

SAR and Power Density Characterization

Revision History

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V1	2026/06/27	Initial Issue	--

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1. Introduction

The modem is enabled with WWAN/WLAN/Bluetooth/Thread/MSS/NTN TAS technology feature to control and manage transmitting power, in real time.

This DUT supports a time-average method of transmit power control for the aforementioned technologies. Consumed SAR from active radios is tracked and stored for the duration of the applicable regulatory averaging window. Rolling time-averaged SAR values are calculated from the consumed SAR reported from active radios. The time-averaged SAR is always maintained less than the applicable SAR_{Reported} .

In this report, the DUT SAR and power density (PD) are characterized for all radios that implement a TAS function to determine the power limit that corresponds to the exposure target after accounting for all device design related uncertainties, i.e., SAR_{Reported} for Sub-7.2 GHz radio(s) and PD_{Reported} for millimeter wave radio(s).

SAR Characterization and PD Characterization will be used as input for the algorithm to operate. Both SAR Characterization and PD Characterization will be loaded and stored in the DUT.

2. SAR Characterization

SAR Characterization is generated to cover all radio configurations and usage scenarios that are reported in the initial submission.

2.1. Worst-case SAR Determination

Based on FCC KDBs and ISED RSS standards, in general, for a smartphone, the SAR evaluation is required for all the applicable exposure scenarios.

Depending on the detection scheme implemented in the smartphone, the worst-case SAR is further grouped and determined for each or combined exposure scenario(s). Note, for the 1-g SAR versus 10-g SAR, the worst-case is determined in terms of exposure ratio (i.e., exposure level relative to the corresponding 1-g or 10-g SAR limit).

- If the device does not have any detection mechanism, then the worst-case SAR is determined by taking the maximum SAR value among all exposure scenarios, i.e., worst-case SAR = $\max \{SAR_{\text{Head}}, SAR_{\text{Body}}, SAR_{\text{Hotspot}}, SAR_{\text{Extremity/Extremity Held-to-Head}}\}$
- If the device can distinguish each of the above scenarios, then the worst-case SAR for each individual exposure scenario is given by corresponding SAR_{Head} , SAR_{Body} , SAR_{Hotspot} , and $SAR_{\text{Extremity/Extremity Held-to-Head}}$
- If the device can only distinguish a subset of the scenarios, then the worst-case SAR is given by:
 - Corresponding SAR for each exposure scenario that can be distinguished
 - Worst-case SAR among all other exposure scenario(s) that cannot be distinguished

2.2. Usage Scenarios in SAR Evaluation

The corresponding usage scenarios supported by DUT are summarized in Table 2-1:

Table 2-1: Usage/Exposure Scenario

RF Exposure	Power/Index State	Description
Head	Mode A	Max permissible power relative to P_{Limit} when the device is used against the user's head
Body-worn	Mode B	Max permissible power relative to P_{Limit} when the device is used in a Body-worn configuration
Hotspot	Mode B	Max permissible power relative to P_{Limit} when the device is used in a Hotspot configuration
Extremity	Mode B	Max permissible power relative to P_{Limit} when the device is used in an Extremity configuration

2.3. $SAR_{Reported}$

The total device design and related uncertainties of the DUT, including TxAGC and device to device variation, are accounted for by the following equation:

$$SAR_{Reported} < SAR_{regulatorylimit} \times 10^{\frac{-total\ uncertainty}{10}}$$

For the regulatory requirement of 1.6 W/kg, and 4.0 W/kg, 1-g, 10-g SAR respectively, the $SAR_{Reported}$ values, accounting for total uncertainty, are outlined within the SAR Characterization tables:

2.4. SAR Characterization

The worst-case *reported* SAR for each antenna/technology/band/Power/Index State is summarized in Table 2-2:

Table 2-2: Worst-case reported SAR

Tech/Band	Antenna			Worst-case SAR (W/kg)			P_{Limit} (dBm) + Uncertainty (dBm)		
	Head	Body	Extremity	Head	Body	Extremity	Head	Body	Extremity
GSM 850 GMSK 2 Slot(s)	ANT 2	ANT 3	N/A	1.142	1.117	N/A	31.50	32.50	N/A
GSM 1900 GMSK 2 Slot(s)	ANT 4	ANT 14	N/A	1.163	1.115	N/A	26.50	28.00	N/A
W-CDMA B2	ANT 4	ANT 3	N/A	1.132	1.141	N/A	20.50	23.30	N/A
W-CDMA B4	ANT 4	ANT 14	N/A	1.165	1.110	N/A	21.90	21.50	N/A
W-CDMA B5	ANT 2	ANT 2	N/A	1.035	1.028	N/A	25.30	25.70	N/A
LTE FDD B2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LTE FDD B4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LTE FDD B5	ANT 2	ANT 2	N/A	1.171	0.958	N/A	25.30	25.70	N/A
LTE FDD B7	ANT 4	ANT 14	N/A	1.171	1.103	N/A	18.40	20.00	N/A
LTE FDD B12	ANT 2	ANT 2	N/A	1.189	1.082	N/A	25.70	25.70	N/A
LTE FDD B13	ANT 2	ANT 3	N/A	1.187	1.069	N/A	25.10	25.70	N/A
LTE FDD B14	ANT 2	ANT 2	N/A	1.165	0.977	N/A	24.90	24.90	N/A
LTE FDD B17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LTE FDD B25	ANT 4	ANT 14	N/A	1.151	1.111	N/A	20.40	20.80	N/A
LTE FDD B26	ANT 2	ANT 2	N/A	1.179	1.104	N/A	25.30	25.50	N/A
LTE FDD B30	ANT 4	ANT 3	N/A	1.167	1.160	N/A	20.70	21.10	N/A
LTE TDD B41 PC3	ANT 4	ANT 1	N/A	1.121	1.191	N/A	21.10	23.20	N/A
LTE TDD B41 PC2	ANT 3	N/A	N/A	0.568	N/A	N/A	28.70	N/A	N/A
LTE TDD B48	ANT 4	ANT 4	N/A	1.173	1.118	N/A	22.90	23.40	N/A
LTE TDD B53	ANT 14	ANT 14	N/A	0.153	0.671	N/A	20.70	20.70	N/A
LTE FDD B66	ANT 14	ANT 4	N/A	1.176	1.111	N/A	23.00	21.20	N/A
LTE FDD B71	ANT 2	ANT 3	N/A	0.907	0.828	N/A	25.70	25.70	N/A
LTE FDD B106	ANT 2	ANT 3	N/A	0.877	0.851	N/A	24.60	25.70	N/A
MSS (L-Band)	N/A	N/A	ANT 4	N/A	N/A	2.657	N/A	N/A	26.70
FR-1 FDD n2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FR-1 FDD n5	ANT 2	ANT 2	N/A	1.178	0.994	N/A	25.30	25.70	N/A
FR-1 FDD n7	ANT 4	ANT 14	N/A	1.102	1.116	N/A	19.40	19.90	N/A
FR-1 FDD n12	ANT 2	ANT 2	N/A	1.175	1.073	N/A	25.70	25.70	N/A
FR-1 FDD n14	ANT 2	ANT 2	N/A	1.193	1.041	N/A	24.80	24.90	N/A
FR-1 FDD n25	ANT 4	ANT 1	N/A	1.078	1.092	N/A	20.90	23.60	N/A
FR-1 FDD n26	ANT 2	ANT 2	N/A	1.036	0.950	N/A	25.30	25.70	N/A
FR-1 FDD n30	ANT 4	ANT 3	N/A	1.142	1.113	N/A	20.60	20.30	N/A
FR-1 TDD n41 PC3	ANT 4	ANT 3	N/A	1.141	1.165	N/A	19.80	21.60	N/A
FR-1 TDD n41 PC2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FR-1 TDD n48	ANT 4	ANT 4	N/A	1.176	1.119	N/A	21.00	21.40	N/A
FR-1 TDD n53	ANT 14	ANT 14	N/A	0.149	0.704	N/A	20.70	20.10	N/A
FR-1 FDD n66	ANT 4	ANT 1	N/A	1.121	1.063	N/A	22.00	25.40	N/A
FR-1 FDD n70	ANT 4	ANT 3	N/A	1.159	1.134	N/A	23.00	22.80	N/A
FR-1 FDD n71	ANT 2	ANT 2	N/A	0.996	0.938	N/A	25.70	25.70	N/A
FR-1 TDD n77 (Block A) PC3	ANT 4	ANT 9	N/A	1.172	1.171	N/A	21.00	21.80	N/A
FR-1 TDD n77 (Block A) PC2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FR-1 TDD n77 (Block C) PC3	ANT 8	ANT 7	N/A	1.151	1.105	N/A	25.10	23.70	N/A
FR-1 TDD n77 (Block C) PC2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wi-Fi 2.4 GHz	ANT 4	ANT 4	N/A	1.156	1.169	N/A	19.50	20.50	N/A
Wi-Fi U-NII 1	N/A	ANT 16	N/A	N/A	0.986	N/A	N/A	18.25	N/A
Wi-Fi U-NII 2A	ANT 6	ANT 6	N/A	0.295	0.978	N/A	20.00	18.50	N/A
Wi-Fi U-NII 2C	ANT 6	ANT 16	N/A	0.732	1.157	N/A	20.00	16.00	N/A
Wi-Fi U-NII 3	ANT 6	ANT 16	N/A	0.917	1.068	N/A	20.00	16.00	N/A
Wi-Fi U-NII 5	ANT 6	ANT 6	N/A	0.282	0.794	N/A	16.75	16.75	N/A
Wi-Fi U-NII 6	ANT 6	ANT 6	N/A	0.326	0.626	N/A	17.00	17.00	N/A
Wi-Fi U-NII 7	ANT 6	ANT 6	N/A	0.406	0.759	N/A	17.50	17.50	N/A
Wi-Fi U-NII 8	ANT 6	ANT 16	N/A	0.616	1.055	N/A	18.50	16.75	N/A
Bluetooth 2.4 GHz	ANT 4	ANT 3	N/A	1.075	1.111	N/A	19.50	21.00	N/A
NB U-NII 1	ANT 16	ANT 16	N/A	0.013	0.454	N/A	14.00	14.00	N/A
NB U-NII 3	ANT 6	ANT 6	N/A	0.669	1.169	N/A	19.00	19.00	N/A
NB U-NII 5	ANT 16	ANT 16	N/A	0.000	0.011	N/A	2.00	2.00	N/A
802.15.4	ANT 4	ANT 4	N/A	1.139	1.139	N/A	19.50	20.00	N/A

Using the reported SAR listed in Table 2-2, and following the procedure described in §2.1, the SAR Characterization¹ of this DUT is listed in Table 2-3.

