APPENDIX C: TOTAL EXPOSURE RATIO

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The Total Exposure Ratio (TER) is calculated by combining all SAR measurements and power density measurements after normalizing to their respective limits. The general expression is below.

$$TER = \sum_{a=1}^{A} \frac{SAR_a}{SAR_a, limit} + \sum_{b=1}^{B} \frac{psPD_b}{psPD_b, limit} < 1$$

The TER shall be less than unity to ensure compliance with the limits.

$$\sum_{n=1}^{N} \frac{4G SAR_n}{4G SAR_n, limit} + \sum_{m=1}^{M} \frac{5G mmW NR psPD_m}{5G mmW NR psPD_m, limit} + \sum_{p=1}^{P} \frac{WLAN SAR_p}{WLAN SAR_p, limit} < 1$$

Qualcomm[®] Smart Transmit algorithm for WWAN adds directly the time-averaged RF exposure from 4G and timeaveraged RFexposure from 5G mmW NR. Smart Transmit algorithm controls the total RF exposure from both 4G and 5G mmW NR to not exceed FCC limit. Therefore, per FCC guidance, TER does not need to be evaluated directly for the 4G and 5G simultaneous compliance via summation. The following equations are derived later in Appendix C. The validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report. The report SN could be found in Bibliography section.

$$\sum_{n=1}^{N} \frac{4G SAR_n}{4G SAR_n, limit} + \sum_{p=1}^{P} \frac{WLAN SAR_p}{WLAN SAR_p, limit} < 1$$

$$\sum_{n=1}^{M} \frac{5G mmW NR psPD_m}{5G mmW NR psPD_m, limit} + \sum_{p=1}^{P} \frac{WLAN SAR_p}{WLAN SAR_p, limit} < 1$$

For 5G mmW NR, since there is total design-related uncertainty arising from TxAGC and device-to-device variation, the worst-case RF exposure should be determined by accounting for device uncertainty. For this device, the manufacturer has added an additional permanent back-off (indicated below as WWAN backoff) for every beam in the calculations for input.power.limits used in the EFS file. The back-off levels can be found in the Part 0 Test report. Therefore, 5G mmW NR RF exposure for this DUT is evaluated by reported psPD calculated as:

reported_psPD= (PD_design_target+PD_uncertainty) x 10^{(-WWAN backoff in dB)/10}

Note that since not all the beams supported by this EUT are measured, *reported_psPD* cannot be computed based on limited *measured psPD* data. Alternatively, since *measured psPD* for all the beams will be \leq *PD_design_target* + *PD_uncertainty* uncertainty, *reported_psPD* is computed based on this worst-case psPD as shown above.

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The compliance analysis for simultaneous transmission scenarios of WWAN (4G LTE & 5G mmW NR) with Smart Transmit and 4G & WLAN can be found in two reports indicated in the table below. This appendix demonstrates compliance for the 5G + WLAN scenarios. The report SNs can be found in Bibliography section.

Ī		Simultaneous Scenario	Evaluation Report
Ī	1.	4G LTE WWAN + WLAN	FCC SAR Evaluation Report (Part 1)
	2.	4G LTE WWAN + 5G mmW NR WWAN	RF Exposure Part 2 Test Report

RF exposure compliance with 5G mmW NR WWAN+WLAN simultaneous transmission scenarios is demonstrated for various radio configurations below.

Note that the above *reported psPD* applies to the worst-case surfaces of the DUT at 2mm evaluation distance.

Worst-case PD on other surfaces of the DUT are calculated from simulated PD data (see Power Density Simulation Report), by multiplying reported psPD with the highest proportion out of all beams and out of all three channels in each band, where the adjustment for each beam/channel is computed as the proportion of "simulated PD on desired surface" to "simulated PD on worst-surface". For example, to determine worst-case PD on front surface (needed for Head RF Exposure evaluation during simultaneous transmission), highest proportion of (simulated PD on worst surface) was determined out of all supported beams and out of all three channels by the DUT in each band.

In some cases, the simulation vs measurement for some surfaces can exceed the device's total uncertainty. In those cases, if the measured psPD > simulated adjusted psPD (assuming a linear congruency of the psPD across surfaces), then measured psPD should be used towards the simultaneous TX analysis. Table C-1 lists the relevant worst-case reported psPD values based on the additional surfaces and evaluation distances needed to perform the TER analysis. The highest of the adjusted Reported_psPD and Measured Total psPD was chosen for TER analysis and the chosen values are indicated by bolded psPD values.

