

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. The more conservative standalone reported SAR between the permissive change and the original filing was used to determine simultaneous transmission compliance. Please see the original filing for the standalone reported SAR for modes and bands that were not evaluated or higher than the permissive change.

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 antenna groups (AG0 and AG1). Sub6 antennas cannot be decoupled from each other due to lack of regulatory criteria. 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)

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- 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. These criteria must be demonstrated for all antenna combinations for each pair of AGs.

This device supports two AGs: AG0 and AG1, with AG0 having 4 antennas (A, B, C, D) and AG1 having 4 antennas (E, F, G, H).

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 Ratio to Limit* for each antenna group, i.e., maximum *reported* SAR at EFS $P_{limit} + unc$ (or max of $\{P_{max} + unc, EFS P_{limit}\}$ when $EFS P_{limit} > P_{max}$) 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: $\{max.norm.exp.AG0 + max.norm.exp.AG1 + normalized\ NFC\ SAR + normalized\ UWB\ SAR\} \leq 1$.
- 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 Ratio to Limit* at EFS $P_{limit} + unc$ (or max of $\{P_{max} + unc, EFS P_{limit}\}$ when $EFS P_{limit} > P_{max}$) 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 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 bottom AG0, Y_max coordinates 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:

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

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E.4 Exposure Ratios

Exposure ratio (ER) for different transmitters is calculated as following:

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

$$ER_{PD,n} = \frac{PD_n}{PD_{limit}}$$

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
- P_{txm} is the higher of maximum time-averaged conducted power or EIRP associated with the m -th UWB transmitters

Compliance with the SAR-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 = 3) SAR Antenna Group Analysis

Table E-1
DSI=3 Held-to-ear AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit							
Head	Configuration	A	B	A+C	C	D	Max
	Right Cheek	0.258	0.348	0.321	0.000	0.012	0.348
	Right Tilt	0.181	0.215	0.214	0.000	0.000	0.215
	Left Cheek	0.227	0.246	0.206	0.000	0.000	0.246
	Left Tilt	0.136	0.126	0.136	0.000	0.000	0.136

Table E-2
DSI=3 Held-to-ear AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
Head	Configuration	E	F	G	H	MIMO	Max
	Right Cheek	0.545	0.518	0.641	0.614	0.520	0.641
	Right Tilt	0.613	0.610	0.779	0.203	0.621	0.779
	Left Cheek	0.624	0.608	0.743	0.618	0.551	0.743
	Left Tilt	0.619	0.619	0.857	0.395	0.616	0.857

Table E-3
DSI=3 Held-to-ear AG Verifications

Head	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Right Cheek	0.348	0.641	0.989
	Right Tilt	0.215	0.779	0.994
	Left Cheek	0.246	0.743	0.989
	Left Tilt	0.136	0.857	0.993

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.

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E.6 Body-worn (DSI = 1) SAR Antenna Group Analysis

Table E-4
DSI=1 Body-worn AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit							
Bodyworn	Configuration	A	B	A+C	C	D	Max
	Back	0.536	0.821	0.624	0.460	0.116	0.821
	Front	0.194	0.417	0.214	0.042	0.019	0.417

Table E-5
DSI=1 Body-worn AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
Bodyworn	Configuration	E	F	G	H	MIMO	Max
	Back	0.740	0.801	0.822	0.619	0.823	0.823
	Front	0.169	0.174	0.345	0.079	0.217	0.345

Table E-6
DSI=1 Body-worn AG Verification

Bodyworn	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Back	0.821	0.823	See Table Below
	Front	0.417	0.345	0.762

Back							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant D	0.116	N/A	Ant E	0.740	N/A	0.856	N/A
Ant D	0.116	N/A	Ant F	0.801	N/A	0.917	N/A
Ant D	0.116	N/A	Ant G	0.822	N/A	0.938	N/A
Ant D	0.116	N/A	Ant H	0.619	N/A	0.735	N/A
Ant D	0.116	N/A	MIMO	0.823	N/A	0.939	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. Please see the original filing for the standalone reported SAR for modes and bands that were not evaluated for this permissive change. The standalone reported SAR in the original filing was used to determine simultaneous transmission compliance as it is more conservative.

