

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 other transmitters.

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 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 physical test configuration is ≤ 1.6 W/kg. Alternatively, simultaneous transmission SAR test exclusion may be evaluated using Total Exposure Ratio (TER). The different test positions in an exposure condition may be considered collectively to determine SAR test exclusion according to the TER.

This device is enabled with Qualcomm® FastConnect Time Average SAR with pre-defined antenna groups (AG0 and AG1) for WLAN. 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 and BT/NFC.

Qualcomm FastConnect TAS algorithm directly adds the time-averaged RF exposure of all simultaneous transmissions of WLAN radios within an antenna group and controls the total RF exposure from all WLAN radios to not exceed FCC limit. Therefore, simultaneous transmission compliance between WLAN operations is demonstrated in the Part 2 Report during algorithm validation.

Per FCC KDB 447498 D04v01 Appendix B Section B.4, when the separation distance is between 0.5 cm and 40 cm for between 0.3 GHz and 6 GHz, the standalone SAR is not required to be measured when P_{ant} , the maximum time-averaged power or effective radiated power (ERP), whichever is greater, is less than or equal to the threshold P_{th} (mW). The following formulas can be used to determine P_{th} . Please see table E-1 for applicable exclusion criteria for this device.

$$ERP_{20cm}(mW) = \begin{cases} 2040f & 0.3 \text{ GHz} \leq f < 1.5 \text{ GHz} \\ 3060 & 1.5 \text{ GHz} \leq f < 6 \text{ GHz} \end{cases}$$

$$P_{th}(mW) = \begin{cases} ERP_{20cm}(d/20 \text{ cm})^{-\log_{10}(60/ERP_{20cm}\sqrt{f})} & d \leq 20 \text{ cm} \\ ERP_{20cm} & 20 \text{ cm} < d \leq 40 \text{ cm} \end{cases}$$

For transmitters that meet the above criteria, per FCC KDB 447498 D04v01 Appendix E Section E.1 the following equation must be used to estimate the standalone ER for simultaneous transmission assessment involving that transmitter. The estimated ER for each excluded transmitter can be found in table E-1.

$$\text{Estimated ER} = \frac{P_{ant}}{P_{th}}$$

Please refer to report S/N: 1M2412090111-01.C3K for NFC SAR data.

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Table F-1
Exclusion Criteria and Estimated ER

Position	Antenna	Mode	Frequency (GHz)	Distance (cm)	P _{ant} (mW)	P _{th} (mW)	Estimated ER
Bottom Edge (0 mm)	R	2.4 GHz WLAN	2.437	18.323	53.1	2590.7	0.020
	R	5 GHz WLAN	5.855	18.323	50.1	2547.9	0.020
	R	2.4 GHz Bluetooth	2.441	18.323	53.1	2590.6	0.020
	R	2.4 GHz Bluetooth (WLAN active case)	2.441	18.323	15.9	2590.6	0.006
	L	2.4 GHz WLAN	2.437	18.334	53.1	2593.7	0.020
	L	5 GHz WLAN	5.855	18.334	50.1	2551.1	0.020
	L	2.4 GHz Bluetooth	2.441	18.334	53.1	2593.6	0.020
	L	2.4 GHz Bluetooth (WLAN active case)	2.441	18.334	15.9	2593.6	0.006
Right Edge (0 mm)	R	2.4 GHz WLAN	2.437	5.914	53.1	301.9	0.176
	R	5 GHz WLAN	5.855	5.914	50.1	239.4	0.209
	R	2.4 GHz Bluetooth	2.441	5.914	53.1	301.7	0.176
	R	2.4 GHz Bluetooth (WLAN active case)	2.441	5.914	15.9	301.7	0.053
	L	2.4 GHz WLAN	2.437	17.145	53.1	2283.3	0.023
	L	5 GHz WLAN	5.855	17.145	50.1	2217.3	0.023
	L	2.4 GHz Bluetooth	2.441	17.145	53.1	2283.2	0.023
	L	2.4 GHz Bluetooth (WLAN active case)	2.441	17.145	15.9	2283.2	0.007
Left Edge (0 mm)	R	2.4 GHz WLAN	2.437	17.142	53.1	2282.5	0.023
	R	5 GHz WLAN	5.855	17.142	50.1	2216.5	0.023
	R	2.4 GHz Bluetooth	2.441	17.142	53.1	2282.4	0.023
	R	2.4 GHz Bluetooth (WLAN active case)	2.441	17.142	15.9	2282.4	0.007
	L	2.4 GHz WLAN	2.437	5.822	53.1	293.0	0.181
	L	5 GHz WLAN	5.855	5.822	50.1	231.7	0.216
	L	2.4 GHz Bluetooth	2.441	5.822	53.1	292.9	0.181
	L	2.4 GHz Bluetooth (WLAN active case)	2.441	5.822	15.9	292.9	0.054
Right Edge (25 mm)	R	2.4 GHz WLAN	2.437	8.414	199.5	590.1	0.338
	R	5 GHz WLAN	5.855	8.414	141.3	500.4	0.282
	R	2.4 GHz Bluetooth	2.441	8.414	112.2	589.9	0.190
	L	2.4 GHz WLAN	2.437	19.645	199.5	2957.6	0.067
	L	5 GHz WLAN	5.855	19.645	141.3	2947.5	0.048
	L	2.4 GHz Bluetooth	2.441	19.645	112.2	2957.6	0.038
Left Edge (25 mm)	R	2.4 GHz WLAN	2.437	19.642	199.5	2956.7	0.067
	R	5 GHz WLAN	5.855	19.642	141.3	2946.6	0.048
	R	2.4 GHz Bluetooth	2.441	19.642	112.2	2956.7	0.038
	L	2.4 GHz WLAN	2.437	8.322	199.5	577.9	0.345
	L	5 GHz WLAN	5.855	8.322	141.3	489.0	0.289
	L	2.4 GHz Bluetooth	2.441	8.322	112.2	577.7	0.194

