

APPENDIX E: MULTI-TX AND ANTENNA SAR CONSIDERATIONS

E.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

E.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.

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 (“-“).

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. Below analysis demonstrates the mutually exclusive operation of AG0 and AG1 and the compliance between AG0 and BT/WLAN/NFC, and between AG1 and 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.

E.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 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 two sub6 AG: AG0 and AG1, with AG0 having 2 antennas (Main 1, Main 2) and AG1 having 4 antennas (Sub, Sub-UHB, 3rd-LMHB, 4th-MBH), and two WIFI/BT antennas outside of Smart Transmit. 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

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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 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: $\{ [\text{max.SAR.AG0} + \text{max.SAR.AG1}] + \text{WIFI/BT WiFi Main} + \text{WIFI/BT WiFi Sub} \} \leq 1.6$ (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, Sub-UHB, 3rd-LMHB, 4th-MBH) 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: $\{ \text{max.SAR.AG0} + \text{WIFI/BT WiFi Main} + \text{WIFI/BT WiFi Sub} \} \leq 1.6$ and $\{ \text{max.SAR.AG1} + \text{WIFI/BT WiFi Main} + \text{WIFI/BT WiFi Sub} \} \leq 1.6$ for compliance demonstration (for 1g, or 4.0 for 10g).

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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 the Highest Report SAR and Hotspot Location Section below for each DSI configuration.

For this device, AG0 is located at the bottom of the device along with the BT/WIFI WiFi Sub. Per April 2022 TCB Workshop Notes, AG0 was summed algebraically with the BT/WIFI WiFi Sub for the purposes of hybrid SPLSR combination, identified in this report as the “bottom set”. Similarly, AG1 and the BT/WIFI WiFi Main are located at the top of the device and were summed algebraically together as the “top set” for hybrid SPLSR calculation. The minimum distance when considering all transmissions between the top set and bottom set groups was considered when calculating the SPLSR. The sum of the transmissions within set are less than the SAR limit (for ex: AG0+BT/WIFI WiFi Sub < 1.6 W/kg (1g) for bottom set, and AG1+BT/WIFI WiFi Main < 1.6 W/kg (1g) for top set).

For bottom set (AG0), Y_max coordinate represents the worst case hotspot location that is closest to the top set (AG1 + BT/WIFI Antennas). Similarly, for top set (AG1 + BT/WIFI Antennas), Y_min coordinate represents the worst case hotspot location that is closest to the bottom set (AG0).

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

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

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

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

AG0 SAR (W/kg)				
Head SAR	Configuration	Main 1	Main 2	Max
	Right Cheek	0.227	0.251	0.251
	Right Tilt	0.096	0.131	0.131
	Left Cheek	0.176	0.155	0.176
	Left Tilt	0.089	0.157	0.157

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

AG1 SAR (W/kg)						
Head SAR	Configuration	Sub	Sub-UHB	3rd-LMHB	4th-MHB	Max
	Right Cheek	0.700	0.213	0.027	0.149	0.700
	Right Tilt	0.757	0.153	0.012	0.093	0.757
	Left Cheek	0.953	0.225	0.052	0.106	0.953
	Left Tilt	0.987	0.149	0.023	0.043	0.987

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

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)
	1	2	3	4	5	6
Right Cheek	0.450	0.278	0.193	0.027	0.221	0.000
Right Tilt	0.078	0.051	0.079	0.041	0.033	0.000
Left Cheek	0.093	0.059	0.177	0.012	0.049	0.005
Left Tilt	0.027	0.019	0.040	0.011	0.009	0.001

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)	2.4 GHz Bluetooth WiFi Main + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub + 6 GHz WLAN MIMO SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1	3	4	2+3	2+4	5	6	5+3	6+3	5+4	6+4	
Right Cheek	0.450	0.193	0.027	0.471	0.305	0.221	0.000	0.414	0.193	0.248	0.027	0.471
Right Tilt	0.078	0.079	0.041	0.130	0.092	0.033	0.000	0.112	0.079	0.074	0.041	0.130
Left Cheek	0.093	0.177	0.012	0.236	0.071	0.049	0.005	0.226	0.182	0.061	0.017	0.236
Left Tilt	0.027	0.040	0.011	0.059	0.030	0.009	0.001	0.049	0.041	0.020	0.012	0.059

**Table E-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	0.251	0.700	0.471	1.422
	Right Tilt	0.131	0.757	0.130	1.018
	Left Cheek	0.176	0.953	0.236	1.365
	Left Tilt	0.157	0.987	0.059	1.203

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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E.5 Body-Worn (DSI = 3) SAR Antenna Group Analysis

Table E-5
DSI=3 Body-Worn AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Body-Worn SAR	Configuration	Main 1	Main 2	Max
		Back	0.935	0.280

Table E-6
DSI=3 Body-Worn AG1 Highest Reported SAR

AG1 SAR (W/kg)						
Body-Worn SAR	Configuration	Sub	Sub-UHB	3rd-LMHB	4th-MHB	Max
		Back	0.234	0.371	0.046	0.173

Table E-7
Simultaneous Transmission Scenarios of WLAN/BT (Body-Worn)

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)
	1	2	3	4	5	6
Back	0.109	0.057	0.080	0.024	0.045	0.044

