APPENDIX E: MULTI-TX AND ANTENNA SAR CONSIDERATIONS

E.1 Introduction

The following procedures adopted from FCC KDB Publication 447498 D01v06 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 D01v06 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. Total Exposure Ratio (TER) is used to show the maximum TER between APD and SAR values therefor the limit for simultaneous exposure becomes TER ≤ 1.0.

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). This device operates using GEN2_SUB6 (Sub6-favor mode). 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 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 the conditions below 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. 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 2 antennas (A, B) and AG1 having 5 antennas (E, F, H, I, J). 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} +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: $\{max.norm.exp.AG0 + max.norm.exp.AG1 + \text{normalized NFC SAR} + \text{normalized UWB SAR}\} \leq 1$.

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* 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 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:

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

E.4 Head (DSI = 1) 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	0.622	0.627	0.627
	Right Tilt	0.390	0.175	0.390
	Left Cheek	0.376	0.264	0.376
	Left Tilt	0.358	0.241	0.358

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

AG1 Ratio to Limit							
	Configuration	E	F	H	J	MIMO	Max
Head	Right Cheek	0.623	0.561	0.620	0.361	0.621	0.623
	Right Tilt	0.489	0.733	0.351	0.056	0.332	0.733
	Left Cheek	0.745	0.454	0.177	0.623	0.344	0.745
	Left Tilt	0.637	0.499	0.167	0.088	0.308	0.637

Table E-3
DSI=1 Held-to-ear AG Verification

Head	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Right Cheek	0.627	0.623	See Table Below
	Right Tilt	0.390	0.733	See Table Below
	Left Cheek	0.376	0.745	See Table Below
	Left Tilt	0.358	0.637	0.995

Right Cheek							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant A	0.622	-77.38	Ant E	0.623	6.26	See Note 1	0.01
Ant A	0.622	-77.38	Ant F	0.561	5.31	See Note 1	0.01
Ant A	0.622	-77.38	Ant H	0.620	-15.41	See Note 1	0.02
Ant A	0.622	N/A	Ant J	0.361	N/A	0.983	N/A
Ant A	0.622	-77.38	MIMO	0.621	-12.41	See Note 1	0.02
Ant B	0.627	-77.38	Ant E	0.623	6.26	See Note 1	0.01
Ant B	0.627	-77.38	Ant F	0.561	5.31	See Note 1	0.01
Ant B	0.627	-77.38	Ant H	0.620	-15.41	See Note 1	0.02
Ant B	0.627	N/A	Ant J	0.361	N/A	0.988	N/A
Ant B	0.627	-77.38	MIMO	0.621	-12.41	See Note 1	0.02

Right Tilt							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant A	0.390	N/A	Ant E	0.489	N/A	0.879	N/A
Ant A	0.390	-59.49	Ant F	0.733	1.49	See Note 1	0.02
Ant A	0.390	N/A	Ant H	0.351	N/A	0.741	N/A
Ant A	0.390	N/A	Ant J	0.056	N/A	0.446	N/A
Ant A	0.390	N/A	MIMO	0.332	N/A	0.722	N/A
Ant B	0.175	N/A	Ant E	0.489	N/A	0.664	N/A
Ant B	0.175	N/A	Ant F	0.733	N/A	0.908	N/A
Ant B	0.175	N/A	Ant H	0.351	N/A	0.526	N/A
Ant B	0.175	N/A	Ant J	0.056	N/A	0.231	N/A
Ant B	0.175	N/A	MIMO	0.332	N/A	0.507	N/A
Left Cheek							
AG0			AG1			AG0 + AG1 Ratio to Limit	SPLSR
Antenna	Ratio to Limit	Position	Antenna	Ratio to Limit	Position		
Ant A	0.376	-58.26	Ant E	0.745	1.12	See Note 1	0.02
Ant A	0.376	N/A	Ant F	0.454	N/A	0.830	N/A
Ant A	0.376	N/A	Ant H	0.177	N/A	0.553	N/A
Ant A	0.376	N/A	Ant J	0.623	N/A	0.999	N/A
Ant A	0.376	N/A	MIMO	0.344	N/A	0.720	N/A
Ant B	0.264	-52.30	Ant E	0.745	1.12	See Note 1	0.01
Ant B	0.264	N/A	Ant F	0.454	N/A	0.718	N/A
Ant B	0.264	N/A	Ant H	0.177	N/A	0.441	N/A
Ant B	0.264	N/A	Ant J	0.623	N/A	0.887	N/A
Ant B	0.264	N/A	MIMO	0.344	N/A	0.608	N/A