Simultaneous transmission evaluation was completed using ER values from the reference model RF Exposure Test report and this variant model test report. The more conservative ER value was chosen when applicable. Please see the Multi-TX and Antenna SAR Considerations Appendix in the Reference Model Report for Power Level 1 (DSI=0) simultaneous evaluation.

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F.3 Exposure Ratios

The exposure ratio (ER), for different transmitters is calculated as following:

$$ER_{SAR,n} = \frac{SAR_n}{SAR_{limit}}$$

Where:

- SAR_n is the SAR value for the n -th transmitter/test frequency
- SAR_{limit} is the basic restriction limit that is applicable to the n -th transmitter/test frequency

Compliance with the SAR based RF exposure limits is achieved if $TER_{SAR} \leq 1$. When $TER_{SAR} > 1$, SPLSR is additionally evaluated per below equation:

$$SPLSR = \frac{(ER_j + ER_k)^{1.5}}{R}$$

Where:

- ER_j and ER_k are exposure ratio of transmitter j and k
- R is the distance between transmitter j and k

When SPLSR is ≤ 0.02 for 1g exposure conditions simultaneous SAR evaluation is not required.

F.4 Antenna Groups

Qualcomm's FastConnect WLAN TAS operates based on pre-defined antenna groups (AG). 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 TER of one antenna from each of the AGs and the RF exposure from radios outside TAS is less than regulatory limits. This condition must be demonstrated for all antenna combinations of AGs.
 - (or)
- b) Every antenna from each AG meets SPLSR criteria (Section 4.3.2(c) in FCC KDB 447498 D04) with every antenna from another AG. This criteria must be demonstrated for all antenna combinations for each pair of AGs.

This device supports two AG: AG0 and AG1, with AG0 having 1 antennas (R) and AG1 having 1 antennas (L), and two BT/NFC antennas outside of TAS. The conditions are verified through the following criteria:

- a) (TER1 + TER2 criteria): If SPLSR criteria is not used, then the highest reported TER at Plimit (or Pmax when Plimit > Pmax) for each antenna should be obtained out of all supported technologies and frequency bands for each DSI. Demonstrate that the sum of reported TER of one antenna from each of the AGs and the sum of RF exposure from all supported radios outside of TAS should be less than the regulatory limit as given below for each DSI.
 - Obtain the worst-case reported ER for each antenna group (i.e., maximum reported TER at Plimit (or Pmax when Plimit > Pmax) out of all supported technologies, frequency bands and antennas in AG0 and AG1), denoted as max.TER.AG0 and max.TER.AG1, and obtain the worst-case RF exposure for each external radio, and demonstrate that the TER sum of these RF exposures meets: { [max.TER.AG0 + max.TER.AG1] + BT Ant 1 + BT Ant 2 + NFC} ≤ 1 .
- ii) (SPLSR criteria): For each antenna, obtain the highest reported SAR value at P_{lim} 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:

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- SPLSR criteria should be met for all antenna pair combinations of AG0 and AG1: {antenna (R) in AG0; antenna (L) in AG1. As it can be seen, these include all combinations of antenna groups, antennas, and frequency bands.
- iii) (combination of SPLSR & TER1+TER2 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: $\{\max.\text{TER.AG0} + \text{BT Ant 1} + \text{BT Ant 2}\} \leq 1$ and $\{\max.\text{TER.AG1} + \text{BT Ant 1} + \text{BT Ant 2}\} \leq 1$ for compliance demonstration.

F.5 Power Mode 2 Antenna Group Analysis

**Table F-2
Power Mode 2 AG0 Highest Reported ER**

AG0 Ratio to Limit		
Body	Configuration	R
	Back	0.509
	Top	0.632
	Bottom	0.020
	Right	0.209
	Left	0.023

**Table F-3
Power Mode 2 AG1 Highest Reported ER**

AG1 Ratio to Limit		
Body	Configuration	L
	Back	0.369
	Top	0.675
	Bottom	0.020
	Right	0.023
	Left	0.216

**Table F-4
Simultaneous Transmission Scenarios of BT (Power Mode C)**

Configuration	2.4 GHz Bluetooth Ant R at 10 dBm Ratio to Limit	2.4 GHz Bluetooth Ant L at 10 dBm Ratio to Limit	2.4 GHz Bluetooth Ant R at 10 dBm Ratio to Limit + 2.4 GHz Bluetooth Ant L at 10 dBm Ratio to Limit	Worst-case BT Scenario Ratio to Limit
Back	0.008	0.009	0.017	0.017
Top	0.093	0.115	0.208	0.208
Bottom	0.006	0.006	0.012	0.012
Right	0.053	0.007	0.060	0.060
Left	0.007	0.054	0.061	0.061

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Table F-5
Simultaneous Transmission Scenarios of NFC

	Configuration	Wireless Charger NFC Ratio to Limit
Body	Back	0.000
	Top	0.000
	Bottom	0.000
	Right	-
	Left	0.000

Right edge for Wireless Charging NFC antenna was excluded from testing due to equipment limitations

Table F-6
Power Mode 2 AG Verification

Body	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	Wireless Charger NFC Ratio to Limit	Worst Case BT Scenario Ratio to Limit	AG0 + AG1 + NFC + BT Ratio to Limit
		AG0 Ratio to Limit	AG1 Ratio to Limit	Wireless Charger NFC Ratio to Limit	Worst Case BT Scenario Ratio to Limit	AG0 + AG1 + NFC + BT Ratio to Limit
	Back	0.509	0.369	0.000	0.017	0.895
	Top	0.632	0.675	0.000	0.208	See Note 2
	Bottom	0.020	0.020	0.000	0.012	0.052
	Right	0.209	0.023	-	0.060	0.292
	Left	0.023	0.216	0.000	0.061	0.300

Table F-7
Power Mode 2 Top Edge Sum and SPLSR

Antenna Pair		Standalone Values		Standalone Sum	Peak Separation Distance (mm)	SPLS Ratio
		Exposure Ratio (ER)	Exposure Ratio (ER)			
Ant "a"	Ant "b"	a	b	a+b	D _{a-b}	(a+b) ^{1.5} /D _{a-b}
AG0 + BT Co-Located Ant R	AG1 + BT Co-Located Ant L	0.725	0.790	1.515	103.73	0.02
AG0 + BT Co-Located Ant R	Wireless Charging NFC	0.725	0.000	0.725	214.22	0.00
AG1 + BT Co-Located Ant L	Wireless Charging NFC	0.790	0.000	0.79	110.58	0.01

