

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 physical test configuration is ≤ 1.6 W/kg (or 4 W/kg for 10g). 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. 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.

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 Plus with pre-defined antenna groups (AG0 and AG1). The 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 with non-Smart Transmit Radios. For this model, WWAN/WLAN/BT Radios are managed under Smart Transmit. Non-Smart Transmit Radios include NFC/UWB.

When operating in the same antenna group, the compliance under dynamic transmission condition, including all supported simultaneous transmission scenarios, should be assessed and demonstrated in the Part 2 Report during algorithm validation. Therefore, no further simultaneous analysis is needed within an antenna group.

When all WWAN/WLAN/BT Radios are managed under Smart Transmit, TER for WWAN/WLAN/BT is covered in Part 2 testing. Only external radios outside of WWAN/WLAN/BT (UWB, NFC) require TER analysis with WWAN/WLAN/BT during simultaneous transmissions.

E.3 Sub6 Antenna Groups

The 2nd generation of Smart Transmit (GEN2) operates based on pre-defined antenna groups (AG). Sub6/WLAN/BT 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 AGs: AG0 and AG1, with AG0 having 2 antennas (A, B) and AG1 having 4 antennas (E, F, G, I).

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The conditions are verified through the following criteria:

- i) Sum of SAR: Demonstrate that the sum of *max.norm.exp.AG0* and *max.norm.exp.AG1* and the reported normalized SAR values from radios outside Smart Transmit (denoted as *reported.norm.exp.ER*) should be less than the regulatory limit for each supported DSI following the below procedure:
 1. Obtain the worst-case *adjusted SAR* for each antenna group, i.e., maximum *reported SAR* at EFS $P_{limit} + \text{unc}$ (or max of $\{P_{max} + \text{unc}, \text{EFS } P_{limit}\}$ when $\text{EFS } P_{limit} > P_{max}$) out of all supported technologies, frequency bands and antennas in AG0 and AG1, then normalized to the regulatory limit to get the maximum normalized SAR for each antenna group, denoted as: *max.norm.exp.AG0* and *max.norm.exp.AG1*
 2. For external radios outside of Smart Transmit (NFC/UWB): Obtain the worst-case RF exposure for each external radio normalized to regulatory limit to get the normalized SAR for each external radio, denoted as: *reported.norm.exp.NFC* and *reported.norm.exp.UWB*
 3. Demonstrate that the sum of these RF exposures meets: $\{max.norm.exp.AG0 + max.norm.exp.AG1 + reported.norm.exp.NFC + reported.norm.exp.UWB\} \leq 1$.
- ii) SPLSR or composite exposure distribution criteria: when TER sum of an antenna pair is over the limit for a DSI/exposure position, SPLSR or composite exposure distribution can be done to demonstrate simultaneous transmission compliance.
 1. SPLSR analysis for sub6 antenna pairs: For each antenna, obtain the highest *adjusted SAR* at EFS $P_{limit} + \text{unc}$ (or max of $\{P_{max} + \text{unc}, \text{EFS } P_{limit}\}$ when $\text{EFS } P_{limit} > P_{max}$) out of all supported technologies for each frequency band. Using these values, demonstrate for a given DSI that every antenna from one AG meets SPLSR criteria with every antenna in another AG for all frequency bands. This criterion must be demonstrated for all antenna pair combinations irrespective of supported simultaneous transmission scenarios as given below for each DSI. As it can be seen, these include all combinations of antenna groups, antennas, and frequency bands.
 - If SPLSR criteria evaluation and analysis are 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 ER and Hotspot Location Section below for each DSI configuration. For bottom AG0, Y_min coordinates represents the worst-case hotspot location that is closest to the top AG1. Similarly, for top AG1, Y_max 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:

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

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E.4 Exposure Ratios

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-PD-UWB based RF exposure limits is achieved if $TER_{SAR-UWB} \leq 1$. When $TER_{SAR-UWB} > 1$, 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 or SPLSR is ≤ 0.013 for 10g exposure conditions simultaneous SAR evaluation is not required.