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E.7 Hotspot (DSI = 1) SAR Antenna Group Analysis

Table E-7
DSI=1 Hotspot AG0 Adjusted Ratio to Limit

AG0 Ratio to Limit							
Hotspot	Configuration	A	B	A+C	C	D	Max
	Back	0.536	0.821	0.624	0.460	0.116	0.821
	Front	0.194	0.417	0.214	0.042	0.019	0.417
	Top	-	-	-	-	-	-
	Bottom	0.116	0.518	0.169	0.095	-	0.518
	Right	0.253	-	0.416	0.012	0.014	0.416
	Left	-	0.073	0.123	0.010	-	0.123

Table E-8
DSI=1 Hotspot AG1 Adjusted Ratio to Limit

AG1 Ratio to Limit							
Hotspot	Configuration	E	F	G	H	MIMO	Max
	Back	0.625	0.801	0.822	0.619	0.666	0.822
	Front	0.169	0.090	0.345	0.079	0.168	0.345
	Top	0.249	0.229	0.417	-	0.389	0.417
	Bottom	-	-	-	-	-	-
	Right	0.328	-	0.065	0.166	0.189	0.328
	Left	-	0.035	-	-	0.051	0.051

Table E-9
DSI=1 Hotspot AG Verification

Hotspot		AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Back	0.821	0.822	See Table Below
	Front	0.417	0.345	0.762
	Top	-	0.417	0.417
	Bottom	0.518	-	0.518
	Right	0.416	0.328	0.744
	Left	0.123	0.051	0.174

Back							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant D	0.116	N/A	Ant E	0.625	N/A	0.741	N/A
Ant D	0.116	N/A	Ant F	0.801	N/A	0.917	N/A
Ant D	0.116	N/A	Ant G	0.822	N/A	0.938	N/A
Ant D	0.116	N/A	Ant H	0.619	N/A	0.735	N/A
Ant D	0.116	N/A	MIMO	0.666	N/A	0.782	N/A

Notes:

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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. Please see the original filing for the standalone reported SAR for modes and bands that were not evaluated for this permissive change. The standalone reported SAR in the original filing was used to determine simultaneous transmission compliance as it is more conservative.

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E.8 Max Tablet (DSI=0) SAR Antenna Group Analysis

Table E-10
DSI=0 Max Tablet AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit							
Body	Configuration	A	B	A+C	C	D	Max
	Back	0.553	0.824	0.740	0.623	0.166	0.824
	Front	-	-	-	-	-	-
	Top	0.001	0.052	0.041	0.000	0.003	0.052
	Bottom	0.068	0.767	0.546	0.464	0.006	0.767
	Right	0.053	0.047	0.739	0.150	0.042	0.739
	Left	0.000	0.015	0.030	0.006	0.010	0.030

Table E-11
DSI=0 Max Tablet AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
Body	Configuration	E	F	G	H	MIMO	Max
	Back	0.761	0.696	0.857	0.807	0.835	0.857
	Front	-	-	-	-	-	-
	Top	0.833	0.817	0.653	0.047	0.795	0.833
	Bottom	0.062	0.003	0.031	0.007	0.009	0.062
	Right	0.727	0.124	0.865	0.581	0.669	0.865
	Left	0.028	0.009	0.144	0.003	0.015	0.144

Table E-12
Simultaneous Transmission Scenarios of NFC/UWB (Tablet)

Body SAR	Right	NFC Ratio to Limit	UWB Ratio to Limit
	Back	0.001	0.001
	Front	-	-
	Top	0.000	0.003
	Bottom	0.000	0.001
	Right	0.000	0.001
	Left	0.000	0.001

Table E-13
DSI=0 Max Tablet AG Verification

Body	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	NFC + UWB Ratio to Limit	AG0 + AG1 + NFC + UWB Ratio to Limit
	Back	0.824	0.857	0.002	See Table Below
	Top	0.052	0.833	0.003	0.888
	Bottom	0.767	0.062	0.001	0.830
	Right	0.739	0.865	0.001	See Table Below
	Left	0.030	0.144	0.001	0.175