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			5G mmW	<u>/ NR FR2 psP</u>	D		
NR Band	<u>Antenna</u>	<u>Surface</u>	Evaluation Distance (mm)	Adjustment Factor due to Simulation	Adjusted Reported psPD (mW/cm ²)	<u>Measured Total</u> psPD (mW/cm ²)	Final Reported psPD (mW/cm ²)
n258	М	Back	2	1.000	0.891	0.601	0.891
n258	М	Front	2	0.370	0.329	0.036	0.329
n258	М	Тор	2	0.244	0.217	0.073	0.217
n258	М	Bottom	2	0.022	0.020	-	0.020
n258	М	Right	2	0.059	0.053	-	0.053
n258	М	Left	2	0.857	0.764	0.241	0.764
n258	N	Back	2	1.000	0.891	0.384	0.891
n258	N	Front	2	0.466	0.416	0.090	0.416
n258	N	Тор	2	0.034	0.030	-	0.030
n258	N	Bottom	2	0.131	0.117	-	0.117
n258	N	Right	2	1.000	0.891	0.284	0.891
n258	N	Left	2	0.052	0.046	-	0.046
n261	М	Back	2	1.000	0.891	0.609	0.891
n261	М	Front	2	0.170	0.152	0.022	0.152
n261	М	Тор	2	0.153	0.137	0.100	0.137
n261	М	Bottom	2	0.020	0.018	-	0.018
n261	М	Right	2	0.047	0.041	-	0.041
n261	М	Left	2	0.803	0.716	0.268	0.716
n261	N	Back	2	1.000	0.891	0.507	0.891
n261	N	Front	2	0.483	0.431	0.126	0.431
n261	N	Тор	2	0.034	0.030	-	0.030
n261	N	Bottom	2	0.067	0.060	-	0.060
n261	N	Right	2	1.000	0.891	0.463	0.891
n261	N	Left	2	0.035	0.032	-	0.032
n260	М	Back	2	1.000	0.891	0.510	0.891
n260	М	Front	2	0.249	0.222	0.040	0.222
n260	М	Тор	2	0.227	0.202	0.069	0.202
n260	М	Bottom	2	0.023	0.020	-	0.020
n260	М	Right	2	0.048	0.043	-	0.043
n260	М	Left	2	0.970	0.865	0.476	0.865
n260	N	Back	2	0.665	0.593	-	0.593
n260	N	Front	2	0.736	0.656	0.400	0.656
n260	N	Тор	2	0.042	0.037	-	0.037
n260	N	Bottom	2	0.100	0.089	-	0.089
n260	N	Right	2	1.000	0.891	0.501	0.891
n260	N	Left	2	0.039	0.035	-	0.035
n258	М	Back	10	0.613	0.546	0.269	0.546
n258	М	Left	10	0.402	0.358	0.074	0.358
n258	N	Back	10	0.620	0.553	0.106	0.553
n261	М	Back	10	0.643	0.573	0.359	0.573
n261	М	Left	10	0.451	0.402	0.143	0.402
n261	N	Back	10	0.538	0.479	0.139	0.479
n260	M	Back	10	0.663	0.591	0.175	0.591
n260	М	Left	10	0.566	0.504	0.207	0.504
n260	N	Back	10	0.337	0.300	-	0.300
	<u>.</u>	ad DD are desired				tion distance) suit s	

Table C-1 5G mmW NR FR2 psPD

Note: Adjusted factor is (simulated PD on desired exposure plane)/(PD on worst-surface at 2mm evaluation distance) out of all beams and out of all channels. See Power Density Simulation Report.

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					Т	abl	e C-	2					
50	Gm	۱mV	/ NF	R FF	R2 H	lead	d To	otal	Ехр	osi	ire F	Rati	0

