PD2343F Test strategy of Qualcomm Smart Transmit（Force Peak）SAR algorithm

We would like to adopt Qualcomm Smart Transmit—Force Peak algorithm with our new product PD2343F. This device is enabled with the Smart Transmit DE3.1—Force Peak algorithm to control and manage transmitting power in real-time and to ensure the time-averaged SAR values from all cellular bands are compliant with proper regulatory requirements. According to the work mode of cellular transmitters of the device, if only one transmitter is activated then a constant power (Plimit) will be applied at all time during the transmission, whereas if multiple transmitters are involved (such as EN-DC) then the algorithm will employ dynamic power control mechanism (smart transmit) to make sure the time-averaged SAR is compliant. The ST EFS version is V20, but only 2G/3G/4G/5G NR are enabled with Qualcomm Smart Transmit feature.

MCC List	Exposure Mode	Averaging Windows	SAR Limit	PD Limit	Smart Tx Gen	Multi Tx Factor	Hand applicability when device held next to head	Note: Please list out the MCCs corresponding to each list in the same row																
Default MCC	Peak	FCC_timewindow	FCC_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No																	
MCC List 1	Time-Averaged	FCC_timewindow	FCC_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No																	
MCC List 2	Peak	FCC_timewindow	FCC_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No	310	311	314	315	316	302	730	716	732	334	330	332	534	535	544	1	
MCC List 3	Time-Averaged	ICNIRP1998_timewindow	ICNIRP_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No																	
MCC List 4	Peak	ICNIRP1998_timewindow	ICNIRP_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No	350	346	366	742	376	348	260	262	222	214	208	230	226	232	268	284	202
MCC List 5	Time-Averaged	ICNIRP1998_timewindow	FCC_FR1_Limits	FCC_FR2_Limits	GEN1	1.0	No																	

As stated above, for a given wireless device, a certification lab shall conduct conventional SAR evaluation at Plimit for non-simultaneous transmission condition on specific technology/freq band/antenna/DSI for all cellular/Wlan/BT technologies. For TDD LTE/NR bands, the device implements Qualcomm Smart Transmit—Force Peak algorithm to boost conducted power according to duty cycle setup of the device.

As for simultaneous transmission such as EN-DC, the dynamic power control mechanism will be employed by Qualcomm modem with Smart Transmit algorithm. So, the test lab shall conduct time-averaged SAR evaluation as per regulation guidance. The algorithm dynamically adjusts the conducted power both for LTE and NR as need in EN-DC, however the time-averaged power shall not higher than corresponding single transmission of LTE or NR mode. Thus, to calculate the summed SAR of EN-DC with Wlan and/or BT transmit, the test lab may pick the worst SAR value from either LTE or NR single SAR result together with Wlan and/or BT SAR values.

SAR is proportional to the transmitting power, in other words, once the SAR of the wireless device is characterized at a transmit power level via SAR measurement, SAR at a different power level for the characterized configuration(s) can be scaled by the change in the corresponding power level. Therefore, for a characterized device, SAR compliance can be achieved through transmit power control and management. The Smart Transmit algorithm incorporated in Qualcomm modems reliably controls the transmit power of the wireless device in real-time to maintain the time-averaged transmit power (in turn, time-averaged SAR) below the threshold predefined for a given technology and band. This predefined average power limit, denoted as Plimit, is determined so that the wireless device when continuously transmitting at Plimit level complies with SAR limit. The basic concept of the

algorithm is that if time-averaged transmit power approaches the Plimit, then the modem needs to limit instantaneous transmit power to make sure that the time-averaged transmit power does not exceed the Plimit in any SAR_time_window (i.e., the time-averaged SAR complies with the CE/FCC SAR limit in any SAR_time_window). The wireless device can instantaneously transmit at high transmit powers and exceed the Plimit for a short duration before limiting the power to maintain the time-averaged transmit power under the Plimit. (see Figure 1).