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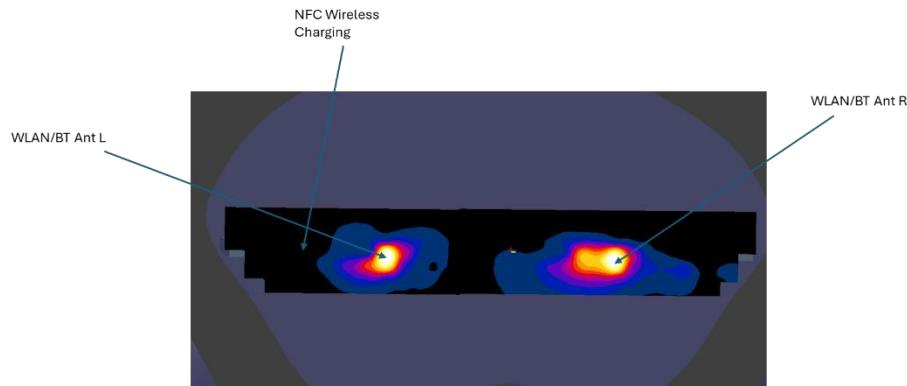


Figure F-1
Power Mode 2 Top Edge Peak Location Ratio Plot

Notes:

1. For all combinations where the sum of AG0+AG1+NFC+BT is less than 1, there's no further analysis required for compliance demonstration.
2. No evaluation was performed to determine the aggregate 1g TER for these configurations as the SPLS ratio between the antenna pairs was not greater than 0.02 per FCC KDB 447498 D04v01. Please see the Highest Report ER and Hotspot Location Section for peak locations.
3. Per KDB Workshop Notes, if the sum of two overlapping distributions is <1.0, those antennas can be determined to be co-located. In SPLSR analysis, the sum of the two ER values will be used with the worst-case coordinate. AG0 + BT Co-Located Ant R value in the table above is from AG0 WLAN ER + 2.4GHz Bluetooth Ant 1 at 10dBm, and AG1 + BT Co-Located Ant L value in the table above is from AG1 WLAN ER + 2.4 GHz Bluetooth Ant L at 10 dBm.

Table F-8
Simultaneous Transmission Scenarios of BT (Power Mode B)

Configuration	2.4 GHz Bluetooth Ant R at 15.25 dBm Ratio to Limit	2.4 GHz Bluetooth Ant L at 15.25 dBm Ratio to Limit	2.4 GHz Bluetooth Ant R at 15.25 dBm Ratio to Limit + 2.4 GHz Bluetooth Ant L at 15.25 dBm Ratio to Limit	Worst-case BT Scenario Ratio to Limit
Back	0.034	0.044	0.078	0.078
Top	0.412	0.552	0.964	0.964
Bottom	0.020	0.020	0.040	0.040
Right	0.176	0.023	0.199	0.199
Left	0.023	0.181	0.204	0.204

Table F-9
NFC + BT Power Mode B (WLAN not Active)

Body	Configuration	Wireless Charger NFC Ratio to Limit	Worst Case BT Scenario Ratio to Limit	NFC + BT Ratio to Limit
	Back	0.000	0.078	0.078
	Top	0.000	0.964	0.964
	Bottom	0.000	0.040	0.040
	Right	-	0.199	0.199
	Left	0.000	0.204	0.204

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F.6 Highest Report ER Hotspot Locations

Table F-10
Top Edge at 0mm Peak X, Y Coordinates

Mode/Band	Antenna	x (mm)	y (mm)	ER
2.4 WLAN	R	-19.20	58.60	0.573
5 GHz WLAN	R	-25.70	57.90	0.632
6 GHz WLAN	R	-18.70	58.50	0.602
2.4 GHz Bluetooth	R	-18.90	62.40	0.093
AG0 + BT Co-Located	R	-25.70	57.90	0.746
2.4 WLAN	L	-21.20	-59.50	0.424
5 GHz WLAN	L	-23.10	-45.80	0.675
6 GHz WLAN	L	-21.30	-57.50	0.424
2.4 GHz Bluetooth	L	-25.40	-59.10	0.115
AG1 + BT Co-Located	L	-23.10	-45.80	0.790
Wireless Charging NFC	-	-14.00	-156.00	0.000

F.7 Conclusion

The above numerical summed 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 limit and therefore no measured volumetric simultaneous summation is required per FCC KDB Publication 447498 D04v01 and IEEE 1528- 2013 Section 6.3.4.1.

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