			NR FR2		2.4 GHz WLAN Ant 2 Reported SAR 16.0 dBm	2.4 GHu WLAN MIMO Reported SAR 19.0 dBm	1	2	MIMO Reported SAR	S GRI WLAN MIMO Reported SAR SE.0 dBm	MIMO	NR FR2 + 2.4 GH WLAN Art 1	NEFE2+2.4 GH WLAN Art 2	NR IR2 + 2.4 GHJ WLAN MIMO	NR FR2 + Bluetaoth Ant 1	NRFR2 + Blastauth Ast 2	NR H2 + Blustaath MINO	NR FR2 + 5 GHJ WLAN MIMO	NR FR2 + 6 GHG WLAN MINO		WLAN Art 2 + 5 GH	NR FR2 + 2.4 GH2 WEAN MINO + 5 GH2 WEAN MINO	NR FR2 + Bioetooth Ant 1 + 5 GHG WLAN MIMO	NR H12 + Bluetouth Ant 2 + 5 GH2 WLAN MIMO	MMO+5 GH	WLAN AND 1 + 6 GPG	WLAN Art 2 + 5 GHz	NR 192 + 2.4 GHG WLAN MIND + 6 GHG WLAN MIND	ANT 1 + 6 GHL WLAN	AND 2 + 6 GPG WLAN	NR FR2 + Bluetooth MMR0 + 6 GPG WLAN MIMO
			1	1	1		1	6	7	*	•	1+2	1+1	1+4	1+5	1+6	1+7	1+8	1+9	1+2+8	1+2+8	1+4+8	1+5+8	1+6+8	1+7+8	1+2+9	1+2+9	1+4+9	1+1+9	1+6+9	1+7+9
	Applicable Linit		1.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.0	1.0	1.0	1.0	10	1.0	10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10
From	Reporte	NValue	0.656	0.028	0.178	0.182	0.136	0.194	0.141	0.263	0.290																				
Pillon	Ratio 5	to Limit	0.656	0.018	0.111	0.114	0.065	0.121	0.088	0.164	0.185	0.671	6.262	0.722	0.201	0.777	0.745	0.822	0.837	0.838	0.832	0.836	0.905	0.942	0.929	0.855	0.959	0.850	0.822	0.939	0.925

Table C-3

5G mmW NR FR2 Body-Worn Total Exposure Ratio

		NR FR2	2.4 GHz WLAN Ant 1 Reported SAR 18.5 dBm	2.4 GHz WLAN Ant 2 Reported SAR	MIMO	1	2	MIMO Reported SAR	S GRU WLAN MIMO Reported SAR 37.5 dBm	MIMO Reported SAR	NR 1912 + 2.4 GPG WLAN Ast 1	NR 192 + 2.4 GHz WLAN Avit 2		NR FR2 + Bluetooth Art 1		NR RE2 + Blurtooth MBMO	NK FR2 + 5 GHG WLAN MMO			NR PR2 + 2.4 GPG WLAN Are 2 + 5 GPG WLAN MMD						WLAN Are 2 + 6 GHz			MALE + SIGNS WEAR	
	H																													
																													14545	
ta Side	Reported Volue	0.595	0.082	0.060	0.062	0.012	0.061	0.027	0.245	0.118																				
1.4.147	Ratio to Limit	0.595	022.0	0.038	0.026	0.008	0.051	0.057	0.158	0.0%	0.611	0.629	0.617	0.599	0.642	0.608	0.755	0.665	0.764	0.782	0.770	0.752	0.795	0.761	0.685	0.722	0.691	0.672	0.715	0.682

