

7.3 MAXIMUM PERMISSIBLE EXPOSURE & SAR Evaluation

LIMITS for FCC RF Exposure Evaluation

§1.1310 The criteria listed in Table 1 shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in §1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of §2.1093 of this chapter.

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
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
300–1500 .....	.....	.....	f/300	6
1500–100,000 .....	.....	.....	5	6
(B) 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

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)—Continued

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
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

NOTE 1 TO TABLE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2 TO TABLE 1: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

LIMITS for FCC SAR Evaluation

KDB 447498 D04 Interim General RF Exposure Guidance v01, section 2.1.3 SAR-Based Exemption:

“A more comprehensive exemption, considering a variable power threshold that depends on both the *separation distance* and power, is provided in § 1.1307(b)(3)(i)(B). This exemption is applicable to the frequency range between 300 MHz and 6 GHz, with *test separation distances* between 0.5 cm and 40 cm, and for all RF sources in fixed, mobile, and portable device exposure conditions.”

For 100 MHz to 6 GHz and test separation distances ≤ 50 mm, the 1-g and 10-g SAR test exclusion thresholds are determined by the following:

$$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \cdot [\sqrt{f(\text{GHz})}] \leq 3.0$$
 for 1-g SAR, and ≤ 7.5 for 10-g extremity SAR,
 where f(GHz) is the RF channel transmit frequency in GHz

FCC KDB 447498 D01 General RF Exposure Guidance v06, section 4.3.1 & Appendix A provides the SAR Test Exclusion Thresholds (ERP/Conducted) to verify that the device is exempt from 1-g extremity SAR at different separation distances. As example, for 900MHz Tx: 16mW (12dBm); For 2450MHz Tx: 10mW (10dBm) at ≤ 5 mm.

Details in calculation formula for reference, given in § 1.1307(b)(3)(i)(B) to calculate the exemption:

$$P_{th} \text{ (mW)} = \begin{cases} ERP_{20 \text{ cm}} (d/20 \text{ cm})^x & d \leq 20 \text{ cm} \\ ERP_{20 \text{ cm}} & 20 \text{ cm} < d \leq 40 \text{ cm} \end{cases}$$

Where

$$x = -\log_{10} \left(\frac{60}{ERP_{20 \text{ cm}} \sqrt{f}} \right) \text{ and } f \text{ is in GHz;}$$

and

$$ERP_{20 \text{ cm}} \text{ (mW)} = \begin{cases} 2040f & 0.3 \text{ GHz} \leq f < 1.5 \text{ GHz} \\ 3060 & 1.5 \text{ GHz} \leq f \leq 6 \text{ GHz} \end{cases}$$

d = the separation distance (cm);

LIMITS per ISSED RSS-102 (issue 6)

Section 6.3 & Table 11 for Exemption Limits for Routine Evaluation — SAR Evaluation

Table 11: Power limits for exemption from routine SAR evaluation based on the separation distance

Frequency (MHz)	≤ 5 mm (mW)	10 mm (mW)	15 mm (mW)	20 mm (mW)	25 mm (mW)	30 mm (mW)	35 mm (mW)	40 mm (mW)	45 mm (mW)	> 50 mm (mW)
≤ 300	45	116	139	163	189	216	246	280	319	362
450	32	71	87	104	124	147	175	208	248	296
835	21	32	41	54	72	96	129	172	228	298
1900	6	10	18	33	57	92	138	194	257	323
2450	3	7	16	32	56	89	128	170	209	245
3500	2	6	15	29	50	72	94	114	134	158
5800	1	5	13	23	32	41	54	74	102	128

For limb-worn devices where the 10 gram value applies, the exemption limits for routine evaluation in Table 1 are multiplied by a factor of 2.5.

Example: Exclusion Thresholds to verify that the 2450MHz Tx is exempt from
1-g SAR at separation distance of ≤5 mm: 3mW (4.77dBm) & 10-g SAR at separation distance of ≤5 mm: 7.5mW (8.75dBm).

Section 5.3.2 Table 7&8 for Exemption Limits for Routine Evaluation – RF Exposure Evaluation (10MHz ro300GHz)

Table 7: RF field strength and power density limits for devices used by the general public (uncontrolled environment)

Frequency range (MHz)	Electric field (V _{RMS} /m)	Magnetic field (A _{RMS} /m)	Power density (W/m ²)	Reference period (minutes)
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	$0.158 f^{0.5}$	$4.21 \times 10^{-4} f^{0.5}$	$6.67 \times 10^{-5} f$	$616000 / f^{1.2}$

Note: f is frequency in MHz.

Table 8: RF field strength and power density limits for controlled-use devices (controlled environment)

Frequency range (MHz)	Electric field (V _{RMS} /m)	Magnetic field (A _{RMS} /m)	Power density (W/m ²)	Reference period (minutes)
10-20	61.4	0.163	10	6
20-48	$129.8 / f^{0.25}$	$0.3444 / f^{0.25}$	$44.72 / f^{0.5}$	6
48-100	49.33	0.1309	6.455	6
100-6000	$15.60 f^{0.25}$	$0.04138 f^{0.25}$	$0.6455 f^{0.5}$	6
6000-15000	137	0.364	50	6
15000-150000	137	0.364	50	$616000 / f^{1.2}$
150000-300000	$0.354 f^{0.5}$	$9.40 \times 10^{-4} f^{0.5}$	$3.33 \times 10^{-4} f$	$616000 / f^{1.2}$

Note: f is frequency in MHz.

In these cases, the information contained in the RF exposure technical brief may be limited to information that demonstrates how the e.i.r.p. was derived.