¹ WLAN/Bluetooth/NB U-NII/802.15.4 do not have declared uncertainties. The $SAR_{Reported}$ is 75% of its respective regulatory limit.

Table 2-3: SAR Characterization

RF Exposure Condition	Antenna	Technology	P _{Max} (dBm)	P _{Limit} (dBm)	P _{Limit, nom} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)	Uncertainty dB (±)	RF Exposure Condition	Antenna	Technology	P _{Max} (dBm)	P _{Limit} (dBm)	P _{Limit, nom} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)	Uncertainty dB (±)
Head	ANT 2	GSM 850 GMSK 2 Slot(s)	31.5	31.5	30.4	0.889	1.142	1.09	Body	ANT 2	GSM 850 GMSK 2 Slot(s)	31.5	31.5	30.4	0.585	0.752	1.09
Head	ANT 3	GSM 850 GMSK 2 Slot(s)	32.5	32.5	32.5	0.331	0.331	0.00	Body	ANT 3	GSM 850 GMSK 2 Slot(s)	32.5	32.5	31.7	0.921	1.117	0.84
Head	ANT 1	GSM 1900 GMSK 2 Slot(s)	29.5	29.5	29.5	0.201	0.201	0.00	Body	ANT 1	GSM 1900 GMSK 2 Slot(s)	29.5	29.5	28.7	0.860	1.038	0.82
Head	ANT 3	GSM 1900 GMSK 2 Slot(s)	30.8	30.8	30.8	0.381	0.381	0.00	Body	ANT 3	GSM 1900 GMSK 2 Slot(s)	30.8	29.4	28.6	0.991	1.200	0.83
Head	ANT 4	GSM 1900 GMSK 2 Slot(s)	29.5	26.5	25.3	0.908	1.200	1.21	Body	ANT 4	GSM 1900 GMSK 2 Slot(s)	29.5	26.2	24.6	0.826	1.200	1.62
Head	ANT 14	GSM 1900 GMSK 2 Slot(s)	31.0	29.3	28.5	1.005	1.200	0.77	Body	ANT 14	GSM 1900 GMSK 2 Slot(s)	31.0	28.0	27.1	0.984	1.200	0.86
Head	ANT 1	W-CDMA B2	24.9	24.9	24.9	0.257	0.257	0.00	Body	ANT 1	W-CDMA B2	24.9	23.6	22.8	0.994	1.200	0.82
Head	ANT 3	W-CDMA B2	25.7	25.7	25.7	0.397	0.397	0.00	Body	ANT 3	W-CDMA B2	25.7	23.3	22.5	0.991	1.200	0.83
Head	ANT 4	W-CDMA B2	24.9	20.5	19.3	0.908	1.200	1.21	Body	ANT 4	W-CDMA B2	24.9	20.2	18.6	0.826	1.200	1.62
Head	ANT 14	W-CDMA B2	25.7	23.4	22.6	1.005	1.200	0.77	Body	ANT 14	W-CDMA B2	25.7	21.1	20.2	0.984	1.200	0.86
Head	ANT 1	W-CDMA B4	25.7	25.7	25.7	0.244	0.244	0.00	Body	ANT 1	W-CDMA B4	25.7	25.4	24.5	0.975	1.200	0.90
Head	ANT 3	W-CDMA B4	25.7	25.7	25.7	0.273	0.273	0.00	Body	ANT 3	W-CDMA B4	25.7	22.6	21.7	0.984	1.200	0.86
Head	ANT 4	W-CDMA B4	25.7	21.9	20.7	0.904	1.200	1.23	Body	ANT 4	W-CDMA B4	25.7	22.2	20.9	0.888	1.200	1.31
Head	ANT 14	W-CDMA B4	25.7	23.0	22.1	0.971	1.200	0.92	Body	ANT 14	W-CDMA B4	25.7	21.5	20.6	0.975	1.200	0.90
Head	ANT 2	W-CDMA B5	25.7	25.3	24.2	0.934	1.200	1.09	Body	ANT 2	W-CDMA B5	25.7	25.7	24.6	0.800	1.028	1.09
Head	ANT 3	W-CDMA B5	25.7	25.7	25.7	0.224	0.224	0.00	Body	ANT 3	W-CDMA B5	25.7	25.7	24.9	0.797	0.967	0.84
Head	ANT 2	LTE FDD B5	25.7	25.3	24.2	0.934	1.200	1.09	Body	ANT 2	LTE FDD B5	25.7	25.7	24.6	0.745	0.958	1.09
Head	ANT 3	LTE FDD B5	25.7	25.7	25.7	0.197	0.197	0.00	Body	ANT 3	LTE FDD B5	25.7	25.7	24.9	0.685	0.831	0.84
Head	ANT 1	LTE FDD B7	24.2	24.2	24.2	0.277	0.277	0.00	Body	ANT 1	LTE FDD B7	24.2	21.5	20.3	0.904	1.200	1.23
Head	ANT 3	LTE FDD B7	25.7	25.7	25.7	0.565	0.565	0.00	Body	ANT 3	LTE FDD B7	25.7	20.7	20.0	1.017	1.200	0.72
Head	ANT 4	LTE FDD B7	23.9	18.4	17.5	0.971	1.200	0.92	Body	ANT 4	LTE FDD B7	23.9	20.7	19.6	0.836	1.200	1.08
Head	ANT 14	LTE FDD B7	25.7	25.7	24.8	0.800	0.988	0.92	Body	ANT 14	LTE FDD B7	25.7	20.0	19.1	0.982	1.200	0.87
Head	ANT 2	LTE FDD B12	25.7	25.7	24.6	0.923	1.189	1.10	Body	ANT 2	LTE FDD B12	25.7	25.7	24.7	0.867	1.082	0.96
Head	ANT 3	LTE FDD B12	25.7	25.7	25.7	0.198	0.198	0.00	Body	ANT 3	LTE FDD B12	25.7	25.7	24.8	0.766	0.941	0.89
Head	ANT 2	LTE FDD B13	25.7	25.1	24.0	0.940	1.200	1.06	Body	ANT 2	LTE FDD B13	25.7	25.0	24.0	0.953	1.200	1.00
Head	ANT 3	LTE FDD B13	25.7	25.7	25.7	0.246	0.246	0.00	Body	ANT 3	LTE FDD B13	25.7	25.7	24.6	0.828	1.069	1.11
Head	ANT 2	LTE FDD B14	25.7	24.9	23.8	0.931	1.200	1.10	Body	ANT 2	LTE FDD B14	25.7	24.9	23.9	0.962	1.200	0.96
Head	ANT 3	LTE FDD B14	25.7	25.7	25.7	0.236	0.236	0.00	Body	ANT 3	LTE FDD B14	25.7	25.7	24.6	0.702	0.912	1.14
Head	ANT 1	LTE FDD B25	24.9	24.9	24.9	0.219	0.219	0.00	Body	ANT 1	LTE FDD B25	24.9	23.4	22.6	0.994	1.200	0.82
Head	ANT 3	LTE FDD B25	25.7	25.7	25.7	0.323	0.323	0.00	Body	ANT 3	LTE FDD B25	25.7	22.8	22.0	0.991	1.200	0.83
Head	ANT 4	LTE FDD B25	24.9	20.4	19.2	0.908	1.200	1.21	Body	ANT 4	LTE FDD B25	24.9	20.7	19.1	0.826	1.200	1.62
Head	ANT 14	LTE FDD B25	25.7	22.4	21.6	1.005	1.200	0.77	Body	ANT 14	LTE FDD B25	25.7	20.8	19.9	0.984	1.200	0.86
Head	ANT 2	LTE FDD B26	25.7	25.3	24.2	0.938	1.200	1.07	Body	ANT 2	LTE FDD B26	25.7	25.5	24.5	0.944	1.200	1.04
Head	ANT 3	LTE FDD B26	25.7	25.7	25.7	0.223	0.223	0.00	Body	ANT 3	LTE FDD B26	25.7	25.7	25.0	0.723	0.855	0.73
Head	ANT 1	LTE FDD B30	24.2	24.2	24.2	0.272	0.272	0.00	Body	ANT 1	LTE FDD B30	24.2	23.6	22.9	1.010	1.200	0.75
Head	ANT 3	LTE FDD B30	25.2	25.2	25.2	0.488	0.488	0.00	Body	ANT 3	LTE FDD B30	25.2	21.1	20.3	1.005	1.200	0.77
Head	ANT 4	LTE FDD B30	24.2	20.7	19.8	0.966	1.200	0.94	Body	ANT 4	LTE FDD B30	24.2	20.7	19.5	0.914	1.200	1.18
Head	ANT 14	LTE FDD B30	25.7	25.7	24.6	0.411	0.525	1.06	Body	ANT 14	LTE FDD B30	25.7	20.5	19.6	0.971	1.200	0.92
Head	ANT 1	LTE TDD B41 PC3	25.7	25.7	25.7	0.253	0.253	0.00	Body	ANT 1	LTE TDD B41 PC3	25.7	23.2	22.3	0.964	1.200	0.95
Head	ANT 3	LTE TDD B41 PC3	25.7	25.7	25.7	0.417	0.417	0.00	Body	ANT 3	LTE TDD B41 PC3	25.7	23.3	22.5	0.998	1.200	0.80
Head	ANT 4	LTE TDD B41 PC3	25.7	21.1	20.0	0.921	1.200	1.15	Body	ANT 4	LTE TDD B41 PC3	25.7	22.0	20.6	0.865	1.200	1.42
Head	ANT 14	LTE TDD B41 PC3	25.7	25.7	24.6	0.396	0.508	1.08	Body	ANT 14	LTE TDD B41 PC3	25.7	22.3	21.4	0.982	1.200	0.87
Head	ANT 1	LTE TDD B41 PC2	28.5	28.5	28.5	0.247	0.247	0.00	Body	ANT 1	LTE TDD B41 PC2	28.5	24.8	23.9	0.964	1.200	0.95
Head	ANT 3	LTE TDD B41 PC2	28.7	28.7	28.7	0.568	0.568	0.00	Body	ANT 3	LTE TDD B41 PC2	28.7	24.9	24.1	0.998	1.200	0.80
Head	ANT 4	LTE TDD B41 PC2	28.7	22.7	21.6	0.921	1.200	1.15	Body	ANT 4	LTE TDD B41 PC2	28.7	23.6	22.2	0.865	1.200	1.42
Head	ANT 14	LTE TDD B41 PC2	28.7	28.7	27.6	0.223	0.286	1.08	Body	ANT 14	LTE TDD B41 PC2	28.7	23.9	23.0	0.982	1.200	0.87
Head	ANT 4	LTE TDD B48	25.2	22.9	20.9	0.757	1.200	2.00	Body	ANT 4	LTE TDD B48	25.2	23.4	22.6	0.996	1.200	0.81
Head	ANT 7	LTE TDD B48	26.0	26.0	26.0	0.079	0.079	0.00	Body	ANT 7	LTE TDD B48	26.0	26.0	24.3	0.634	0.931	1.67
Head	ANT 8	LTE TDD B48	23.9	23.5	22.1	0.873	1.200	1.38	Body	ANT 8	LTE TDD B48	23.9	20.6	19.4	0.919	1.200	1.16
Head	ANT 9	LTE TDD B48	23.9	23.9	23.9	0.172	0.172	0.00	Body	ANT 9	LTE TDD B48	23.9	23.7	22.2	0.844	1.200	1.53
Head	ANT 1	LTE TDD B53	20.7	20.7	20.7	0.081	0.081	0.00	Body	ANT 1	LTE TDD B53	20.7	20.7	19.6	0.276	0.360	1.15
Head	ANT 14	LTE TDD B53	20.7	20.7	19.8	0.123	0.153	0.95	Body	ANT 14	LTE TDD B53	20.7	20.7	19.8	0.539	0.671	0.95
Head	ANT 1	LTE FDD B66	25.7	25.7	25.7	0.275	0.275	0.00	Body	ANT 1	LTE FDD B66	25.7	25.4	24.5	0.975	1.200	0.90
Head	ANT 3	LTE FDD B66	25.7	25.7	25.7	0.295	0.295	0.00	Body	ANT 3	LTE FDD B66	25.7	22.9	22.0	0.984	1.200	0.86
Head	ANT 4	LTE FDD B66	25.7	22.0	20.8	0.904	1.200	1.23	Body	ANT 4	LTE FDD B66	25.7	21.2	19.9	0.888	1.200	1.31
Head	ANT 14	LTE FDD B66	25.7	23.0	22.1	0.971	1.200	0.92	Body	ANT 14	LTE FDD B66	25.7	21.5	20.6	0.975	1.200	0.90
Head	ANT 2	LTE FDD B71	25.7	25.7	24.5	0.689	0.907	1.19	Body	ANT 2	LTE FDD B71	25.7	25.7	24.5	0.592	0.778	1.19
Head	ANT 3	LTE FDD B71	25.7	25.7	25.7	0.172	0.172	0.00	Body	ANT 3	LTE FDD B71	25.7	25.7	24.9	0.691	0.828	0.79
Head	ANT 2	LTE FDD B106	25.7	24.6	23.5	0.936	1.200	1.08	Body	ANT 2	LTE FDD B106	25.7	25.7	24.9	0.674	0.805	0.77
Head	ANT 3	LTE FDD B106	25.7	25.7	25.7	0.299	0.299	0.00	Body	ANT 3	LTE FDD B106	25.7	25.7	25.0	0.718	0.851	0.74
Head	ANT 2	FR-1 FDD n5	25.7	25.3	24.1	0.919	1.200	1.16	Body	ANT 2	FR-1 FDD n5	25.7	25.7	24.6	0.779	0.994	1.06
Head	ANT 3	FR-1 FDD n5	25.7	25.7	25.7	0.214	0.214	0.00	Body	ANT 3	FR-1 FDD n5	25.7	25.7	24.9	0.669	0.802	0.79
Head	ANT 1	FR-1 FDD n7	24.2	24.2	24.2	0.308	0.308	0.00	Body	ANT 1	FR-1 FDD n7	24.2	21.7	20.4	0.892	1.200	1.29
Head	ANT 3	FR-1 FDD n7	25.7	25.7	25.7	0.453	0.453	0.00	Body	ANT 3	FR-1 FDD n7	25.7	20.8	20.1	1.017	1.200	0.72
Head	ANT 4	FR-1 FDD n7	23.9	19.4	18.5	0.982	1.200	0.87	Body	ANT 4	FR-1 FDD n7	23.9	21.5	20.4	0.936	1.200	1.08
Head	ANT 14	FR-1 FDD n7	25.7	25.7	24.8	0.191	0.236	0.92	Body	ANT 14	FR-1 FDD n7	25.7	19.9	19.0	0.980	1.200	0.88
Head	ANT 2	FR-1 FDD n12	25.7	25.7	24.6	0.906	1.175	1.13	Body	ANT 2	FR-1 FDD n12	25.7	25.7	24.5	0.808	1.073	1.23
Head	ANT 3	FR-1 FDD n12	25.7	25.7	25.7	0.179	0.179	0.00	Body	ANT 3	FR-1 FDD n12	25.7	25.7	24.7	0.741	0.927	0.97
Head	ANT 2	FR-1 FDD n14	25.7	24.8	23.7	0.929	1.200	1.11	Body	ANT 2	FR-1 FDD n14	25.7	24.9	24.0	0.980	1.200	0.88
Head	ANT 3	FR-1 FDD n14	25.7	25.7	25.7	0.268	0.268	0.00	Body	ANT 3	FR-1 FDD n14	25.7	25.7	24.8	0.770	0.958	0.95
Head	ANT 1	FR-1 FDD n25	24.9	24.9	24.9	0.097	0.097	0.00	Body	ANT 1	FR-1 FDD n25	24.9	23.6	22.8	1.005	1.200	0.77