Table C-45G mmW NR FR2 Hotspot Total Exposure Ratio

		NO 703	Ant 1	Ant 2	2.4 GHz WLAN MIMO Reported SAR	1	2	Bluetooth MIMO Reported SAR	5 GHz WLAN MIMO Reported SAR	NR FR2 + 2.4 GHz WLAN Ant 1	NR FR2 + 2.4 GHz WLAN Ant 2	NR FR2 + 2.4 GHz WLAN MIMO	NR FR2 + Bluetooth Ant 1	Nit FR2 + Bluetooth Ant 2	NR FR2 + Bluetooth MIMO	NR FR2 + 5 GHz WLAN MIMO	Nit FR2 + 2.4 GHz WLAN Ant 1 + 5 GHz WLAN MIMO	WLAN Ant 2 + 5 GHz				
			19.5 dBm	19.5 dBm	19.0 dBm	17.0 dBm	16.5 dBm	14.0 dBm	16.0 dBm													()
		mW/cm*	W/kg	WAg	W/kg	W/kg	W/kg	W/kg	W/kg													l j
		1	2	3	4	5	6	7	8	1+2	1+3	1+4	1+5	1+6	1+7	1+8	1+2+8	1+3+8	1+4+8	1+5+8	1+6+8	1+7+8
	Applicable Limit	1.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Back Side	Reported Value	0.591	0.108	0.171	0.089	0.035	0.185	0.055	0.231													
Diack Side	Ratio to Limit	0.591	0.068	0.107	0.056	0.022	0.116	0.034	0.144	0.659	0.698	0.647	0.613	0.707	0.625	0.735	0.803	0.842	0.791	0.757	0.851	0.770
Front Side	Reported Value	0.656	0.108	0.208	0.052	0.013	0.088	0.037	0.231													
Pront sale	Ratio to Limit	0.656	0.068	0.130	0.033	0.008	0.055	0.023	0.144	0.724	0.786	0.689	0.664	0.711	0.679	0.800	0.868	0.930	0.833	0.809	0.855	0.824
Top Edge	Reported Value	0.217	0.108	0.000	0.018	0.009	0.000	0.013	0.231													
10p coge	Ratio to Limit	0.217	0.068	0.000	0.011	0.005	0.000	0.008	0.144	0.285	0.217	0.228	0.223	0.217	0.225	0.361	0.429	0.361	0.373	0.367	0.361	0.370
Bottom Edge	Reported Value	0.117	0.000	0.000	0.000	0.000	0.000	0.000	0.000													
pottom colle	Ratio to Limit	0.117	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
Right Edge	Reported Value	0.891	0.000	0.000	0.000	0.000	0.000	0.000	0.000		-											
regist c ciga	Ratio to Limit	0.891	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891
Left Edge	Reported Value	0.504	0.023	0.208	0.115	0.010	0.220	0.074	0.193													
Lett Edge	Ratio to Limit	0.504	0.014	0.130	0.072	0.005	0.138	0.046	0.121	0.518	0.634	0.576	0.510	0.642	0.550	0.625	0.639	0.755	0.697	0.631	0.762	0.671

Table C-55G mmW NR FR2 Phablet Total Exposure Ratio

		NR FR2	5 GHz WLAN MIMO Reported SAR 14.0 dBm	6 GHz WLAN MIMO Reported SAR 12.0 dBm	NR FR2 + 5 GHz WLAN MIMO	NR FR2 + 6 GHz WLAN MIMO
		mW/cm²	W/kg	W/kg		
		1	2	3	1+2	1+3
Ap	plicable Limit	1.0	4.0	4.0	1.0	1.0
Back Side	Reported Value	0.891	0.430	0.138		
Dack Side	Ratio to Limit	0.891	0.108	0.035	0.999	0.926
Front Side	Reported Value	0.656	0.157	0.140		
FIONE SIDE	Ratio to Limit	0.656	0.039	0.035	0.695	0.691
Top Edgo	Reported Value	0.217	0.094	0.028		
Top Edge	Ratio to Limit	0.217	0.024	0.007	0.241	0.224
Bottom Edge	Reported Value	0.117	0.000	0.000		
Bottom Euge	Ratio to Limit	0.117	0.000	0.000	0.117	0.117
Dight Edgo	Reported Value	0.891	0.000	0.000		
Right Edge	Ratio to Limit	0.891	0.000	0.000	0.891	0.891
Left Edge	Reported Value	0.865	0.407	0.238		
Leit Euge	Ratio to Limit	0.865	0.102	0.060	0.967	0.925

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Notes:

- 1. Worst-case power density results for each test configuration among all antenna arrays and among all supported bands were considered for TER analysis.
- 2. If test positions were not required to be evaluated for WLAN SAR per FCC KDB publication 248227, the worst-case WLAN SAR result for the applicable exposure conditions was used for simultaneous transmission analysis. Any such values are indicated in the above tables in blue.
- 3. If Part 1 SAR report does not include standalone WLAN MIMO results, then per KDB Publication 248227 D01v02r02, SAR for MIMO was evaluated by following the simultaneous SAR provisions from KDB Publication 447498 D01v06 by evaluating the sum of the 1g SAR values of each antenna transmitting independently. Any such values are indicated in the above tables in green.
- 4. When additional sides were tested at a distance greater than 2mm for hotspot and body-worn configurations, those power density results were used for TER. Otherwise, power density results at 2mm were considered as a more conservative evaluation.
- 5. Per FCC guidance, the bands/modes that are not required to be evaluated for Phablet SAR are not considered for TER analysis.
- 6. Per FCC guidance, for power density measurements, a test separation distance of 2 mm was used for phablet configuration due to probe restraints.
- 7. Worst-case front side reported psPD was considered for Head TER analysis.
- 8. The worst-case between Adjusted Reported_psPD and Measured Total psPD was chosen for TER analysis. The bolded psPD values in Table C-1 indicate the worst-case Reported psPD used in TER analysis.
- 9. In WLAN MIMO operations, the target power of the combined antenna output power is listed above.

