3+4	7+3+4	6+5	7+5	5	
Back	0.205	0.149	0.354	0.340	0.036	0.022	0.185	0.171	0.171	0.157	0.135	0.354

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**Table F-8
DSI=0 Body-worn AG Verification**

Body-Worn SAR	Configuration	AG0 SAR (W/kg)	AG1 SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)	AG0 + AG1 + WLAN/BT SAR (W/kg)
	Back	0.393	0.462	0.354	1.209

Notes:

1. For all combinations where the sum of AG0+AG1+WLAN/BT is less than 1.6 W/kg, there's no further analysis required for compliance demonstration.

F.6 Hotspot (DSI = 3) SAR Antenna Group Analysis

**Table F-9
DSI=3 Hotspot AG0 Highest Reported SAR**

AG0 SAR (W/kg)				
Hotspot SAR	Configuration	Main 1	Main 2	Max
	Back	0.319	0.393	0.393
	Front	0.221	0.320	0.320
	Top	-	-	-
	Bottom	0.221	0.578	0.578
	Right	-	0.218	0.218
	Left	0.238	-	0.238

**Table F-10
DSI=3 Hotspot AG1 Highest Reported SAR**

AG1 SAR (W/kg)				
Hotspot SAR	Configuration	Sub	4th path	Max
	Back	0.392	0.462	0.462
	Front	0.439	0.021	0.439
	Top	0.079	0.035	0.079
	Bottom	-	-	-
	Right	0.479	-	0.479
	Left	0.339	0.051	0.339

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Table F-11
Simultaneous Transmission Scenarios of WLAN/BT (Hotspot at 1.0 cm)

Configuration	2.4 GHz WLAN Chain 0 SAR (W/kg)	2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 SAR (W/kg)	5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)
	1	2	3	4	5	6
Back	0.176*	0.084	0.110*	0.084	0.036	0.022
Front	0.176*	0.084*	0.110*	0.084*	0.025	0.000
Top	0.176*	-	0.110*	-	0.002	-
Bottom	-	0.084*	-	0.084*	-	0.001
Right	-	-	-	-	-	-
Left	0.176	0.084*	0.110	0.084*	0.067	0.000

Configuration	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 SAR (W/kg)	5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz WLAN Chain 0 + 2.4 GHz WLAN Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 0 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	2.4 GHz Bluetooth Chain 1 + 5 GHz WLAN Chain 0 + 5 GHz WLAN Chain 1 SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1+2	3+4	1+2+3+4	5	6	5+3+4	6+3+4	
Back	0.260	0.194	0.454	0.036	0.022	0.230	0.216	0.454
Front	0.260	0.194	0.454	0.025	0.000	0.219	0.194	0.454
Top	0.176	0.110	0.286	0.002	-	0.112	0.110	0.286
Bottom	0.084	0.084	0.168	-	0.001	0.084	0.085	0.168
Right	-	-	-	-	-	-	-	-
Left	0.260	0.194	0.454	0.067	0.000	0.261	0.194	0.454

Table F-12
DSI=3 Hotspot AG Verification

Hotspot SAR	Configuration	AG0 SAR (W/kg)	AG1 SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)	AG0 + AG1 + WLAN/BT SAR (W/kg)
	Back		0.393	0.462	0.454
Front		0.320	0.439	0.454	1.213
Top		-	0.079	0.286	0.365
Bottom		0.578	-	0.168	0.746
Right		0.218	0.479	-	0.697
Left		0.238	0.339	0.454	1.031

Notes:

- For all combinations where the sum of AG0+AG1+WLAN/BT is less than 1.6 W/kg, there's no further analysis required for compliance demonstration.

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F.7 Max Phablet (DSI = 0) SAR Antenna Group Analysis

Per FCC KDB Publication 648474 D04 Handset SAR, Phablet SAR tests were not required if wireless router 1g SAR (scaled to the maximum output power, including tolerance) < 1.2 W/kg. Therefore no further analysis beyond the tables included in this section was required to determine that possible simultaneous transmission scenarios would not exceed the SAR limit.

Table F-13
DSI=0 Max Phablet AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Phablet SAR	Configuration	Main 1	Main 2	Max
	Back	-	1.614	1.614
	Front	0.841	1.382	1.382
	Top	-	-	-
	Bottom	0.865	2.248	2.248
	Right	-	-	-
	Left	-	-	-

Table F-14
DSI=0 Max Phablet AG1 Highest Reported SAR

AG1 SAR (W/kg)				
Phablet SAR	Configuration	Sub	4th path	Max
	Back	-	1.391	1.391
	Front	-	-	-
	Top	-	-	-
	Bottom	-	-	-
	Right	-	-	-
	Left	-	-	-

Table F-15
Simultaneous Transmission Scenarios of WLAN/BT

Configuration	5 GHz WLAN Chain 0 SAR (W/kg)	5 GHz WLAN Chain 1 SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)
	1	2	3
Back	0.522*	0.378	0.238
Front	0.522*	0.378*	0.035
Top	0.522*	-	0.000
Bottom	-	0.378*	0.017
Left	0.522	0.378*	0.313

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Table F-16
DSI=0 Max Phablet AG Verification

Phablet SAR	Configuration	AG0 SAR (W/kg)	AG1 SAR (W/kg)	NFC SAR (W/kg)	WLAN Worst-case Combination SAR (W/kg)	AG0 + AG1 + NFC + WLAN/BT SAR (W/kg)
	Back	1.614	1.391	0.017	0.900	3.922
	Front	1.382	-	0.000	0.900	2.282
	Top	-	-	0.000	0.522	0.522
	Bottom	2.248	-	-	0.378	2.626
	Right	-	-	0.000	-	-
	Left	-	-	0.000	0.900	0.900

Notes:

1. For all combinations where the sum of AG0+AG1+WLAN/BT is less than 4 W/kg, there's no further analysis required for compliance demonstration.

F.8 Simultaneous Transmission Conclusion

The above numerical summed SAR results for all of the combinations of sub6 antenna groups 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.

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