Summary

For FCC and IC, that max. declared power level can be modified by any duty cycle over the time averaging period. Time-averaging period is a time period not to exceed 30 minutes for fixed RF sources or a time period inherent from device transmission characteristics not to exceed 30 minutes for mobile and portable RF sources.

For rf exposure, the averaging period is 6 minutes for ISED Canada and for FCC it varies by frequency but 1~60 second for RF exposure or the period specified by product design spec. for RF exposure can be used.

So the power value for RF exposure= Declared power x Duty Cycle factor

CALCULATIONS for MPE distance and Power Density

Given

$$E = \sqrt{(30 * P * G) / d}$$

and

$$S = E^2 / 3770$$

where

E = Field Strength in Volts/meter

P = Power in Watts

G = Numeric antenna gain

d = Distance in meters

S = Power Density in milliwatts/square centimeter

Combining equations and rearranging the terms to express the distance as a function of the remaining variables yields:

$$d = \sqrt{((30 * P * G) / (3770 * S))}$$

Changing to units of Power to mW and Distance to cm, using:

$$P(\text{mW}) = P(\text{W}) / 1000 \text{ and}$$

$$d(\text{cm}) = 100 * d(\text{m})$$

yields

$$d = 100 * \sqrt{((30 * (P / 1000) * G) / (3770 * S))}$$

$$d = 0.282 * \sqrt{(P * G / S)}$$

where

d = distance in cm

P = Power in mW

G = Numeric antenna gain

S = Power Density in mW/cm²

Substituting the logarithmic form of power and gain using: P

$$(mW) = 10^{(P(\text{dBm}) / 10)} \text{ and}$$

$$G(\text{numeric}) = 10^{(G(\text{dBi}) / 10)}$$

yields

$$d = 0.282 * 10^{((P + G) / 20)} / \sqrt{S}$$

Equation (1)

$$S = 0.0795 * 10^{((P + G) / 10)} / d^2$$

Equation (2)

where

d = MPE distance in cm

P = Power in dBm

G = Antenna Gain in dBi

S = Power Density Limit in mW/cm²

Equation (1) and the measured Output power is used to calculate the MPE distance.

Equation (2) and the measured Output power is used to calculate the Power density.

APPLICABLE LIMITS

RF MPE for separation $\geq 20\text{cm}$

FCC: From §1.1310 Table 1 (B), for Public $S = 1.0 \text{ mW/cm}^2$ (for Professional, $S = 5.0 \text{ mW/cm}^2$)

Limits For Maximum Permissible Exposure (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (minutes)
Limits For General Population / Uncontrolled Exposure				
300-1,500	-	-	F/1500	30
1,500-100,000	-	-	1.0	30

IC: Per RSS-102, Sec. 5.3.2 Table 7,

Limits For Maximum Permissible Exposure (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Average Time (minutes)
Limits For General Population / Uncontrolled Exposure				
48-300	22.06	0.05852	1.291	6
30-6000	$3.142 \cdot f^{0.3417}$	$0.008335 \cdot f^{0.3417}$	$0.02619 \cdot f^{0.6834}$	6

With formula of $2.619 \times 10^{-2} f^{0.6834} \text{ W/m}^2$, most restricted power density limit values are 2.74 W/m^2 at 902MHz, 5.34 W/m^2 at 2400MHz.

SAR Exclusion Thresholds for separation $\leq 5\sim 40\text{cm}$:

FCC : Use Formular in FCC § 1.1307(b)(3)(i)(B) & KDB 447498 D04

IC: Use RSS-102 Table11

Apply duty cycle factor & 2.5 factor for extremity or limb-worn devices

RESULTS

No non-compliance noted.

For 2.4GHz Transmitter:

with Hand-held /limb-worn usage: **SAR Exemption Evaluation** (2.5 factor with 10-g extremity SAR)

2.4GHz Module Information:

Modular: C.E. / CE3871-0 & CE3871-1 (RF Module with PCB antenna)

FCC ID: XXXXX-CE3871 & IC: YYYYY-CE3871

Preset max. RF power:

2.4GHz Band /8dBm (6.31mW) with integral antenna gain -0.5dBi (max. EIRP 7.5dBm (5.62mW)

Max. duty cycle factor for O-QPSK modulation with a bit rate of 250 kbps is close to 10%.

Worst Case Scenario:

	RF Module		
Frequency (MHz)	2.4GHz Band		
Antenna Gain (dBi)	-0.5		
Conducted Power (dBm/mW)	Max. 8/6.31		
EIRP (dBm/mW)	7.5/ 5.62		
Max. Duty Cycle Factor (1s ~6 minutes)	10%		
Power value for RF exposure= Declared power x Duty Cycle Factor (DCF)	0.562mW		

With minimum separation distance, 5mm

---For FCC:

Using the formula in 1.1307(b)(3)(i)(B), $ERP_{20cm}=3060mW$, $d=5mm$,

min. $x = -\log_{10}(60/(3060*\sqrt{2.4})) = 1.898$ corresponding to the lowest frequency of 2.4GHz band. Then the most restricted conducted $P_{th} = 3060 * (0.5/20)^{1.898} = 2.786mW$.

By applying the duty cycle factor, 10%, then the final SAR exemption limit is 27.86mW, which is more than 6.3mW. So the SAR test exclusion condition is met.

--- For IC:

With the max. 10% DCF power calculated above, considering a factor of 2.5 for 10-g extremity SAR, the EIRP value used to compare Table 1 threshold is

0.562/2.5=0.225mW for 2.4GHz Band, which is **below** the limit of 3mW for 2.4GHz Band at mini. separation distance of 5mm.

Conclusion: This module is used limited portable application (Handheld/limb-worn) with minimum 5mm separation distance from antenna to user's hand/wrist, which meets the requirement for SAR test exclusion.