The above numerical summed PD and SAR for all the worst-case simultaneous transmission conditions were below the Total Exposure Ratio. Therefore, the above analysis is sufficient to determine no further test cases are required and that simultaneous transmission is compliant to the FCC RF Exposure Limit.

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Mathematical Derivation of TER Compliance

Total Normalized RFx = Normalized RFx $_{Time Averaged WWAN}$ + Normalized RFx $_{WLAN} \leq 1.0$ (1)

Since WWAN Smart Transmit algorithm adds directly the time-averaged RF exposure from 4G and time-averaged RF exposure from 5G mmW NR, per chipset manufacturer's guidance, Normalized RF exposure from 4G and from 5G mmW NR could be assumed as

Normalized RFx _{Time Averaged WWAN} = $\frac{4G SAR}{4G SAR Limit} + \frac{5G mmW NR psPD}{5G mmW NR psPD Limit} \leq 1.0$ (2)

Smart Transmit algorithm assumes that 4G and 5G mmW NR hotspots are co-located and therefore:

Time Averaged WWAN =
$$[x(t) \times A] + [(1-x(t)) \times B] \le 1.0$$
 Normalized Limit (3)

A = Max normalized time-averaged SAR exposure from 4G B = Max normalized time-averaged PD exposure from 5G mmW NR

x(t) = Ranges between [0,1] $x(t) \times A =$ Percentage of normalized time-averaged RF exposure from 4G $(1-x(t)) \times B = Remaining percentage of RF exposure contribution from 5G mmW NR$

Smart Transmit controls "x" in real time such that the sum of these exposures never exceeds 1.0 Normalized Limit. If the equations below (4a, 4b) are proven, then, mathematically equation (5) would be proven.

$A + norm. SAR from WLAN \leq 1.0 normalized limit$	(4a)
$B + norm. SAR from WLAN \leq 1.0 normalized limit$	(4b)
$[x(t) \times A] + [(1-x(t)) \times B] + norm. SAR from WLAN \le 1.0 normalized limit$	(5)

Without 5G mmW NR, Smart Transmit limits the maximum RF exposure contributed from 4G to 100% normalized exposure. For this device, the manufacturer has added an additional permanent back-off (indicated below as WWAN backoff) for every beam in the calculations for input power.limits used in the EFS file. Therefore, Smart Tx WWAN: A = max (normalized SAR exposure from $4G \le 1.0$ normalized limit (6a) Smart Tx WWAN: B = max (normalized PD exposure from 5G mmW NR)x10^{(-WWAN backoff in dB)/10} < 1.0 normalized limit (6b)

To demonstrate simultaneous transmission compliance in equation (1), below equations (7a & 7b) obtained by combining equations (4a & 4b) and (6a & 6b), should be proven for simultaneous transmission compliance:

$$\begin{array}{ll} Total \ Normalized \ RFx &= \ Normalized \ SAR \ _{4G \ WWAN} + Normalized \ SAR \ _{WLAN} < 1.0 \\ Total \ Normalized \ RFx &= \ 10^{(-WWAN \ backoff \ in \ dB)/10} x \ Normalized \ psPD \ _{5G \ mmW \ NR \ WWAN} + \\ Normalized \ SAR \ _{WLAN} < 1.0 \end{array}$$

$$\begin{array}{l} (7a) \\ (7b) \end{array}$$

(8a)

which are re-written as:

Total Normalized RFx =
$$\frac{4G SAR}{4G SAR Limit} + \frac{WLAN SAR}{WLAN SAR Limit} < 1$$

 $Total Normalized RFx = 10^{(-WWAN \ backoff \ in \ dB)/10} * \frac{5G \ mWW \ NR \ psPD}{5G \ mWW \ NR \ psPD \ Limit} + \frac{WLAN \ SAR}{WLAN \ SAR \ Limit} < 1$ (8b)

Analysis for equation (8a) is performed in Appendix E of FCC SAR Evaluation Report (Part 1). Analysis for equation (8b) is performed in this appendix.

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