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E.5 Head (DSI = 1) SAR Antenna Group Analysis

Table E-1
DSI=1 Held-to-ear AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit				
	Configuration	A	B	Max
Head	Right Cheek	0.154	0.139	0.154
	Right Tilt	0.103	0.084	0.103
	Left Cheek	0.171	0.173	0.173
	Left Tilt	0.101	0.079	0.101

Table E-2
DSI=1 Held-to-ear AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
	Configuration	E	F	G	I	MIMO	Max
Head	Right Cheek	0.602	0.653	0.839	0.450	0.756	0.839
	Right Tilt	0.521	0.692	0.509	0.052	0.555	0.692
	Left Cheek	0.822	0.357	0.208	0.672	0.806	0.822
	Left Tilt	0.706	0.433	0.206	0.078	0.746	0.746

Table E-3
Held-to-ear UWB Highest Ratio to Limit

	Configuration	UWB
Head	Right Cheek	0.001
	Right Tilt	0.002
	Left Cheek	0.001
	Left Tilt	0.001

Table E-4
DSI=1 Held-to-ear AG Verification

	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	UWB Ratio to Limit	AG0 + AG1 + UWB Ratio to Limit
Head	Right Cheek	0.154	0.839	0.001	0.994
	Right Tilt	0.103	0.692	0.002	0.797
	Left Cheek	0.173	0.822	0.001	0.996
	Left Tilt	0.101	0.746	0.001	0.848

Notes:

1. For all combinations where the TER sum of AG0+AG1+UWB is not greater than 1, there's no further analysis required for compliance demonstration.

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E.6 Body-worn (DSI = 0) SAR Antenna Group Analysis

Table E-5
DSI=0 Body-worn AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit				
	Configuration	A	B	Max
Body-worn	Back	0.800	0.605	0.800

Table E-6
DSI=0 Body-worn AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
	Configuration	E	F	G	I	MIMO	Max
Body-worn	Back	0.691	0.672	0.666	0.635	0.670	0.691

Table E-7
Body-worn UWB Highest Ratio to Limit

	Configuration	UWB
Body-worn	Back	0.001

Table E-8
DSI=0 Body-worn AG Verification

Bodyworn	Configuration		AG0 Ratio to Limit		AG1 Ratio to Limit		UWB Ratio to Limit		AG0 + AG1 + UWB Ratio to Limit	
	Back		0.800		0.691		0.001		See Table Below	

Back									
Bottom Set			Top Set					Bottom Set + Top Set Ratio to Limit	SPLSR
AG0			AG1			UWB			
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position	Ratio to Limit	Position		
Ant A	0.800	62.1	Ant E	0.691	-62.2	0.001	-92.8	1.492	0.01
Ant A	0.800	62.1	Ant F	0.672	-78.1	0.001	-92.8	1.473	0.01
Ant A	0.800	62.1	Ant G	0.666	-54.7	0.001	-92.8	1.467	0.02
Ant A	0.800	62.1	Ant I	0.635	-30.8	0.001	-92.8	1.436	0.02
Ant A	0.800	62.1	MIMO	0.670	-51.8	0.001	-92.8	1.471	0.02
Ant B	0.605	75.0	Ant E	0.691	-62.2	0.001	-92.8	1.297	0.01
Ant B	0.605	75.0	Ant F	0.672	-78.1	0.001	-92.8	1.278	0.01
Ant B	0.605	75.0	Ant G	0.666	-54.7	0.001	-92.8	1.272	0.01
Ant B	0.605	75.0	Ant I	0.635	-30.8	0.001	-92.8	1.241	0.01
Ant B	0.605	75.0	MIMO	0.670	-51.8	0.001	-92.8	1.276	0.01

Notes:

- For all combinations where the TER sum of AG0+AG1+UWB is not greater than 1, there's no further analysis required for compliance demonstration.
- 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 0.02 per FCC KDB 447498 D04v01. Please see the Highest Report ER and Hotspot Location Section for Y-axis peak locations

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E.7 Hotspot (DSI = 0) SAR Antenna Group Analysis

Table E-9
DSI=0 Hotspot AG0 Adjusted Ratio to Limit

AG0 Ratio to Limit				
	Configuration	A	B	Max
Hotspot	Back	0.800	0.605	0.800
	Front	0.751	0.387	0.751
	Top	-	-	-
	Bottom	0.719	0.246	0.719
	Right	0.149	0.136	0.149
	Left	0.171	-	0.171

Table E-10
DSI=0 Hotspot AG1 Adjusted Ratio to Limit

AG1 Ratio to Limit							
	Configuration	E	F	G	I	MIMO	Max
Hotspot	Back	0.691	0.672	0.666	0.635	0.516	0.691
	Front	0.540	0.450	0.571	0.612	0.281	0.612
	Top	0.287	0.395	0.114	0.009	0.079	0.395
	Bottom	-	-	-	-	-	-
	Right	0.194	-	-	0.061	0.036	0.194
	Left	-	0.058	0.554	-	0.344	0.554

Table E-11
DSI=0 Hotspot AG Verification

		AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
Hotspot	Back	0.800	0.691	See Table Below
	Front	0.751	0.612	See Table Below
	Top	-	0.395	0.395
	Bottom	0.719	-	0.719
	Right	0.149	0.194	0.343
	Left	0.171	0.554	0.725

Back							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant A	0.800	62.1	Ant E	0.691	-66.6	1.491	0.01
Ant A	0.800	62.1	Ant F	0.672	-78.1	1.472	0.01
Ant A	0.800	62.1	Ant G	0.666	-54.7	1.466	0.02
Ant A	0.800	62.1	Ant I	0.635	-34.8	1.435	0.02
Ant A	0.800	62.1	MIMO	0.516	-51.8	1.316	0.01
Ant B	0.605	75.0	Ant E	0.691	-66.6	1.296	0.01
Ant B	0.605	75.0	Ant F	0.672	-78.1	1.277	0.01
Ant B	0.605	75.0	Ant G	0.666	-54.7	1.271	0.01
Ant B	0.605	75.0	Ant I	0.635	-34.8	1.24	0.01
Ant B	0.605	75.0	MIMO	0.516	-51.8	1.121	0.01
Front							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant A	0.751	70.1	Ant E	0.54	-77.2	1.291	0.01
Ant A	0.751	70.1	Ant F	0.45	-80	1.201	0.01
Ant A	0.751	70.1	Ant G	0.571	-51.6	1.322	0.01
Ant A	0.751	70.1	Ant I	0.612	-33.5	1.363	0.02
Ant A	0.751	70.1	MIMO	0.281	-54.5	1.032	0.01
Ant B	0.387	78.1	Ant E	0.54	-77.2	0.927	N/A
Ant B	0.387	78.1	Ant F	0.45	-80	0.837	N/A
Ant B	0.387	78.1	Ant G	0.571	-51.6	0.958	N/A
Ant B	0.387	78.1	Ant I	0.612	-33.5	0.999	0.01
Ant B	0.387	78.1	MIMO	0.281	-54.5	0.668	N/A

Notes:

1. For all combinations where the TER sum of AG0+AG1 is not greater than 1, there's no further analysis required for compliance demonstration.
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 0.02 per FCC KDB 447498 D04v01. Please see the Highest Report ER and Hotspot Location Section for Y-axis peak locations

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E.8 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 E-12
DSI=0 Phablet AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit						
	Configuration	E	G	I	MIMO	Max
Phablet	Back	0.091	0.327	0.147	0.476	0.476
	Front	0.093	0.196	0.421	0.262	0.421
	Top	0.058	0.077	0.004	0.167	0.167
	Bottom	-	-	-	-	-
	Right	0.037	-	0.101	0.046	0.101
	Left	-	0.564	-	0.587	0.587