RF Exposure Condition	Antenna	Technology	P _{Max} (dBm)	P _{Limit} (dBm)	P _{Limit, nom} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)	Uncertainty dB (±)	RF Exposure Condition	Antenna	Technology	P _{Max} (dBm)	P _{Limit} (dBm)	P _{Limit, nom} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)	Uncertainty dB (±)
Head	ANT 2	FR-1 FDD n26	25.7	25.3	24.0	0.881	1.200	1.34	Body	ANT 2	FR-1 FDD n26	25.7	25.7	24.4	0.709	0.950	1.27
Head	ANT 3	FR-1 FDD n26	25.7	25.7	25.7	0.207	0.207	0.00	Body	ANT 3	FR-1 FDD n26	25.7	25.7	24.9	0.594	0.713	0.79
Head	ANT 1	FR-1 FDD n30	24.2	24.2	24.2	0.237	0.237	0.00	Body	ANT 1	FR-1 FDD n30	24.2	23.9	23.1	0.989	1.200	0.84
Head	ANT 3	FR-1 FDD n30	25.2	25.2	25.2	0.479	0.479	0.00	Body	ANT 3	FR-1 FDD n30	25.2	20.3	19.5	1.003	1.200	0.78
Head	ANT 4	FR-1 FDD n30	24.2	20.6	19.6	0.947	1.200	1.03	Body	ANT 4	FR-1 FDD n30	24.2	21.3	20.2	0.931	1.200	1.10
Head	ANT 14	FR-1 FDD n30	25.7	25.7	24.6	0.141	0.182	1.10	Body	ANT 14	FR-1 FDD n30	25.7	20.7	19.7	0.947	1.200	1.03
Head	ANT 1	FR-1 TDD n41 PC3	25.7	25.7	25.7	0.291	0.291	0.00	Body	ANT 1	FR-1 TDD n41 PC3	25.7	21.6	20.6	0.951	1.200	1.01
Head	ANT 3	FR-1 TDD n41 PC3	25.7	25.7	25.7	0.394	0.394	0.00	Body	ANT 3	FR-1 TDD n41 PC3	25.7	21.6	20.5	0.940	1.200	1.06
Head	ANT 4	FR-1 TDD n41 PC3	25.7	19.8	18.4	0.869	1.200	1.40	Body	ANT 4	FR-1 TDD n41 PC3	25.7	21.8	20.4	0.863	1.200	1.43
Head	ANT 14	FR-1 TDD n41 PC3	25.7	25.7	24.4	0.287	0.385	1.28	Body	ANT 14	FR-1 TDD n41 PC3	25.7	20.0	18.9	0.921	1.200	1.15
Head	ANT 4	FR-1 TDD n48	25.2	21.0	19.0	0.757	1.200	2.00	Body	ANT 4	FR-1 TDD n48	25.2	21.4	20.4	0.953	1.200	1.00
Head	ANT 7	FR-1 TDD n48	26.0	26.0	26.0	0.204	0.204	0.00	Body	ANT 7	FR-1 TDD n48	26.0	24.5	23.0	0.842	1.200	1.54
Head	ANT 8	FR-1 TDD n48	23.9	21.6	20.2	0.863	1.200	1.43	Body	ANT 8	FR-1 TDD n48	23.9	19.1	17.9	0.904	1.200	1.23
Head	ANT 9	FR-1 TDD n48	23.9	23.9	23.9	0.136	0.136	0.00	Body	ANT 9	FR-1 TDD n48	23.9	22.5	20.9	0.821	1.200	1.65
Head	ANT 1	FR-1 TDD n53	20.7	20.7	20.7	0.123	0.123	0.00	Body	ANT 1	FR-1 TDD n53	20.7	20.7	19.5	0.489	0.648	1.22
Head	ANT 14	FR-1 TDD n53	20.7	20.7	19.6	0.117	0.149	1.06	Body	ANT 14	FR-1 TDD n53	20.7	20.1	19.0	0.925	1.200	1.13
Head	ANT 1	FR-1 FDD n66	25.7	25.7	25.7	0.113	0.113	0.00	Body	ANT 1	FR-1 FDD n66	25.7	25.4	24.4	0.942	1.200	1.05
Head	ANT 3	FR-1 FDD n66	25.7	25.7	25.7	0.310	0.310	0.00	Body	ANT 3	FR-1 FDD n66	25.7	22.8	21.8	0.960	1.200	0.97
Head	ANT 4	FR-1 FDD n66	25.7	22.0	20.8	0.906	1.200	1.22	Body	ANT 4	FR-1 FDD n66	25.7	21.5	20.2	0.892	1.200	1.29
Head	ANT 14	FR-1 FDD n66	25.7	23.0	22.0	0.955	1.200	0.99	Body	ANT 14	FR-1 FDD n66	25.7	21.7	20.6	0.940	1.200	1.06
Head	ANT 1	FR-1 FDD n70	25.7	25.7	25.7	0.233	0.233	0.00	Body	ANT 1	FR-1 FDD n70	25.7	25.7	24.7	0.856	1.068	0.96
Head	ANT 3	FR-1 FDD n70	25.7	25.7	25.7	0.301	0.301	0.00	Body	ANT 3	FR-1 FDD n70	25.7	22.8	22.0	1.003	1.200	0.78
Head	ANT 4	FR-1 FDD n70	25.7	23.0	21.7	0.898	1.200	1.26	Body	ANT 4	FR-1 FDD n70	25.7	22.6	21.3	0.885	1.200	1.32
Head	ANT 14	FR-1 FDD n70	25.7	24.0	23.1	0.969	1.200	0.93	Body	ANT 14	FR-1 FDD n70	25.7	22.0	21.1	0.978	1.200	0.89
Head	ANT 2	FR-1 FDD n71	25.7	25.7	24.5	0.759	0.996	1.18	Body	ANT 2	FR-1 FDD n71	25.7	25.7	24.5	0.715	0.938	1.18
Head	ANT 3	FR-1 FDD n71	25.7	25.7	25.7	0.173	0.173	0.00	Body	ANT 3	FR-1 FDD n71	25.7	25.7	24.6	0.706	0.901	1.06
Head	ANT 4	FR-1 TDD n77 (Block A) PC3	26.0	21.0	19.2	0.795	1.200	1.79	Body	ANT 4	FR-1 TDD n77 (Block A) PC3	26.0	22.1	21.2	0.966	1.200	0.94
Head	ANT 7	FR-1 TDD n77 (Block A) PC3	26.0	26.0	26.0	0.239	0.239	0.00	Body	ANT 7	FR-1 TDD n77 (Block A) PC3	26.0	24.6	23.3	0.892	1.200	1.29
Head	ANT 8	FR-1 TDD n77 (Block A) PC3	26.0	21.9	20.3	0.828	1.200	1.61	Body	ANT 8	FR-1 TDD n77 (Block A) PC3	26.0	20.1	18.6	0.851	1.200	1.49
Head	ANT 9	FR-1 TDD n77 (Block A) PC3	26.0	26.0	26.0	0.415	0.415	0.00	Body	ANT 9	FR-1 TDD n77 (Block A) PC3	26.0	21.8	20.4	0.867	1.200	1.41
Head	ANT 4	FR-1 TDD n77 (Block C) PC3	26.0	23.3	22.0	0.879	1.200	1.35	Body	ANT 4	FR-1 TDD n77 (Block C) PC3	26.0	21.7	20.0	0.813	1.200	1.69
Head	ANT 7	FR-1 TDD n77 (Block C) PC3	26.0	26.0	26.0	0.101	0.101	0.00	Body	ANT 7	FR-1 TDD n77 (Block C) PC3	26.0	23.7	22.4	0.896	1.200	1.27
Head	ANT 8	FR-1 TDD n77 (Block C) PC3	26.0	25.1	23.4	0.804	1.200	1.74	Body	ANT 8	FR-1 TDD n77 (Block C) PC3	26.0	20.2	18.2	0.748	1.200	2.05
Head	ANT 9	FR-1 TDD n77 (Block C) PC3	26.0	26.0	26.0	0.230	0.230	0.00	Body	ANT 9	FR-1 TDD n77 (Block C) PC3	26.0	21.6	19.6	0.762	1.200	1.97
Head	ANT 4	MSS (L-Band)	N/A	N/A	N/A	N/A	N/A	N/A	Extremity	ANT 4	MSS (L-Band)	28.7	26.7	26.7	3.000	3.000	0.00