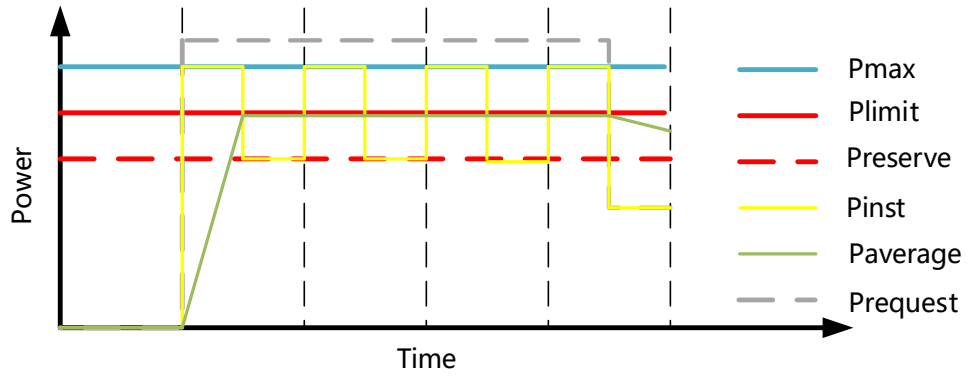

Figure 1

Two exposure modes are different. In Time-Averaged Exposure mode, the wireless device can instantaneously transmit at high transmit powers and exceed the Plimit for a short duration before limiting the power to maintain the time-averaged transmit power under the Plimit; while in Peak Exposure mode, the maximum instantaneous transmit power is limited to Plimit. (see Figure 1.1)

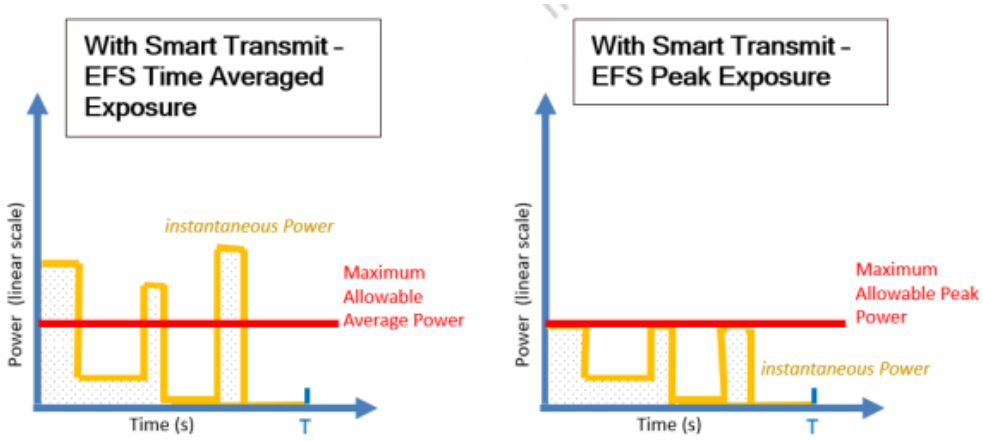

Figure 1.1

The Smart Transmit algorithm can be configured to manage the instantaneous transmit power (Tx power) to keep the time-averaged power to not exceed Plimit. If the wireless device transmits at high power for a long duration, then the radio link needs to be dropped in order to be compliant with time-averaged Tx power requirement (see Figure 2). To avoid dropping the radio link, Smart Transmit algorithm starts the power limiting enforcement earlier in time to back off the Tx power to a reserve level (denoted as Preserve) so that wireless device can maintain the radio link at a minimum reserve power level for as long as needed and at the same time ensure that the time-averaged Tx power over any

SAR_time_window is less than Plimit at all times (see Figure 3).
At all times, Smart Transmit meets the below equation:

$$time\ avg.Tx\ power = \frac{1}{T}\int_{t}^{t+T} inst.Tx\ power(t)\,dt \leq P_{limit}$$

where, *time avg.Tx power* is the power averaged between *t* and *t+T* time period; *T* is *SAR_time_window*; *inst. Tx power (t)* is the instantaneous transmit power at *t* time instant; *Plimit* is the predefined time averaged power limit.

