

FCC §1.1307 & §2.1091 –MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Applicable Standard

According to subpart §2.1091 and subpart §1.1310, 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 level in excess of the Commission's guidelines.

Limits for Maximum Permissible Exposure (MPE) (§1.1310, §2.1091)

(B) Limits for General Population/Uncontrolled Exposure				
Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm ²)	Averaging Time (minutes)
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
300-1500	/	/	f/1500	30
1500-100,000	/	/	1.0	30

f = frequency in MHz; * = Plane-wave equivalent power density;

According to §1.1310 and §2.1091 RF exposure is calculated.

Calculated Formulary:

Predication of MPE limit at a given distance

$S = PG/4\pi R^2$ = power density (in appropriate units, e.g. mW/cm²);

P = power input to the antenna (in appropriate units, e.g., mW);

G = power gain of the antenna in the direction of interest relative to an isotropic radiator, the power gain factor, is normally numeric gain;

R = distance to the center of radiation of the antenna (appropriate units, e.g., cm);

For simultaneously transmit system, the calculated power density should comply with:

$$\sum_i \frac{S_i}{S_{Limit,i}} \leq 1$$

Calculated Data:

Mode	Frequency Range (MHz)	Antenna Gain		Tune-up Conducted Power		Evaluation Distance (cm)	Power Density (mW/cm ²)	MPE Limit (mW/cm ²)	MPE ratio
		(dBi)	(numeric)	(dBm)	(mW)				
802.11b	2412~2462	1.30	1.35	23	199.53	20	0.0535	1.00	0.0535
802.11g		1.30	1.35	21	125.89	20	0.0338	1.00	0.0338
802.11n-HT20		1.30	1.35	21	125.89	20	0.0338	1.00	0.0338
802.11n-HT40	2422~2452	1.30	1.35	21	125.89	20	0.0338	1.00	0.0338
BLE	2402-2480	1.30	1.35	5	3.16	20	0.0008	1.00	0.0008
BT 3.0	2402~2480	1.30	1.35	6	3.98	20	0.0011	1.00	0.0011
LoRa	902-928	0.87	1.22	20	100.00	20	0.0243	0.60	0.0405
Sigfox	902-928	0.87	1.22	20	100.00	20	0.0243	0.60	0.0405

Calculation of maximum antenna gain based on ERP/EIRP

Mode	Max Tune-up Power (dBm)	ERP/EIRP Limit (dBm)	Max Antenna Gain (dBi)
FDD (Band 4)	23.00	30.00	7.00
FDD (Band 12)	23.50	34.77	11.27
FDD (Band 13)	23.00	34.77	11.77

Calculation of maximum antenna gain based on MPE Ratio

Mode	Frequency Range	Tune-up Conducted Power		Power Density Limit	Maximum Power Density	Evaluation Distance	Maximun Antenna Gain Allowed based on MPE		MPE ratio
	(MHz)	(dBm)	(mW)	(mW/cm ²)	(mW/cm ²)		(numeric)	(dBi)	
FDD (Band 4)	1710-1755	23.00	199.53	1.0000	0.9051	20	13.58	22.80	0.9051
FDD (Band 12)	699-716	23.50	223.87	0.4717	0.4263	20	9.81	9.57	0.9037
FDD (Band 13)	777-787	23.00	199.53	0.5213	0.4717	20	10.75	11.89	0.9049

Note: Wi-Fi/ BLE/ BT 3.0& LoRa/Sigfox & FDD can transmit simultaneously; the worst condition is 802.11b of Wi-Fi & FDD (Band 4), as below:

$$\sum_i \frac{S_i}{S_{Limit,i}} = 0.0535 + 0.0405 + 0.9051 = \mathbf{0.9991} < \mathbf{1.0}$$

Mode	Max Allow Antenna Gain (dBi)
FDD (Band 4) Uplink Frequency: 1710 MHz~1755 MHz	7.00
FDD (Band 12) Uplink Frequency: 699 MHz~716MHz	9.81
FDD (Band 13) Uplink Frequency: 777 MHz~787 MHz	10.75

Result: For FDD mode, to meet RF exposure & ERP/ERIP, the maximum net gains of antennas allowed are 7.00 dBi @ FDD (Band 4), 9.81 @ FDD (Band 12) and 10.75 @ FDD (Band 13). The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.