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)	2.4 GHz Bluetooth WiFi Main + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main + 6 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub + 6 GHz WLAN MIMO SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1	3	4	2+3	2+4	5	6	5+3	6+3	5+4	6+4	
Back	0.109	0.080	0.024	0.137	0.081	0.045	0.044	0.125	0.124	0.069	0.068	0.137

Table E-8
DSI=3 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	0.935	0.371	0.137

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

Table E-9
DSI=3 Hotspot AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Hotspot SAR	Configuration	Main 1	Main 2	Max
	Back	0.935	0.280	0.935
	Front	0.409	0.296	0.409
	Top	-	-	-
	Bottom	0.186	0.462	0.462
	Right	-	0.124	0.124
	Left	0.158	-	0.158

Table E-10
DSI=3 Hotspot AG1 Highest Reported SAR

AG1 SAR (W/kg)						
Hotspot SAR	Configuration	Sub	Sub-UHB	3rd-LMHB	4th-MHB	Max
	Back	0.234	0.371	0.046	0.173	0.371
	Front	0.192	0.028	0.008	0.006	0.192
	Top	0.341	0.044	0.005	0.006	0.341
	Bottom	-	-	-	-	-
	Right	0.175	-	0.016	-	0.175
	Left	-	0.093	-	0.022	0.093

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Table E-11
Simultaneous Transmission Scenarios of WLAN/BT (Hotspot)

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)
	1	2	3	4	5
Back	0.109	0.057	0.085	0.045	0.044
Front	0.082	0.033	0.030	0.027	0.003
Top	0.017	0.009	0.024	0.005	-
Bottom	0.022	0.011	0.014	-	0.005
Right	-	-	-	-	-
Left	0.179	0.074	0.095	0.092	0.005

Configuration	2.4 GHz WLAN MIMO SAR (W/kg)	5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz WLAN MIMO at 14 dBm + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Main SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub SAR (W/kg)	2.4 GHz Bluetooth WiFi Main + 5 GHz WLAN MIMO SAR (W/kg)	2.4 GHz Bluetooth WiFi Sub + 5 GHz WLAN MIMO SAR (W/kg)	WLAN/BT Worst-case Combination SAR (W/kg)
	1	3	2+3	4	5	4+3	5+3	
Back	0.109	0.085	0.142	0.045	0.044	0.130	0.129	0.142
Front	0.082	0.030	0.063	0.027	0.003	0.057	0.033	0.082
Top	0.017	0.024	0.033	0.005	-	0.029	0.024	0.033
Bottom	0.022	0.014	0.025	-	0.005	0.014	0.019	0.025
Right	-	-	-	-	-	-	-	-
Left	0.179	0.095	0.169	0.092	0.005	0.187	0.100	0.187

Table E-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	0.935	0.371	0.142	1.448
	Front	0.409	0.192	0.082	0.683
	Top	-	0.341	0.033	0.374
	Bottom	0.462	-	0.025	0.487
	Right	0.124	0.175	-	0.299
	Left	0.158	0.093	0.187	0.438

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

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E.7 Phablet (DSI = 3) 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 E-13
DSI=3 Phablet AG0 Highest Reported SAR

AG0 SAR (W/kg)				
Phablet SAR	Configuration	Main 1	Main 2	Max
	Back	1.510	-	1.510
	Front	-	1.718	1.718
	Top	-	-	-
	Bottom	-	1.083	1.083
	Right	-	-	-
	Left	-	-	-

Table E-14
DSI=3 Phablet AG1 Highest Reported SAR

AG1 SAR (W/kg)						
Phablet SAR	Configuration	Sub	Sub-UHB	3rd-LMHB	4th-MHB	Max
	Back	0.550	1.178	-	0.662	1.178
	Front	-	-	-	-	-
	Top	0.757	-	-	-	0.757
	Bottom	-	-	-	-	-
	Right	-	-	-	-	-
	Left	-	-	-	-	-

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Table E-15
Simultaneous Transmission Scenarios of WLAN (Phablet)

Configuration	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)
	1	2
Back	0.268	0.114
Front	0.211	0.042
Top	0.038	0.010
Bottom	0.036	0.002
Right	-	-
Left	0.626	0.251

Configuration	5 GHz WLAN MIMO SAR (W/kg)	6 GHz WLAN MIMO SAR (W/kg)	WLAN Worst-case Combination SAR (W/kg)
	1	2	
Back	0.268	0.114	0.268
Front	0.211	0.042	0.211
Top	0.038	0.010	0.038
Bottom	0.036	0.002	0.036
Right	-	-	-
Left	0.626	0.251	0.626

Table E-16
Simultaneous Transmission Scenarios of NFC (Phablet)

Configuration	NFC SAR (W/kg)
Back	0.021
Front	0.000
Top	-
Bottom	-
Right	-
Left	0.000

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Table E-17
DSI=3 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	1.510	1.178	0.021	0.268	2.977
	Front	1.718	-	0.000	0.211	1.929
	Top	-	0.757	-	0.038	0.795
	Bottom	1.083	-	-	0.036	1.119
	Right	-	-	-	-	-
	Left	-	-	0.000	0.626	0.626

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

E.8 Conclusion

The above numerical summed SAR results and SPLSR for all 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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