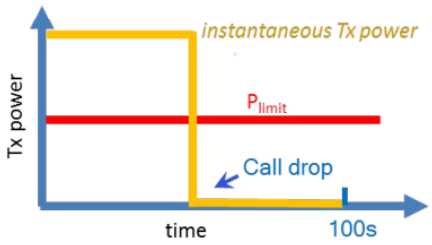

Figure 2

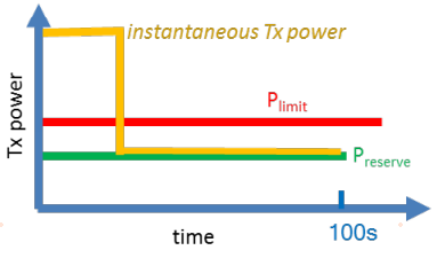

Figure 3

P_{limit}	Maximum tune-up output power for SAR Mode A and Mode B
P_{max}	Maxumum tune-up output power for RF

Power Boost =10*log(1/Duty cycle)
Average Power=instantaneous power-Power Boost
DSI B Average Power≤DSI B P_{limit}
instantaneous power≤P_{max}

Test strategy as below:

1. Standalone Mode

Duty Cycle technology is applied to NR TDD and LTE TDD frequency band, and the conducted power under specific Duty Cycle is compensated according to the following table lookup method in the case of different Duty Cycle stages. We will verify the compliance of the conducted power at different duty cycles to prove that the algorithm meets the CE RF exposure requirement.

1.1 LTE TDD

According to 3GPP TS 36.211, LTE TDD is divided into seven duty cycles in different configurations.Under the condition that the average power remains unchanged, different power increases are adopted for different duty cycles(see Table 1).

Uplink-Downlink Configuration	Duty Cycle	Power Boost（dB）

0	63.33%	2.0
1	43.33%	3.6
2	23.33%	6.3
3	31.67%	5.0
4	21.67%	6.6
5	11.67%	9.3
6	53.33%	2.7

Table 1

The strategy for conducted power measurements:

① Frequency band: verify all LTE TDD frequency bands.

② Antenna: Verify all transmitting antennas in each frequency band.

③ DSI: verify DSI of all scenarios.

④ Test configuration: Test all power configurations under Config 0, and sample conducted power under config1-6 with maximum bandwidth, QPSK modulation, medium channel, and 1RB.

The strategy for SAR measurements:

The power tested under each config mode is uniformly converted into the average power under 100% duty cycle. If Config1 to 6 mode average power is not more than Config 0 mode average power of 0.25dB and above, and the 10-g reported SAR is ≤ 1.2 W/kg, only the SAR of Config 0 mode will be tested, otherwise, the SAR test under the corresponding Config mode will be added.

1.2 NR TDD

This technology is used in NR TDD frequency band, and the detailed test strategy is as follows:

① Considering the testing capability of various callbox in the current industry, three duty cycles of 21.40%, 41.40% and 61.40% are selected for power verification, and the traversal method are as follows:

a. frequency band: verify all NR TDD frequency bands.

b. Antenna: Verify all transmitting antennas in each frequency band.

c. DSI: verify DSI of all scenarios.

d. Bandwidth, modulation, channel, RB: verify the maximum bandwidth, DFT-s-OFDM QPSK and Pi/2 BPSK modulation, unless Pi/2 BPSK Tune-up is less than QPSK, we will only validate QPSK, intermediate channel, Inner RB. If the 10-g reported SAR value is greater than 50% of the limit, additional partial RB and channels will be tested

e. SCS: Only verify the 30kHz

② The signaling power tested under each duty cycle is uniformly converted into the signaling average power under 100% duty cycle. If the signaling average power is not more than 100% Duty Cycle FTM mode power of 0.25dB and above, and the 10-g reported SAR

is ≤ 1.2 W/kg, only the SAR of 100% Duty Cycle FTM mode will be tested, otherwise, the SAR test under the corresponding duty cycle will be added.
Test data as below:

Band	Antenna	BW	Modulation	Channel	RB_config	Duty Cycle	Power Boost(dB)	DSI 1(Full Power)			DSI 2			Remark
								instantaneous power(dBm)	Average power(dBm)	Tune-up Limit(dBm)	instantaneous power(dBm)	Average power(dBm)	Tune-up Limit(dBm)	
n41	11#	100MHz	DFT-s-OFDM QPSK	518598	135@67	21.4%	6.7	22.18	15.48	23.00	22.21	15.51	19.00	Signalling Mode
						41.4%	3.8	22.29	18.46	23.00	22.13	18.30	19.00	
						61.4%	2.1	22.17	20.05	23.00	20.22	18.10	19.00	
						100.0%	0.0	21.89	**21.89**	23.00	18.01	**18.01**	19.00	FTM mode
n77	21#	100MHz	DFT-s-OFDM QPSK	630000	135@67	21.4%	6.7	20.96	14.26	22.00	21.15	14.45	17.00	Signalling Mode
						41.4%	3.8	21.18	17.35	22.00	19.96	16.13	17.00	
						61.4%	2.1	20.94	18.82	22.00	18.14	16.02	17.00	
						100.0%	0.0	21.02	**21.02**	22.00	15.89	**15.89**	17.00	FTM mode
n78	24#	100MHz	DFT-s-OFDM QPSK	630000	135@67	21.4%	6.7	18.12	11.42	19.00	18.16	11.46	14.00	Signalling Mode
						41.4%	3.8	18.16	14.33	19.00	16.91	13.08	14.00	
						61.4%	2.1	18.10	15.98	19.00	15.23	13.11	14.00	
						100.0%	0.0	18.04	**18.04**	19.00	13.12	**13.12**	14.00	FTM mode