RF Exposure Condition	Antenna	Technology	Bandwidth (MHz)	Channel	Frequency (MHz)	P _{Max} (dBm)	P _{Limit} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)	RF Exposure Condition	Antenna	Technology	Bandwidth (MHz)	Channel	Frequency (MHz)	P _{Max} (dBm)	P _{Limit} (dBm)	SAR _{Measured} (W/kg)	SAR _{Reported} (W/kg)
Head	ANT 3	Wi-Fi 2.4 GHz	20 MHz	6	2437	21.5	21.5	0.211	1.200	Body	ANT 3	Wi-Fi 2.4 GHz	20 MHz	2	2417	21.5	21.0	0.076	0.103
Head	ANT 16	Wi-Fi U-NII 2A	40 MHz	54	5270	20.0	20.0	0.086	1.200	Body	ANT 3	Wi-Fi 2.4 GHz	20 MHz	6	2437	21.5	21.0	0.698	0.925
Head	ANT 16	Wi-Fi U-NII 2C	80 MHz	122	5610	20.0	20.0	0.188	1.200	Body	ANT 16	Wi-Fi U-NII 1	40 MHz	38	5190	17.5	17.5	0.585	1.200
Head	ANT 16	Wi-Fi U-NII 3	80 MHz	155	5775	20.0	20.0	0.118	1.200	Body	ANT 16	Wi-Fi U-NII 1	40 MHz	46	5230	20.0	18.3	0.709	0.986
Head	ANT 16	Wi-Fi U-NII 5	160 MHz	47	6185	19.0	15.0	0.007	0.011	Body	ANT 16	Wi-Fi U-NII 2C	160 MHz	114	5570	16.5	16.0	0.717	1.157
Head	ANT 16	Wi-Fi U-NII 6	160 MHz	111	6505	19.0	14.5	0.010	0.016	Body	ANT 16	Wi-Fi U-NII 3	80 MHz	155	5775	20.0	16.0	0.675	1.068
Head	ANT 16	Wi-Fi U-NII 8	160 MHz	207	6985	18.5	16.8	0.015	0.024	Body	ANT 16	Wi-Fi U-NII 5	160 MHz	47	6185	19.0	15.0	0.295	0.464
Head	ANT 4	Wi-Fi 2.4 GHz	20 MHz	1	2412	20.5	19.5	0.814	1.156	Body	ANT 16	Wi-Fi U-NII 6	160 MHz	111	6505	19.0	14.5	0.297	0.489
Head	ANT 4	Wi-Fi 2.4 GHz	20 MHz	6	2437	21.5	19.5	0.799	1.134	Body	ANT 16	Wi-Fi U-NII 7	160 MHz	143	6665	19.0	15.3	0.264	0.366
Head	ANT 6	Wi-Fi U-NII 2A	40 MHz	54	5270	20.0	20.0	0.210	1.200	Body	ANT 16	Wi-Fi U-NII 8	160 MHz	207	6985	18.5	16.8	0.648	1.055
Head	ANT 6	Wi-Fi U-NII 2C	80 MHz	122	5610	20.0	20.0	0.507	1.200	Body	ANT 4	Wi-Fi 2.4 GHz	20 MHz	6	2437	21.5	20.5	0.791	1.072
Head	ANT 6	Wi-Fi U-NII 3	80 MHz	155	5775	20.0	20.0	0.635	1.200	Body	ANT 4	Wi-Fi 2.4 GHz	20 MHz	11	2462	21.5	20.5	0.862	1.169
Head	ANT 6	Wi-Fi U-NII 5	160 MHz	47	6185	19.0	16.8	0.173	0.282	Body	ANT 6	Wi-Fi U-NII 2A	40 MHz	54	5270	20.0	18.5	0.695	0.978
Head	ANT 6	Wi-Fi U-NII 6	160 MHz	111	6505	19.0	17.0	0.217	0.326	Body	ANT 6	Wi-Fi U-NII 2A	40 MHz	62	5310	17.5	17.5	0.568	1.200
Head	ANT 6	Wi-Fi U-NII 7	160 MHz	143	6665	19.0	17.5	0.270	0.406	Body	ANT 6	Wi-Fi U-NII 2C	80 MHz	138	5690	20.0	18.0	0.459	0.694
Head	ANT 6	Wi-Fi U-NII 8	160 MHz	207	6985	18.5	18.5	0.401	1.200	Body	ANT 6	Wi-Fi U-NII 3	80 MHz	155	5775	20.0	19.3	0.676	1.058
Head	ANT 3	Bluetooth 2.4 GHz	N/A	N/A	N/A	21.0	21.0	0.165	1.200	Body	ANT 6	Wi-Fi U-NII 5	160 MHz	47	6185	19.0	16.8	0.488	0.794
Head	ANT 16	NB U-NII 1	N/A	N/A	N/A	14.0	14.0	0.007	1.200	Body	ANT 6	Wi-Fi U-NII 6	160 MHz	111	6505	19.0	17.0	0.417	0.626
Head	ANT 16	NB U-NII 3	N/A	N/A	N/A	19.0	19.0	0.060	1.200	Body	ANT 6	Wi-Fi U-NII 7	160 MHz	143	6665	19.0	17.5	0.505	0.759
Head	ANT 16	NB U-NII 5	N/A	Mid	6263	2.0	2.0	0.001	1.200	Body	ANT 6	Wi-Fi U-NII 8	160 MHz	207	6985	18.5	18.5	0.637	1.200
Head	ANT 4	Bluetooth 2.4 GHz	N/A	N/A	N/A	21.0	19.5	0.748	1.075	Body	ANT 3	Bluetooth 2.4 GHz	N/A	N/A	N/A	21.0	21.0	0.773	1.200
Head	ANT 6	NB U-NII 1	N/A	N/A	N/A	14.0	14.0	0.006	1.200	Body	ANT 16	NB U-NII 1	N/A	N/A	N/A	14.0	14.0	0.249	1.200
Head	ANT 6	NB U-NII 3	N/A	N/A	N/A	19.0	19.0	0.352	1.200	Body	ANT 16	NB U-NII 3	N/A	N/A	N/A	19.0	16.0	0.565	1.026
Head	ANT 3	802.15.4	N/A	N/A	N/A	20.0	20.0	0.062	1.200	Body	ANT 16	NB U-NII 5	N/A	Mid	6263	2.0	2.0	0.006	1.200
Head	ANT 4	802.15.4	N/A	N/A	N/A	20.0	20.0	0.856	1.200	Body	ANT 4	Bluetooth 2.4 GHz	N/A	N/A	N/A	21.0	20.5	0.699	1.055
										Body	ANT 6	NB U-NII 1	N/A	N/A	N/A	14.0	14.0	0.187	1.200
										Body	ANT 6	NB U-NII 3	N/A	N/A	N/A	19.0	19.0	0.615	1.200
										Body	ANT 6	NB U-NII 5	N/A	Mid	6263	2.8	2.8	0.005	1.200
										Body	ANT 3	802.15.4	N/A	N/A	N/A	20.0	20.0	0.760	1.200
										Body	ANT 4	802.15.4	N/A	N/A	N/A	20.0	20.0	0.856	1.200