Table E-13
Simultaneous Transmission Scenarios of NFC/UWB/WPT (Phablet)

	Configuration	WPT	UWB	NFC	WPT + UWB + NFC Ratio to Limit
Phablet	Back	0.000	0.000	0.003	0.003
	Front	0.000	0.000	0.000	0.000
	Top	0.000	0.001	0.000	0.001
	Bottom	0.000	0.000	0.000	0.000
	Right	0.000	0.001	0.000	0.001
	Left	0.000	0.000	0.000	0.000

Table E-14
DSI=0 Phablet AG Verification

	Configuration	AG1 Ratio to Limit	NFC + UWB + WPT Ratio to Limit	AG1 + NFC + UWB + WPT Ratio to Limit
Phablet	Back	0.476	0.003	0.479
	Front	0.421	0.000	0.421
	Top	0.167	0.001	0.168
	Bottom	-	0.000	0.000
	Right	0.101	0.001	0.102
	Left	0.587	0.000	0.587

Notes:

- For all combinations where the TER sum of AG1+WPT+UWB+NFC is not greater than 1, there's no further analysis required for compliance demonstration.

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E.9 Highest Report SAR and SAR Hotspot Locations

As a conservative assessment, the distances between Bottom Set and Top Set were determined using the y-axis coordinates of the peak locations only (assumes 0 mm separation on x/z axis)

Table E-15
DSI=0 Body-worn Back Peak Y Coordinates

Antenna Group	Antenna	Mode/Band	ER	Y-Coord
AG0	A	GSM 850	0.692	65.9
AG1	E	GSM 850	0.578	-88.8
AG0	A	GSM 1900	0.798	81.5
AG0	A	UMTS 850	0.614	66.5
AG1	E	UMTS 850	0.691	-87.0
AG0	A	LTE Band 12	0.613	65.1
AG1	E	LTE Band 12	0.563	-86.3
AG0	A	LTE Band 13	0.621	65.1
AG1	E	LTE Band 13	0.551	-86.3
AG0	A	LTE Band 5	0.623	62.1
AG1	E	LTE Band 5	0.536	-86.0
AG0	A	LTE Band 66	0.800	83.6
AG0	A	LTE Band 2	0.780	80.8
AG0	B	LTE Band 41	0.543	75.0
AG1	F	LTE Band 41	0.672	-78.1
AG0	A	NR Band n5	0.614	72.5
AG1	E	NR Band n5	0.635	-82.4
AG0	A	NR Band n66	0.719	81.7
AG1	F	NR Band n66	0.625	-92.7
AG0	B	NR Band n41	0.605	80.9
AG1	F	NR Band n41	0.585	-81.6
AG1	G	2.4 GHz WIFI	0.666	-54.7
AG1	I	2.4 GHz WIFI	0.635	-34.8
AG1	MIMO	2.4 GHz WIFI	0.516	-51.8
AG1	E	5 GHz WIFI	0.680	-62.2
AG1	G	5 GHz WIFI	0.579	-66.1
AG1	MIMO	5 GHz WIFI	0.670	-67.2
AG1	E	6 GHz WIFI	0.364	-67.9
AG1	G	6 GHz WIFI	0.213	-72.5
AG1	MIMO	6 GHz WIFI	0.326	-58.9
AG1	G	2.4 GHz Bluetooth	0.490	-61.4
AG1	I	2.4 GHz Bluetooth	0.609	-30.8
AG1	MIMO	2.4 GHz Bluetooth	0.650	-53.9
N/A	H	UWB	0.001	-92.8

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Table E-16
DSI=0 Hotspot Back Side Peak Y Coordinates