Table 2

2. Non-standalone Mode

We will verify the SAR exposure switching between two active radios (radio1 and radio2) to prove that Smart Transmit—Force Peak algorithm feature functions correctly and ensures total RF exposure compliance when exposure varies among SAR_radio1 only, SAR_radio1 + SAR_radio2, and SAR_radio2 only scenarios.

The Smart Transmit—Force Peak algorithm time averaging operation is independent of the source of SAR exposure and ensures total time-averaged RF exposure compliance. Hence, validation of Smart Transmit in any one simultaneous SAR transmission scenario (i.e., one combination for LTE + Sub6 NR transmission) is sufficient.

The strategy for testing in Tx varying transmission condition is outlined as follows:
① Demonstrate the total RF exposure averaged over defined time windows does not exceed CE's SAR limits, through time-averaged power measurements
② Measure conducted Tx power (for f < 6GHz) versus time
③ Convert it into RF exposure and divide by respective CE limits to get normalized exposure versus time.
④ Perform running time-averaging over CE defined time windows.
⑤ Demonstrate that the total normalized time-averaged RF exposure is less than 1 at all times.

Mathematical expression:

$$1g\_or\_10gSAR_1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_P_{limit\_1}} * 1g\_or\_10gSAR\_P_{limit\_1}$$

$$1g\_or\_10gSAR_2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_P_{limit\_2}} * 1g\_or\_10gSAR\_P_{limit\_2}$$

$$\frac{1}{T_{SAR}}\left[\int_{t-T_{SAR}}^{t_1} \frac{1g\_or\_10gSAR_1(t)}{FCC\ SAR\ limit}\,dt + \int_{t-T_{SAR}}^{t} \frac{1g\_or\_10gSAR_2(t)}{FCC\ SAR\ limit}\,dt\right] \le 1$$

For device using Smart Transmit peak mode, we follow the required test listed at the end of 4.2.1 of Qualcomm DOC 80-W2112-5.

4.2.1 Peak Exposure Mode

When Smart Transmit is configured for peak exposure mode, all the tests described in Section 4.2 should be validated if P_{limit} or *input.power.limit* configured in Smart Transmit EFS is less than RF P_{max} configured and stored in NV settings on the device.

Since compliance SAR measurements in Part 1 can be performed in peak exposure mode, and for devices with Smart Transmit EFS v18 (or higher), all Part 1 tests should be conducted under Peak exposure mode (see Section 4.2.2 of 80-W2112-4). With Part 1 tested in peak exposure mode, the EUT is requested to transmit at maximum power by the callbox, and Smart Transmit restricts the EUT to transmit at its corresponding maximum time-average Tx power P_{limit} level, it is evident that all single Tx transmission scenarios (i.e., scenarios 1~5 in Section 4.2) are validated . Therefore, the only following tests (if applicable) need to be performed in Part 2 if the EUT is enabled with Smart Transmit EFS version 18 (or higher) and is configured for peak exposure mode:

- time-window switch test (scenario 6, see Appendix G)
- all simultaneous transmission scenarios, i.e., SAR exposure switch test (scenario 7, see Appendix H) and all mmW NR NSA tests (see Section 6)
- verification of WWAN backoff when WiFi/BT is transmitting if Smart Transmit is configured for GEN1 or GEN2_MMW configuration (see Appendix M)
- sub6 and mmW favor mode switch test if Smart Transmit is configured for GEN2_SUB6_MMW configuration (see Appendix O)
- exposure category switch test if Smart Transmit is enabled using EFS version 18 (or higher) and contains DSIs in both head and non-head exposure categories (see Appendix P)