3. Power Density Characterization

The DUT supports 5G millimeter wave NR which is installed at location(s) shown in the operational description. In this chapter, a hybrid approach is used: Using electromagnetic (EM) simulation and actual measurements to efficiently, and conservatively, characterize the power density profile for the DUT.

3.1. Exposure Scenarios in PD Evaluation

In general, for devices operating at frequencies > 6 GHz, PD is required to be assessed for all antenna configurations (beams) from all millimeter wave antenna modules installed inside the device. Furthermore, this PD evaluation should be performed at low, mid, and high channels for each supported millimeter wave band.

For this DUT, the 4 cm² spatially-averaged PD is evaluated along the applicable surfaces and the worst-case PD is determined by taking the maximum PD among all the evaluated surfaces for each beam/band.

3.2. PD Characterization Overview

Parameters used in PD Characterization:

- The supported beams per band are outlined within the DUT codebook, Table 3-1.
- **PD_{Reported}** : It should be less than the regulatory PD limit to account for all device design related uncertainties.
- **P_{Limit}** : For a PD characterized wireless device, the input power level at antenna port(s) for each beam corresponding to PD_{Reported} .
- **PD Characterization**: The table that contains the P_{Limit} fed to the antenna port(s) for all supported beams.

Figure 3-1 outlines the PD Characterization process.

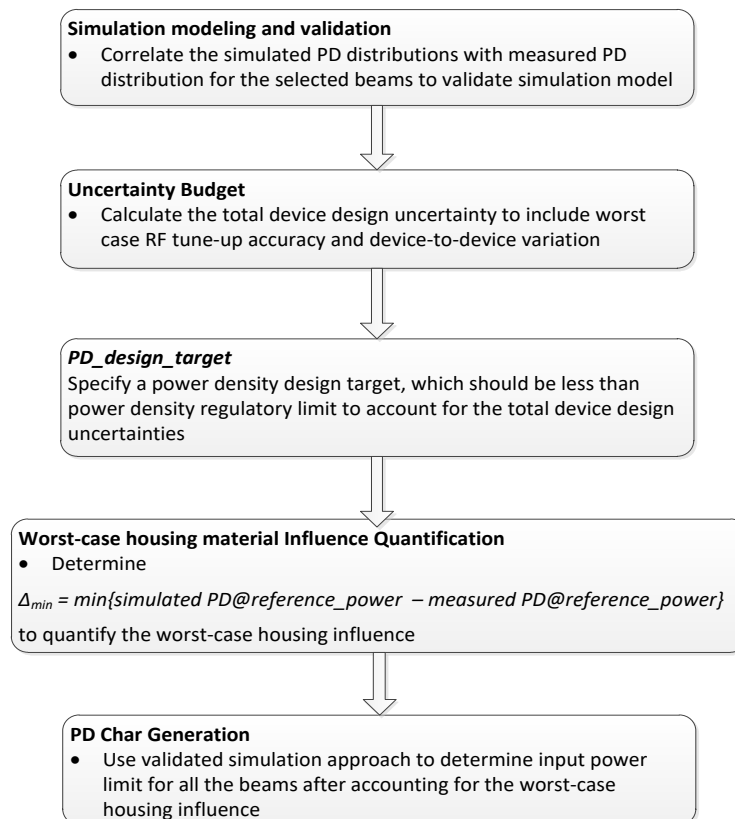


Figure 3-1: High Level Flow Chart for Power Density Characterization

3.3. DUT Codebook

In general, all the beams that the DUT supports are specified in the pre-defined codebook. The codebook is device design specific and generated after evaluating radiation coverage from this specific device.

Table 3-1 shows all the beams and their relevant information.

The PD evaluation needs to be performed for all the beams listed in Table 3-1.

Table 3-1: DUT Codebook

n258				n260				n261			
Beam ID	Module	Antenna Type	# of Elements	Beam ID	Module	Antenna Type	# of Elements	Beam ID	Module	Antenna Type	# of Elements
0	M1	Patch	4	0	M1	Patch	4	0	M1	Patch	4
1	M1	Patch	4	1	M1	Patch	4	1	M1	Patch	4
2	M1	Patch	4	2	M1	Patch	4	2	M1	Patch	4
3	M1	Patch	4	3	M1	Patch	4	3	M1	Patch	4
4	M1	Patch	4	4	M1	Patch	4	4	M1	Patch	4
5	M1	Patch	4	5	M1	Patch	4	5	M1	Patch	4
6	M1	Patch	4	6	M1	Patch	4	6	M1	Patch	4
7	M1	Patch	4	7	M1	Patch	4	7	M1	Patch	4
8	M1	Patch	4	8	M1	Patch	4	8	M1	Patch	4
9	M1	Patch	3	9	M1	Patch	4	9	M1	Patch	3
10	M1	Patch	3	10	M1	Patch	3	10	M1	Patch	3
11	M1	Patch	3	11	M1	Patch	3	11	M1	Patch	3
12	M1	Patch	3	12	M1	Patch	3	12	M1	Patch	3
13	M1	Patch	3	13	M1	Patch	3	13	M1	Patch	3
14	M1	Patch	1	14	M1	Patch	3	14	M1	Patch	1
15	M1	Patch	1	15	M1	Patch	3	15	M1	Patch	1
16	M1	Patch	1	16	M1	Patch	3	16	M1	Patch	1
17	M1	Patch	1	17	M1	Patch	1	17	M1	Patch	1
				18	M1	Patch	1				
				19	M1	Patch	1				
				20	M1	Patch	1				

3.4. Simulation and modeling validation

3.4.1. Modeling for Simulation

Device modeling is described in a supplemental exhibit.

3.4.2. Modeling Validation

To validate modeling and simulation:

1. Select one beam (i.e., antenna array configuration) per antenna type (dipole/patch) and per antenna module. All three antennas contain only patch arrays. Therefore, the beam selection criteria for each millimeter wave antenna are:

- a) Two beams from each antenna module.

