FCC §1.1310, §2.1091& RSS-102 § 4 - MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Applicable Standard

According to 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/f²)	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.

According to RSS-102 § 4Table 4, RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)

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).

Calculation Formula:

Prediction of power density at the distance of the applicable MPE limit:
$S = PG/4\pi R^2$ = power density (in appropriate units, e.g. mW/cm^2);

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);

=>$G=S4\pi R^2/P$

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

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

Calculated Data:

For WLAN part:

Mode	Frequency Band	Antenna Gain		Max. Target Power including Tolerance		Evaluation Distance (cm)	FCC Power Density (mW/cm^2)	ISEDC Power Density (W/m^2)	FCC MPE Limit (mW/cm^2)	ISEDC MPE Limit (W/m^2)
		(dBi)	(numeric)	(dBm)	(mW)					
BDR/EDR	2402-2480	2	1.58	13.5	22.39	20.00	0.007	0.07	1.0	5.35
BLE	2402-2480	2	1.58	2	1.58	20.00	0.0005	0.005	1.0	5.35
WIFI	2412-2462	2	1.58	24	251.19	20.00	0.07924	0.7924	1.0	5.37

Note: Bluetooth and WIFI can`t transmit simultaneously.
　　　Bluetooth or WIFI can transmit simultaneously with WWAN. The maximum MPE to limit ratio for WLAN is WIFI: 0.7924/5.37=0.148 (ISEDC limit was the used for calculation)

Calculated Maximum antenna gain allowed base on ERP/EIRP:

Mode	Frequency Range (MHz)	Conducted Power including Tolerance (dBm)	ERP/EIRP Limit (dBm)	Maximum Antenna Gain Allowed (dBi)
GSM850	824-849	32	38.45	6.45
GSM1900	1850-1910	30	33	3
WCDMA Band 2	1850-1910	24	33	9
WCDMA Band 4	1710-1755	24	30	6
WCDMA Band 5	824-849	24	38.45	14.45
LTE Band 2	1850-1910	24	33	9
LTE Band 4	1710-1755	24	30	6
LTE Band 5	824-849	24	38.45	14.45
LTE band 7	2500-2570	24	33	9
LTE band 12	699-716	24	34.77	10.77
LTE band 13	777-787	24	34.77	10.77
LTE band 17	704-716	24	34.77	10.77
LTE band 25	1850-1915	24	33	9
LTE band 26	814-849	24	38.45	14.45
LTE band 41	2496-2690	24	33	9

Calculated Maximum antenna gain allowed base on MPE:

Mode	Frequency Range (MHz)	Conducted Power including Tolerance (dBm)	power density Limits (W/m²)	Maximum Power Density (S_{WWAN}) (W/m²)	Evaluation Distance (cm)	Maximum Antenna Gain Allowed base on MPE	
						(numeric)	(dBi)
GSM850	824-849	29	2.58	2.198	20	1.39	1.43
GSM1900	1850-1910	27	4.48	3.817	20	3.83	5.83
WCDMA Band 2	1850-1910	24	4.48	3.817	20	7.63	8.83
WCDMA Band 4	1710-1755	24	4.24	3.612	20	7.22	8.59
WCDMA Band 5	824-849	24	2.58	2.198	20	4.40	6.43
LTE Band 2	1850-1910	24	4.48	3.817	20	7.63	8.83
LTE Band 4	1710-1755	24	4.24	3.612	20	7.22	8.59
LTE Band 5	824-849	24	2.58	2.198	20	4.40	6.43
LTE band 7	2500-2570	24	5.50	4.686	20	9.37	9.72
LTE band 12	699-716	24	2.30	1.960	20	3.92	5.93
LTE band 13	777-787	24	2.47	2.104	20	4.21	6.24
LTE band 17	704-716	24	2.31	1.968	20	3.94	5.95
LTE band 25	1850-1915	24	4.48	3.817	20	7.63	8.83
LTE band 26	814-849	24	2.55	2.173	20	4.35	6.38
LTE band 41	2496-2690	24	5.49	4.677	20	9.35	9.71

Note 1: for GSM850 and 1900, maximum time-average was reduced by 3dBc for worst 4 up time slots
Note 2: the strict limit is ISEDC, which was used for MPE evaluation.
Note 3:

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

$= S_{WLAN} / S_{limit-WLAN} + S_{WWAN} / S_{limit-WWAN}$

$\Rightarrow$ Maximum $S_{WWAN} = (1 - S_{WLAN} / S_{limit-WLAN}) * S_{limit-WWAN} = (1-0.148) * S_{limit-WWAN} = 0.852 * S_{limit-WWAN}$

Result: The device meets MPE requirement for Devices Used by the General Public at 20cm distance with the maximum antenna gain for each band as below table:

Frequency Range (MHz)	Maximum Antenna Gain Allowed (dBi)
814-849	1.43
1850-1915	3.0
1710-1755	6.0
699-716	5.93
777-787	6.24
2496-2690	9.0