Antenna Group	Antenna	Mode/Band	ER	Y-Coord
AG0	A	GSM 850	0.692	65.9
AG1	E	GSM 850	0.578	-88.8
AG0	A	GSM 1900	0.798	81.5
AG0	A	UMTS 850	0.614	66.5
AG1	E	UMTS 850	0.691	-87.0
AG0	A	LTE Band 12	0.613	65.1
AG1	E	LTE Band 12	0.563	-86.3
AG0	A	LTE Band 13	0.621	65.1
AG1	E	LTE Band 13	0.551	-86.3
AG0	A	LTE Band 5	0.623	62.1
AG1	E	LTE Band 5	0.536	-86.0
AG0	A	LTE Band 66	0.800	83.6
AG0	A	LTE Band 2	0.780	80.8
AG0	B	LTE Band 41	0.543	75.0
AG1	F	LTE Band 41	0.672	-78.1
AG0	A	NR Band n5	0.614	72.5
AG1	E	NR Band n5	0.635	-82.4
AG0	A	NR Band n66	0.719	81.7
AG1	F	NR Band n66	0.625	-92.7
AG0	B	NR Band n41	0.605	80.9
AG1	F	NR Band n41	0.585	-81.6
AG1	G	2.4 GHz WIFI	0.666	-54.7
AG1	I	2.4 GHz WIFI	0.635	-34.8
AG1	MIMO	2.4 GHz WIFI	0.516	-51.8
AG1	E	5 GHz WIFI	0.473	-66.6
AG1	G	5 GHz WIFI	0.409	-64.5
AG1	MIMO	5 GHz WIFI	0.489	-64.7
AG1	E	6 GHz WIFI	0.364	-67.9
AG1	G	6 GHz WIFI	0.213	-72.5
AG1	MIMO	6 GHz WIFI	0.326	-58.9
AG1	G	2.4 GHz Bluetooth	0.490	-61.4

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Table E-17
DSI=0 Hotspot Front Side Peak Y Coordinates

Antenna Group	Antenna	Mode/Band	ER	Y-Coord
AG0	A	GSM 850	0.260	73.2
AG1	E	GSM 850	0.540	-84.9
AG0	A	GSM 1900	0.751	82.5
AG0	A	UMTS 850	0.270	71.1
AG1	E	UMTS 850	0.526	-86.8
AG0	A	LTE Band 12	0.314	71.1
AG1	E	LTE Band 12	0.442	-86.4
AG0	A	LTE Band 13	0.323	71.1
AG1	E	LTE Band 13	0.450	-86.4
AG0	A	LTE Band 5	0.339	70.1
AG1	E	LTE Band 5	0.437	-86.5
AG0	A	LTE Band 66	0.702	85.3
AG0	A	LTE Band 2	0.729	86.1
AG0	B	LTE Band 41	0.387	78.1
AG1	F	LTE Band 41	0.388	-80.7
AG0	A	NR Band n5	0.291	71.1
AG1	E	NR Band n5	0.462	-87.1
AG0	A	NR Band n66	0.740	80.0
AG1	F	NR Band n66	0.450	-87.0
AG0	B	NR Band n41	0.335	88.1
AG1	F	NR Band n41	0.406	-80.0
AG1	G	2.4 GHz WIFI	0.571	-51.6
AG1	I	2.4 GHz WIFI	0.612	-33.5
AG1	MIMO	2.4 GHz WIFI	0.281	-54.5
AG1	E	5 GHz WIFI	0.128	-78.1
AG1	G	5 GHz WIFI	0.151	-66.9
AG1	MIMO	5 GHz WIFI	0.199	-72.6
AG1	E	6 GHz WIFI	0.043	-77.2
AG1	G	6 GHz WIFI	0.083	-66.1
AG1	MIMO	6 GHz WIFI	0.084	-69.5
AG1	G	2.4 GHz Bluetooth	0.392	-56.2

E.10 Conclusion

The above numerical summed TER results and SPLSR for all the combinations of antenna groups are sufficient to show that AG0 is mutually exclusive from AG1 and TER is < 1. TER 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 6.3.4.1.2.

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