Note: Since the relative phase between two single beams in a beam pair is uncontrolled and could vary from run to run, for the validation purpose, the selection is limited to the single beam antenna array configuration. Additionally, single beam containing a higher number of active antenna elements is selected. For example, a single beam with four active patches should be selected over beam with a single active patch antenna beam.

2. For a given input power, perform both PD simulation and PD measurement to obtain the simulated PD distributions and measured PD distributions on the surface in front of the antenna array as well as the surfaces that are adjacent to the antenna array as they could potentially have strong radiating energy when considering the orientation of antenna array and type of antenna array (i.e., patch array or dipole array).

3. Validate modeling and simulation by correlating the simulated PD distribution and measured PD distribution for all antenna array configurations selected in Step 1 and for all surfaces selected in Step 2.

The modeling validation is performed through correlating the simulated point PD distribution to measured point PD distribution.

The difference in 4 cm^2 -averaged PD is not used for the purpose of validity of the modeling because the housing material property (for non-metal material) used in the simulation is an approximation (note the accurate material properties are not available at millimeter wave frequencies). These discrepancies in PD magnitude will be used to determine the worst-case housing influence (due to non-metal material property uncertainty) in §3.6. The worst-case housing influence will be accounted for in PD Characterization generation for conservative RF exposure assessment, see §3.7 for details.

Based on the selection criteria described in Step 1 and Step 2, the beams and surfaces selected for modeling validation of the DUT are listed in Table 3-2.

Table 3-2: Beams and Surfaces Selection for PD Correlation

Band	Antenna	Beam ID	Pol	Surface
n258	M1	3	H	Top
		4	V	Top
		3	H+V	Top
n260	M1	8	H	Top
		7	V	Top
		0	H+V	Top
n261	M1	2	H	Top
		1	V	Top
		1	H+V	Top

With an input power of 6 dBm for n258, n260, and n261, PD measurement and PD simulation are conducted for all beams and surfaces listed in Table 3-2. Both PD measurement and PD simulation are performed at mid channel of each millimeter wave beam, PD measurement is conducted with CW modulation.

- PD distribution:

Please refer to the operational description.

- 4 cm^2 -averaged PD value

Table 3-3 lists the measured 4 cm^2 -averaged PD and simulated 4 cm^2 -averaged PD for all selected beams and surfaces for n258, n260, and n261 bands. The discrepancy between simulated and measured PD value will be used to determine worst-case housing influence for conservative assessment (see §3.6).

Table 3-3: Measured and Simulated 4 cm^2 -averaged PD for Selected Beams with 6 dBm Input Power for Supported Bands

Band	Antenna	Beam ID	Pol	Surface	4 cm^2 avg. PD		Delta ¹
					Meas.	Sim	
n258	M1	3	H	Top	21.80	21.28	-0.10
		4	V	Top	13.50	19.78	1.66
		3	H+V	Top	29.60	35.86	0.83
n260	M1	8	H	Top	18.30	16.83	-0.36
		7	V	Top	12.20	15.27	0.97
		0	H+V	Top	31.80	31.39	-0.06
n261	M1	2	H	Top	29.60	27.34	-0.34
		1	V	Top	22.80	30.58	1.28
		1	H+V	Top	43.60	53.08	0.85

¹Delta = Sim - Meas (dB)

3.4.3. Simulation for Power Density

The PD exposure of DUT can be reliably assessed using the validated simulation approach.

In general, all six surfaces of the DUT should be assessed for RF exposure from the millimeter wave radio and the worst-case PD should be determined by:

$$PD_{\text{worst-case}} = \max \{PD_{s1}, PD_{s2}, PD_{s3}, PD_{s4}, PD_{s5}, PD_{s6}\} \quad (1)$$

where PD_{s1} , PD_{s2} , PD_{s3} , PD_{s4} , PD_{s5} , PD_{s6} are the highest 4 cm²-averaged PD on surface S1, S2, S3, S4, S5 and S6 of the device. respectively.

However, depending on the location of the millimeter wave module and the antenna array orientation relative to the surface of the device, one or more surface(s) can be excluded for PD calculation as the PD value(s) on the excluded surface(s) will be undoubtedly lower when comparing to other surfaces; thus, the exclusion will have no impact for the worst-case PD determined using Equation 1.

For this DUT, the type of antenna array (containing in each millimeter wave radio), the surface planes identified for PD evaluation to determine the worst-case PD are selected and listed in Table 3-4.

Table 3-4: PD Evaluation Plane

ANT	Front	Left	Right	Top	Bottom	Back
	S1	S3	S4	S5	S6	S7
M1	Yes	No	No	Yes	No	Yes

The EM simulation is performed to characterize PD at low, mid, and high channels for each supported band. The simulation setup (mesh, convergence criteria, and radiation boundary settings) as described in the operational description ensures an accurate and reliable result for PD simulation on the planes identified. Both point PD and 4 cm²-averaged PD distributions on the worst surface plane (i.e., the surface having highest PD value for the beam tested) are plotted and provided in the operational description to show that the PD hotspots are captured in this analysis.

3.5. PD_{Reported}

The manufacturer has their own internal controls for managing uncertainty for use in determining the PD_{Reported} . To account for the total design related uncertainty, PD_{Reported} needs to be:

$$PD_{\text{Reported}} < PD_{\text{regulatory_limit}} \times 10^{\frac{-\text{total uncertainty}}{10}}$$

The regulatory 4 cm²-averaged PD requirement of 10 W/m², the PD_{Reported} is determined as:

3.6. Worst-case Housing Influence Determination

For non-metal material, the material property cannot be accurately characterized at millimeter wave frequencies to date. The estimated material property for the device housing is used in the simulation model, which could influence the accuracy in simulation for PD amplitude quantification. Since the housing influence on PD could vary from surface to surface where the EM field propagates through, the most underestimated surface is used to quantify the worst-case housing influence for conservative assessment.

Depending on the type of antenna array, i.e., dipole antenna array or patch antenna array, the nature of EM field propagation in the near field is different. Therefore, the worst-case housing influence is determined per antenna module and per antenna type.

For this DUT, when comparing a simulated 4 cm²-averaged PD and measured 4 cm²-averaged PD, the worst error introduced for each type of antenna array and antenna module when using the estimated material property in the simulation is accented in bold numbers in Table 3-5. Thus, the worst-case housing influence, denoted as $\Delta_{min} = \text{Sim. PD} - \text{Meas. PD}$, is determined as:

Table 3-5: Δ_{min}

Band	Ant	Pol	Δ_{min} (dB)
n258	M1	H	-0.10
		V	1.66
		H+V	0.83
n260	M1	H	-0.36
		V	0.97
		H+V	-0.06
n261	M1	H	-0.34
		V	1.28
		H+V	0.85

Δ_{min} represents the worst case where RF exposure is underestimated the most in simulation when using the estimated material property for glass/plastics of the housing. For conservative assessment, the Δ_{min} is used as the worst-case factor and applied to all the beams in the corresponding beam group to determine input power limits in PD characterization for compliance (see §**Error! Reference source not found.** for details).

3.7. PD Characterization

This section describes the PD Characterization generation that complies with the PD_{Reported} determined in §3.5 and complies with the regulatory power density limit.

3.7.1. Scaling Factor for Single Beams

To determine the P_{Limit} at each antenna port, perform the simulation at low, mid, and high channel for each millimeter wave band supported, with a given input power per active port:

1. Obtain PD_{surface} value (the worst PD among all identified surfaces of the DUT) at all three channels for all single beams specified in the codebook of Table 5-1.
2. Derive a scaling factor at low, mid and high channel, $s(i)_{\text{low_or_mid_or_high}}$, by:

$$s(i)_{\text{low_or_mid_or_high}} = \frac{PD_{\text{design target}}}{\text{sim.PD}_{\text{surface}}(i)}, i \in \text{single beams} \quad (2)$$

3. Determine the worst-case scaling factor, $s(i)$, among low, mid and high channels:

$$s(i) = \min \{s_{\text{low}}(i), s_{\text{mid}}(i), s_{\text{high}}(i)\}, i \in \text{single beams} \quad (3)$$

4. Determine the simulated P_{Limit} , $\text{sim.power}_{\text{limit}}$, for single beam i by:

$$sim.power_{limit} = 10 * \log_{10}(s(i)) + sim.input.power.at.active.port, i \in single\ beams \quad (4)$$

In the above equation, power is expressed in units of (dBm)

NOTE: $P_{ref}(i) = sim.input.power.at.active.port(i)$

3.7.2. Scaling Factor for Beam Pairs

The relative phase between beam pair is not controlled in the modem's design and could vary from run to run. Therefore, for a beam pair, based on the simulation results, the worst-case scaling factor needs to be determined mathematically to ensure compliance.

For a beam pair, extract the E-fields and H-fields from the corresponding single beams at low, mid, and high channel for each supported band and for all identified surfaces of the DUT.

For a given beam pair containing $beam_a$ and $beam_b$, and for a given channel, let relative phase between $beam_a$ and $beam_b = \phi$, and the total PD of the beam pair can be expressed as:

$$\begin{aligned} total\ PD(\phi) &= \frac{1}{2} \sqrt{Re\{PD_x(\phi)\}^2 + Re\{PD_y(\phi)\}^2 + Re\{PD_z(\phi)\}^2} \\ &= \frac{1}{2} Re\left\{\left(\vec{E}_a + \vec{E}_b e^{j\omega\phi}\right) \times \left(\vec{H}_a + \vec{H}_b e^{j\omega\phi}\right)^*\right\} \quad (5) \end{aligned}$$

where, $PD_x(\phi)$, $PD_y(\phi)$, and $PD_z(\phi)$ are the three components of the $total\ PD(\phi)$; E_a and H_a are the extracted E-fields and H-fields of $beam_a$, while E_b and H_b are the extracted E-fields and H-fields of $beam_b$.

