RF Exposure Analysis

Revision	Report Date	Reason for Revision
∅	08/02/2021	Initial Issue.

FCC RF Exposure Evaluation of Devices

RF Exposure Requirements: **§1.1307(b)(1) and §1.1307(b)(2):** Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines.

RF Radiation Exposure Limit: **§1.1310:** As specified in this section, the Maximum Permissible Exposure (MPE) Limit shall be used to evaluate the environmental impact of human exposure to radiofrequency (RF) radiation as specified in Sec. 1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of Sec. 2.1093 of this chapter.

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(i) Limits for Occupational/Controlled Exposure				
0.3-3.0	614	1.63	*(100)	≤6
3.0-30	1842/f	4.89/f	*($900/f^2$)	<6
30-300	61.4	0.163	1.0	<6
300-1,500			f/300	<6
1,500-100,000			5	<6
(ii) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	*(100)	<30
1.34-30	824/f	2.19/f	*($180/f^2$)	<30
30-300	27.5	0.073	0.2	<30
300-1,500			f/1500	<30
1,500-100,000			1.0	<30

RF Exposure Limits

$$S = PG / 4\pi R^2 \quad \text{or} \quad R = \sqrt{(PG / 4\pi S)}$$

where, S = Power Density (mW/cm^2)
P = Power Input to antenna (mW)
G = Antenna Gain (numeric value)
R = Distance (cm)

For Antenna Gain → **dBi = 10log(Numeric)**

Test Results:

Band	Frequency	Maximum Conducted Power	Conducted Power	Antenna Gain	Antenna Gain	Power Density	Limit	Margin	Distance	Result
	(MHz)	(dBm)	(mW)	(dBi)	(Numeric)	(mW/cm2)	(mW/cm2)		(cm)	
BT	2402	10	10.00	3.00	1.995	0.004	1	0.996	20	Pass
BLE	2480	20	100.00	3.00	1.995	0.040	1	0.960	20	Pass
WiFi 2.4 GHz	2437	24	251.19	3.00	1.995	0.100	1	0.900	20	Pass
WiFi 5.0 GHz	5775	21	125.89	5.00	3.162	0.079	1	0.921	20	Pass

MPE Calculation for Bands (FCC)

Note: Results are based on KDB 447498 D01 (Section 7.2) Transmitters used in mobile devices exposure conditions for simultaneous transmission operations.

Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneously transmitting antennas incorporated in a host device is ≤ 1.0, according to calculated/estimated, numerically modeled, or measured field strengths or power density. The MPE ratio of each antenna is determined at the minimum test separation distance required by the operating configurations and exposure conditions of the host device, according to the ratio of field strengths or power density to the MPE limit at the test frequency.

CPD1/LPD1 + CPD2/LPD2 + „„ CPDn/LPDn < 1

CPD: Calculated Power Density
LPD: Limit of Power Density

Simultaneous Transmission (FCC)

Both BT and WLAN 5GHz can transmit simultaneously.

	Power Density	Limit	Ratio		
BT	0.004	1	0.004		
WiFi 5GHz	0.079	1	0.079		
SUM	NA	NA	0.083	< 1	Pass

ISED RF Exposure Evaluation of Devices

RF Exposure Requirements:

RSS-102(3.2):A device requiring an RF exposure evaluation shall be made in accordance with the latest version of IEEE C95.3.

If the device is designed such that more than one antenna can functionally transmit at the same time, the RF exposure evaluation shall be conducted while all antennas are transmitting. The individual exposure level ratios shall be totaled and used for compliance purposes.

If the device has more than one antenna, but is not designed to have more than one antenna functionally transmit at the same time, the RF exposure evaluation of the device shall be performed for each of the individually transmitting antennas. The maximum RF field strength value shall be recorded and used for compliance purposes.

If the device combines groups of simultaneous and non-simultaneous transmitting antennas, the worst-case of the above scenarios applies.

Exposure Limit:

For a device operating between 300 – 6000 MHz the power density limit for RF Evaluation can be determined from the equation 0.02619 x $f^{0.6834}$ W/m^2, where f is the frequency in MHz.

The Time-Averaged Maximum e.i.r.p. RF Evaluation Exemption limit for devices operating between 300 – 6000 MHz can be found from the equation 0.0131 x $f^{0.6834}$ W, where f is the frequency in MHz.

Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m^2)	Reference Period (minutes)
0.003-10[21]	83	90	-	Instantaneous*
0.1-10	-	0.73/ f	-	6**
1.1-10	87/ $f^{0.5}$	-	-	6**
10-20	27.46	0.0728	-2	6
20-48	58.07/ $f^{0.25}$	0.1540/ $f^{0.25}$	8.944/ $f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	3.142 $f^{0.3417}$	0.008335 $f^{0.3417}$	0.02619 $f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	616000/ $f^{1.2}$
150000-300000	0.158 $f^{0.5}$	4.21 x 10^{-4} $f^{0.5}$	6.67 x 10^{-5} f	616000/$f^{1.2}$

Note: f is frequency in MHz.
* Based on nerve stimulation (NS).
** Based on specific absorption rate (SAR).

RF Field strength limits for devices used by the general public (Un-controlled environment)

$$S = PG / 4\pi R^2 \quad \text{or} \quad R = \sqrt{(PG / 4\pi S)}$$

where, S = Power Density (mW/cm^2)
P = Power Input to antenna (mW)
G = Antenna Gain (numeric value)
R = Distance (cm)

For Antenna Gain → **dBi = 10log(Numeric)**

Band	Frequency	Maximum Conducted Power	Conducted Power	Antenna Gain	Antenna Gain	Power Density	Limit	Margin	Distance	Result
	(MHz)	(dBm)	(W)	(dBi)	(Numeric)	(W/m2)	(W/m2)		(m)	
BT	2402	10	0.010	3.00	1.995	0.040	5.351	5.311	0.2	Pass
BLE	2480	20	0.100	3.00	1.995	0.397	5.469	5.072	0.2	Pass
WiFi 2.4 GHz	2437	24	0.251	3.00	1.995	0.998	5.404	4.406	0.2	Pass
WiFi 5.0 GHz	5775	21	0.126	5.00	3.162	0.792	9.745	8.953	0.2	Pass

MPE Calculation for Bands (ISED)

The safe distance where Power Density is less than the MPE limit listed above was found to be 0.2 m.

Note: Results are based on KDB 447498 D01 (Section 7.2) Transmitters used in mobile devices exposure conditions for simultaneous transmission operations.

Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneously transmitting antennas incorporated in a host device is ≤ 1.0, according to calculated/estimated, numerically modeled, or measured field strengths or power density. The MPE ratio of each antenna is determined at the minimum test separation distance required by the operating configurations and exposure conditions of the host device, according to the ratio of field strengths or power density to the MPE limit at the test frequency.

CPD1/LPD1 + CPD2/LPD2 + „„ CPDn/LPDn < 1

CPD: Calculated Power Density
LPD: Limit of Power Density

Simultaneous Transmission (ISED)

Both BT and WLAN 5GHz can transmit simultaneously.

	Power Density	Limit	Ratio		
BT	0.040	5.351	0.007		
WiFi 5GHz	0.792	9.792	0.081		
SUM	NA	NA	0.088	< 1	Pass