Notes:

1. 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 D01v06. Since TER was used in this evaluation the FCC SPLSR Limit of 0.04 is equivalent to the TER SPLSR of 0.02.
2. As a conservative assessment, the distances between AG0 and AG1 were determined using the worst case Y-axis coordinates of the peak locations only (assumes 0 mm separation on x/z axis) per antenna.
3. For all combinations where the TER sum of AG0+AG1 is not greater than 1, there's no further analysis required for compliance demonstration.

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

Table E-4
DSI=0 Body-worn AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit				
Bodyworn	Configuration	A	B	Max
	Back	0.459	0.269	0.459

Table E-5
DSI=0 Body-worn AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
Bodyworn	Configuration	E	F	H	J	MIMO	Max
	Back	0.483	0.231	0.246	0.361	0.310	0.483

Table E-6
DSI=0 Body-worn AG Verification

Bodyworn	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Back	0.459	0.483	0.942

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.

E.6 Hotspot (DSI = 0) SAR Antenna Group Analysis

Table E-7
DSI=0 Hotspot AG0 Highest Adjusted Ratio to Limit

AG0 Ratio to Limit				
	Configuration	A	B	Max
Hotspot	Back	0.459	0.269	0.459
	Front	0.290	0.191	0.290
	Top	-	-	-
	Bottom	0.731	0.331	0.731
	Right	0.225	0.302	0.302
	Left	0.295	-	0.295

Table E-8
DSI=0 Hotspot AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit							
	Configuration	E	F	H	J	MIMO	Max
Hotspot	Back	0.483	0.231	0.246	0.361	0.256	0.483
	Front	0.549	0.166	0.196	0.622	0.238	0.622
	Top	0.625	0.580	0.163	0.016	0.135	0.625
	Bottom	-	-	-	-	-	-
	Right	0.564	-	-	0.096	0.083	0.564
	Left	-	0.081	0.621	-	0.615	0.621

Table E-9
DSI=0 Hotspot AG Verification

Hotspot	Configuration	AG0 Ratio to Limit	AG1 Ratio to Limit	AG0 + AG1 Ratio to Limit
	Back	0.459	0.483	0.942
	Front	0.290	0.622	0.912
	Top	-	0.625	0.625
	Bottom	0.731	-	0.731
	Right	0.302	0.564	0.866
	Left	0.295	0.621	0.916

Notes:

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

E.7 Phablet (DSI = 0) 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-10
DSI=0 Phablet AG1 Highest Adjusted Ratio to Limit

AG1 Ratio to Limit					
	Configuration	E	H	MIMO	Max
Phablet	Back	0.131	0.239	0.185	0.239
	Front	0.063	0.177	0.185	0.185
	Top	0.059	0.069	0.073	0.073
	Bottom	-	-	-	-
	Right	0.049	-	0.045	0.049
	Left	-	0.654	0.535	0.654

Table E-11
DSI=0 Phablet AG, NFC and UWB Verification

	Configuration	AG1 Ratio to Limit	NFC Ratio to Limit	UWB Ratio to Limit	AG0 + AG1 + NFC + UWB Ratio to Limit
Phablet SAR	Back	0.239	0.005	0.000	0.244
	Front	0.185	0.000	0.000	0.185
	Top	0.073	0.000	0.000	0.073
	Bottom	-	-	-	-
	Right	0.049	-	-	0.049
	Left	0.654	0.000	0.000	0.654

Notes:

3. For all combinations where the TER sum of AG1 +UWB+NFC is not greater than 1, 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 antenna groups are sufficient to show that AG0 is mutually exclusive from AG1. TER simultaneous transmission cases will not exceed the SAR limit or and therefore no measured volumetric simultaneous SAR summation is required per FCC KDB Publication 447498 D01v06 and IEEE 1528- 2013 Section 6.3.