Sweep ϕ with a 5° step from 0° to 360° to determine the worst-case, $\phi_{worstcase}$, which results in the highest $total\ PD(\phi)$ among all identified surfaces for this beam pair at this channel. For details on the worst case $total\ PD(\phi)$ derivation, see Appendix A.

Follow the above procedure to determine $\phi_{worstcase}$ for all three channels to obtain the scaling factor given by the equation below for low, mid, and high channels:

$$s(i)_{low_or_mid_or_high} = \frac{PD\ design\ target}{total\ PD(\phi(i)_{worstcase})}, i \in beam\ pairs \quad (6)$$

The term $\phi_{worstcase}$ varies with channel and beam pair, the lowest scaling factor among all three channels, $s(i)$, is determined for the beam pair i :

$$s(i) = \min\{s_{low}(i), s_{mid}(i), s_{high}(i)\}, i \in beam\ pairs \quad (7)$$

The simulated P_{Limit} , $sim.power_{limit}$, for beam pair i can be determined by:

$$sim.power_{limit} = 10 * \log_{10}(s(i)) + sim.input.power.at.active.port, i \in beam\ pairs \quad (8)$$

In the above equation, power is expressed in units of (dBm)

NOTE: $P_{ref}(i) = sim.input.power.at.active.port(i)$

3.7.3. PD P_{Limit}

The PD Characterization specifies the limit of input power at an antenna port that corresponds to $PD_{Reported}$ for all beams.

Ideally, if there is no uncertainty associated with hardware design, P_{Limit} , denoted as $P_{Limit}(i)$, for beam i can be obtained after accounting for the housing influence (Δ_{min}) determined in Table 3-5 of §3.6, given by:

$$P_{limit}(i) = sim.power_{limit}(i) + \Delta_{min}, i \in all\ beams \quad (8)$$

In the above equation, power is expressed in units of (dBm)

The term $sim.power_{limit}(i)$ includes the design uncertainty, the TxAGC uncertainty, and the scaling factor obtained from Eq. (4) or Eq. (8) for beam i ; the term Δ_{min} is the worst-case housing influence factor (determined in Table 3-5) for beam i .

If simulation overestimates the housing influence, then Δ_{min} (= simulated PD – measured PD) is negative, which means that the measured PD would be higher than the simulated PD. The input power to antenna elements determined via simulation must be decreased for compliance.

Similarly, if simulation underestimates the loss, then Δ_{min} is positive (measured PD would be lower than the simulated value). Input power to antenna elements determined via simulation can be increased and still be PD compliant.

The hardware design has uncertainty which must be properly considered. In §3.6, the TxAGC uncertainty is embedded in the process of Δ_{min} determination. Since TxAGC uncertainty is already accounted for in $PD_{Reported}$ (see §3.5), it needs to be removed to avoid double counting this uncertainty.

Thus, Equation 8 is modified to:

If -TxAGC uncertainty < Δ_{min} < TxAGC uncertainty,

$$input.power.limit(i) = sim.power_{limit}(i), i \in all\ beams \quad (9)$$

else if Δ_{min} < -TxAGC uncertainty,

$$input.power.limit(i) = sim.power_{limit}(i) + (\Delta_{min} + TxAGC\ uncertainty), i \in all\ beams \quad (10)$$

else if Δ_{min} > TxAGC uncertainty,

$$input.power.limit(i) = sim.power_{limit}(i) + (\Delta_{min} - TxAGC\ uncertainty), i \in all\ beams \quad (11)$$

In the above three equations, power is expressed in units of (dBm)

Following the logic above, P_{Limit} for this DUT can be calculated using Equations (9), (10) and (11), i.e.,

Table 3-6: P_{Limit} Calculation

Band	Ant	Pol	Δ_{min} (dB)	P_{Limit} Equation	P_{Limit} (dBm)	Notes
n258	M1	H	-0.10	sim.power_limit(i)	-1.12	Using Eq. 9
		V	1.66	sim.power_limit(i) + 0.41	0.46	Using Eq. 11
		H+V	0.83	sim.power_limit(i)	-2.59	Using Eq. 9
n260	M1	H	-0.36	sim.power_limit(i)	-0.78	Using Eq. 9
		V	0.97	sim.power_limit(i)	-1.28	Using Eq. 9
		H+V	-0.06	sim.power_limit(i)	-3.77	Using Eq. 9
n261	M1	H	-0.34	sim.power_limit(i)	-2.19	Using Eq. 9
		V	1.28	sim.power_limit(i) + 0.03	-1.83	Using Eq. 11
		H+V	0.85	sim.power_limit(i)	-4.40	Using Eq. 9

Thus, the DUT PD Characterization for n258, n260, and n261 bands are as shown in Table 3-7.

Table 3-7: PD Characterization

n258			n260			n261				
Pol.	Beam ID	P_{Limit} (dBm)	Pol.	Beam ID	P_{Limit} (dBm)	Pol.	Beam ID	P_{Limit} (dBm)		
		Freq. Index			Freq. Index			Freq. Index		
		0			4			2		
					5			3		
H	0	-0.10	H	0	0.09	-0.55	H	0	-1.19	-1.19
H	1	-1.12	H	1	0.82	-0.15	H	1	-1.32	-1.08
H	2	2.31	H	2	0.64	0.14	H	2	-2.19	-2.19
H	3	-0.86	H	3	1.25	0.16	H	3	-1.56	-1.83
H	4	2.23	H	4	0.37	-0.47	H	4	-1.68	-1.84
H	5	3.12	H	5	0.45	-0.53	H	5	-1.49	-1.87
H	6	-0.72	H	6	0.79	-0.13	H	6	-0.86	-0.55
H	7	-0.51	H	7	2.07	0.82	H	7	-1.30	-1.35
H	8	-0.08	H	8	-0.10	-0.78	H	8	-1.75	-1.48
H	9	0.55	H	9	0.67	-0.29	H	9	-0.56	-0.59
H	10	2.64	H	10	0.29	-0.21	H	10	-0.99	-1.03
H	11	1.03	H	11	0.83	0.34	H	11	-0.10	-0.26
H	12	0.43	H	12	0.96	-0.34	H	12	-0.61	-0.68
H	13	3.90	H	13	0.20	0.05	H	13	0.28	-0.38
H	14	6.67	H	14	1.25	0.31	H	14	4.68	4.40
H	15	6.52	H	15	0.45	0.49	H	15	4.62	4.32
H	16	6.63	H	16	1.07	0.35	H	16	4.45	4.62
H	17	6.02	H	17	5.30	4.94	H	17	4.54	4.80
V	0	0.40	H	18	4.96	5.00	V	0	-1.51	-1.70
V	1	2.88	H	19	5.73	4.31	V	1	-0.94	-1.06
V	2	0.79	H	20	5.03	4.27	V	2	-1.41	-1.25
V	3	1.80	V	0	0.59	-1.26	V	3	-1.58	-1.30
V	4	1.22	V	1	1.66	0.37	V	4	-1.78	-1.13
V	5	0.45	V	2	1.45	0.14	V	5	-1.37	-1.08
V	6	3.18	V	3	1.48	-0.20	V	6	0.14	0.67
V	7	0.79	V	4	1.31	-0.13	V	7	-0.86	-1.21
V	8	0.73	V	5	0.67	-1.28	V	8	-1.66	-1.49
V	9	1.63	V	6	1.59	1.09	V	9	0.14	-0.28
V	10	0.05	V	7	1.66	0.85	V	10	-0.56	-0.65
V	11	3.37	V	8	1.55	0.62	V	11	0.58	-1.46
V	12	2.82	V	9	1.09	-0.92	V	12	-0.85	-1.85
V	13	0.55	V	10	1.36	-0.50	V	13	-0.50	0.43
V	14	7.20	V	11	2.22	-0.10	V	14	5.14	3.96
V	15	6.31	V	12	1.46	-0.66	V	15	4.62	3.84
V	16	6.62	V	13	1.76	-0.04	V	16	4.20	4.07
V	17	5.61	V	14	1.34	-0.40	V	17	4.19	6.06
H+V	0	-1.86	V	15	2.17	0.53	H+V	0	-4.31	-4.33
H+V	1	-2.59	V	16	1.24	-0.02	H+V	1	-4.47	-3.87
H+V	2	-1.06	V	17	6.42	4.42	H+V	2	-4.98	-4.40
H+V	3	-2.19	V	18	6.45	4.91	H+V	3	-4.01	-4.40
H+V	4	-1.02	V	19	6.20	3.54	H+V	4	-4.69	-3.89
H+V	5	-0.58	V	20	6.51	5.21	H+V	5	-4.29	-3.75
H+V	6	-1.39	H+V	0	-2.50	-3.75	H+V	6	-4.27	-2.77
H+V	7	-2.10	H+V	1	-1.46	-1.92	H+V	7	-4.15	-4.16
H+V	8	-2.31	H+V	2	-1.76	-2.16	H+V	8	-4.42	-3.99
H+V	9	-1.26	H+V	3	-1.63	-2.39	H+V	9	-3.21	-3.03
H+V	10	-1.05	H+V	4	-1.98	-2.77	H+V	10	-3.77	-3.41
H+V	11	-0.27	H+V	5	-2.48	-3.77	H+V	11	-2.74	-3.43
H+V	12	-0.84	H+V	6	-1.70	-1.92	H+V	12	-3.71	-3.85
H+V	13	-0.30	H+V	7	-1.10	-1.79	H+V	13	-3.07	-2.51
H+V	14	4.64	H+V	8	-2.61	-3.75	H+V	14	1.91	1.60
H+V	15	4.21	H+V	9	-2.07	-3.30	H+V	15	1.64	1.52
H+V	16	4.35	H+V	10	-1.67	-3.06	H+V	16	1.33	1.77
H+V	17	3.52	H+V	11	-0.99	-2.59	H+V	17	1.38	2.79
			H+V	12	-1.29	-3.23				
			H+V	13	-1.54	-2.72				
			H+V	14	-1.22	-2.77				
			H+V	15	-1.20	-2.22				
			H+V	16	-1.33	-2.53				
			H+V	17	3.35	1.95				
			H+V	18	3.20	2.25				
			H+V	19	3.48	1.18				
			H+V	20	3.25	1.96				

A Worst Phase Derivation for Beam Pair

For beam pairs, since the relative phase between two beams is unknown, finding the worst-case PD by sweeping the relative phase for all possible angles is required for conservative assessment.