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Back											
Bottom Set			Top Set							Bottom Set + Top Set Ratio to Limit	SPLSR
AG0			AG1			NFC		UWB			
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position	Ratio to Limit	Position	Ratio to Limit	Position		
Ant A	0.553	-74.6	Ant G	0.857	44.9	0.001	37.8	0.001	113.5	See Note 2	0.01
Ant B	0.824	-81.6	Ant G	0.857	44.9	0.001	37.8	0.001	113.5	See Note 2	0.02
Ant A+C	0.74	-77.2	Ant G	0.857	44.9	0.001	37.8	0.001	113.5	See Note 2	0.02
Ant C	0.623	-80.1	Ant G	0.857	44.9	0.001	37.8	0.001	113.5	See Note 2	0.02
Ant D	0.166	-28.8	Ant G	0.857	44.9	0.001	37.8	0.001	113.5	See Note 2	0.02
Right											
Bottom Set			Top Set							Bottom Set + Top Set Ratio to Limit	SPLSR
AG0			AG1			NFC		UWB			
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position	Ratio to Limit	Position	Ratio to Limit	Position		
Ant A	0.053	N/A	Ant F	0.124	N/A	0	N/A	0.001	N/A	0.178	N/A
Ant B	0.047	N/A	Ant E	0.727	N/A	0	N/A	0.001	N/A	0.775	N/A
Ant B	0.047	N/A	Ant F	0.124	N/A	0	N/A	0.001	N/A	0.172	N/A
Ant B	0.047	N/A	Ant G	0.865	N/A	0	N/A	0.001	N/A	0.913	N/A
Ant B	0.047	N/A	Ant H	0.581	N/A	0	N/A	0.001	N/A	0.629	N/A
Ant B	0.047	N/A	MIMO	0.669	N/A	0	N/A	0.001	N/A	0.717	N/A
Ant A+C	0.739	N/A	Ant F	0.124	N/A	0	N/A	0.001	N/A	0.864	N/A
Ant C	0.15	N/A	Ant F	0.124	N/A	0	N/A	0.001	N/A	0.275	N/A
Ant D	0.042	N/A	Ant F	0.124	N/A	0	N/A	0.001	N/A	0.167	N/A

Notes:

1. For all combinations where the TER sum of AG0+AG1+UWB+NFC 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 SPLSR ratio between the antenna pairs was not greater than 0.02 per FCC KDB 447498 D04v01. Please see the Highest Report SAR and Hotspot Location Section for Y-axis peak locations.
3. Please see the original filing for the standalone reported SAR for modes and bands that were not evaluated for this permissive change. The standalone reported SAR in the original filing was used to determine simultaneous transmission compliance as it is more conservative.

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E.9 Reduced Tablet (DSI=4) SAR Antenna Group Analysis

Please refer to the above section, E.9 Max Tablet (DSI=0) SAR Antenna Group Analysis for DSI=4 evaluation for bottom, left, and right tablet edges as there is no change in these edges between DSI=0 and DSI=4.

Table E-14
DSI=4 Reduced Tablet AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
Body	Configuration	E	F	G	H	MIMO	Max
	Top	0.833	0.817	0.807	0.047	0.795	0.833

Table E-15
DSI=4 Reduced Tablet AG Verification

Body	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	NFC + UWB Ratio to Limit	AG0 + AG1 + NFC + UWB Ratio to Limit
	Top	0.052	0.833	0.003	0.888

Please see Table E-12 for AG0 Tablet worst case results and Table E-15 for NFC/UWB Tablet worst case results

Notes:

1. For all combinations where the TER sum of AG0+AG1+UWB+NFC is not greater than 1, there's no further analysis required for compliance demonstration.
2. The standalone reported SAR in the original filing was used to determine simultaneous transmission compliance as it is more conservative. Please see the original filing for complete evaluation of simultaneous transmission analysis

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E.10 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). Please see the original filing for the standalone reported SAR for modes and bands that were not evaluated for this permissive change.

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

		Top Set
		AG1
		G
Mode/Band	Distance	10 mm
NR Band n41 Ant G	ER	0.857
	Y-Axis	78.500

E.11 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.

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