Assuming E-field and H-field of $beam_a$ are $\{E_{x_a}, E_{y_a}, E_{z_a}\}$ and $\{H_{x_a}, H_{y_a}, H_{z_a}\}$, respectively; E-field and H-field of $beam_b$ are $\{E_{x_b}, E_{y_b}, E_{z_b}\}$ and $\{H_{x_b}, H_{y_b}, H_{z_b}\}$, respectively; and the relative phase is $\emptyset$, for beam pair consisting of $beam_a$ and $beam_b$, the combined E- and H-fields, $\{E_{x_pair_i}, E_{y_pair_i}, E_{z_pair_i}\}$ and $\{H_{x_pair_i}, H_{y_pair_i}, H_{z_pair_i}\}$, can be expressed as:

$$Ex(\emptyset)_{pair_i} = E_{x_a} + E_{x_b} \times e^{-j\omega\emptyset}$$

$$Ey(\emptyset)_{pair_i} = E_{y_a} + E_{y_b} \times e^{-j\omega\emptyset}$$

$$Ez(\emptyset)_{pair_i} = E_{z_a} + E_{z_b} \times e^{-j\omega\emptyset}$$

$$Hx(\emptyset)_{pair_i} = H_{x_a} + H_{x_b} \times e^{-j\omega\emptyset}$$

$$Hy(\emptyset)_{pair_i} = H_{y_a} + H_{y_b} \times e^{-j\omega\emptyset}$$

$$Hz(\emptyset)_{pair_i} = H_{z_a} + H_{z_b} \times e^{-j\omega\emptyset}$$

The combined PD can then be calculated:

$$PDx(\emptyset)_{pair_i} = Ey(\emptyset)_{pair_i} \times Hz(\emptyset)_{pair_i}^* - Ez(\emptyset)_{pair_i} \times Hy(\emptyset)_{pair_i}^*$$

$$PDy(\emptyset)_{pair_i} = Ez(\emptyset)_{pair_i} \times Hx(\emptyset)_{pair_i}^* - Ex(\emptyset)_{pair_i} \times Hz(\emptyset)_{pair_i}^*$$

$$PDz(\emptyset)_{pair_i} = Ex(\emptyset)_{pair_i} \times Hy(\emptyset)_{pair_i}^* - Ey(\emptyset)_{pair_i} \times Hx(\emptyset)_{pair_i}^*$$

$$PD(\emptyset) = \frac{1}{2} \sqrt{Re\{PDx(\emptyset)\}_{pair_i}^2 + Re\{PDy(\emptyset)\}_{pair_i}^2 + Re\{PDz(\emptyset)\}_{pair_i}^2}$$

Sweep $\emptyset$ from 0 degree to 360 degree to find the highest PD (out of low, mid, and high channel) and its corresponding $\emptyset$, $\emptyset_{worstcase}$, for all the beam pairs specified in the codebook. The worst-case scaling factor $s(i)$ for beam pair should be determined with $\emptyset(i)_{worstcase}$.

B Simulated Input Power Limit

Table B-1 lists input power limit per frequency index per applicable band for all the beams that DUT supports.

Table B-1: Simulated P_{Limit} for n258, n260, and n261

n258			n260			n261				
Pol.	Beam ID	Frequency Index	Pol.	Beam ID	Frequency Index		Pol.	Beam ID	Frequency Index	
		0			4	5			2	3
H	0	0.52	H	0	1.01	1.19	H	0	-0.70	-0.56
H	1	-0.01	H	1	2.92	1.38	H	1	-0.67	-0.37
H	2	3.13	H	2	1.16	2.22	H	2	-0.88	-1.13
H	3	-0.04	H	3	1.74	1.85	H	3	-0.76	-0.52
H	4	2.43	H	4	1.25	1.76	H	4	-0.70	-0.53
H	5	4.10	H	5	1.99	2.10	H	5	-0.53	-0.96
H	6	0.14	H	6	2.22	1.77	H	6	-0.67	-0.56
H	7	0.42	H	7	2.77	1.34	H	7	-0.68	-0.48
H	8	0.76	H	8	0.98	1.11	H	8	-0.80	-0.56
H	9	1.66	H	9	1.96	2.39	H	9	0.75	0.72
H	10	3.75	H	10	2.39	2.48	H	10	0.32	0.29
H	11	2.13	H	11	2.93	3.02	H	11	1.21	1.06
H	12	1.54	H	12	3.06	2.34	H	12	0.70	0.64
H	13	5.01	H	13	2.30	2.74	H	13	1.59	0.93
H	14	7.78	H	14	3.35	2.99	H	14	5.99	5.71
H	15	7.62	H	15	2.55	3.17	H	15	5.93	5.64
H	16	7.73	H	16	3.17	3.04	H	16	5.76	5.94
H	17	7.13	H	17	7.40	7.62	H	17	5.85	6.12
V	0	1.90	H	18	7.06	7.68	V	0	-0.13	-0.15
V	1	2.28	H	19	7.83	6.99	V	1	-1.06	-1.61
V	2	0.36	H	20	7.13	6.95	V	2	-0.46	0.46
V	3	1.60	V	0	1.57	1.31	V	3	-0.77	-0.46
V	4	0.28	V	1	2.47	1.74	V	4	-0.35	0.54
V	5	0.49	V	2	2.34	2.64	V	5	-0.14	0.49
V	6	2.95	V	3	1.53	2.37	V	6	0.15	-0.92
V	7	1.80	V	4	2.60	2.45	V	7	0.35	0.34
V	8	0.92	V	5	1.45	1.51	V	8	-0.56	-0.37
V	9	3.13	V	6	2.45	2.24	V	9	1.56	1.43
V	10	1.55	V	7	1.40	1.73	V	10	0.86	1.06
V	11	4.87	V	8	2.09	1.61	V	11	2.01	0.25
V	12	4.32	V	9	1.51	2.21	V	12	0.57	-0.15
V	13	2.05	V	10	2.66	2.64	V	13	0.92	2.13
V	14	8.70	V	11	3.51	3.03	V	14	6.56	5.66
V	15	7.81	V	12	2.75	2.48	V	15	6.04	5.55
V	16	8.12	V	13	3.05	3.09	V	16	5.62	5.78
V	17	7.11	V	14	2.63	2.73	V	17	5.61	7.77
H+V	0	-1.85	V	15	3.46	3.66	H+V	0	-3.43	-3.36
H+V	1	-1.99	V	16	2.53	3.11	H+V	1	-3.81	-4.01
H+V	2	-1.47	V	17	7.71	7.55	H+V	2	-3.63	-3.37
H+V	3	-2.30	V	18	7.74	8.04	H+V	3	-3.76	-3.49
H+V	4	-1.78	V	19	7.49	6.67	H+V	4	-3.54	-3.03
H+V	5	-1.05	V	20	7.80	8.34	H+V	5	-3.29	-3.25
H+V	6	-1.65	H+V	0	-1.73	-1.76	H+V	6	-3.23	-3.72
H+V	7	-1.94	H+V	1	-0.30	-1.45	H+V	7	-3.19	-3.08
H+V	8	-2.13	H+V	2	-1.28	-0.56	H+V	8	-3.69	-3.48
H+V	9	-0.66	H+V	3	-1.31	-0.84	H+V	9	-1.87	-1.95
H+V	10	-0.46	H+V	4	-1.12	-0.91	H+V	10	-2.42	-2.33
H+V	11	0.32	H+V	5	-1.28	-1.21	H+V	11	-1.40	-2.35
H+V	12	-0.25	H+V	6	-0.67	-1.01	H+V	12	-2.36	-2.77
H+V	13	0.29	H+V	7	-0.94	-1.47	H+V	13	-1.72	-1.43
H+V	14	5.23	H+V	8	-1.51	-1.65	H+V	14	3.26	2.68
H+V	15	4.80	H+V	9	-1.23	-0.67	H+V	15	2.99	2.60
H+V	16	4.94	H+V	10	-0.47	-0.43	H+V	16	2.68	2.85
H+V	17	4.12	H+V	11	0.21	0.04	H+V	17	2.72	3.87
			H+V	12	-0.09	-0.59				
			H+V	13	-0.34	-0.09				
			H+V	14	-0.03	-0.14				
			H+V	15	0.00	0.41				
			H+V	16	-0.14	0.10				
			H+V	17	4.55	4.58				
			H+V	18	4.40	4.88				
			H+V	19	4.68	3.82				
			H+V	20	4.44	4.59				

END OF REPORT