Test No.13

Name of Test:	*Radio Frequency Exposure*	Test Standard:	*FCC OET Bulletin 65 &RSS-GEN*
Tested By:	WEI LI	Test Date:	02/01/2023-12/16/2022

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:
[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] · [√f(GHz)] ≤ 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:

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

Where

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

and

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

d = the separation distance (cm);

LIMITS per ISED RSS-102, Section 2.5 & Table 1

Per 2.5.1 Exemption Limits for Routine Evaluation — SAR Evaluation

Table 1: SAR evaluation – Exemption limits for routine evaluation based on frequency and separation distance[4,5]

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of ≤5 mm	At separation distance of 10 mm	At separation distance of 15 mm	At separation distance of 20 mm	At separation distance of 25 mm
≤300	71 mW	101 mW	132 mW	162 mW	193 mW
450	52 mW	70 mW	88 mW	106 mW	123 mW
835	17 mW	30 mW	42 mW	55 mW	67 mW
1900	7 mW	10 mW	18 mW	34 mW	60 mW
2450	4 mW	7 mW	15 mW	30 mW	52 mW
3500	2 mW	6 mW	16 mW	32 mW	55 mW
5800	1 mW	6 mW	15 mW	27 mW	41 mW

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of 30 mm	At separation distance of 35 mm	At separation distance of 40 mm	At separation distance of 45 mm	At separation distance of ≥50 mm
≤300	223 mW	254 mW	284 mW	315 mW	345 mW
450	141 mW	159 mW	177 mW	195 mW	213 mW
835	80 mW	92 mW	105 mW	117 mW	130 mW
1900	99 mW	153 mW	225 mW	316 mW	431 mW
2450	83 mW	123 mW	173 mW	235 mW	309 mW
3500	86 mW	124 mW	170 mW	225 mW	290 mW
5800	56 mW	71 mW	85 mW	97 mW	106 mW

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: 4mW (6dBm) & 10-g SAR at separation distance of ⩽5 mm: 10mW (10dBm).

Per 2.5.2 Exemption Limits for Routine Evaluation – RF Exposure Evaluation

RF exposure evaluation is required if the separation distance between the user and/or bystander and the device's radiating element is greater than 20 cm, except when the device operates as follows:
• below 20 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1 W (adjusted for tune-up tolerance);
• at or above 20 MHz and below 48 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than $4.49/f^{0.5}$ W (adjusted for tune-up tolerance), where f is in MHz;
• at or above 48 MHz and below 300 MHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 0.6 W (adjusted for tune-up tolerance);
• at or above 300 MHz and below 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than $1.31 \times 10^{-2} f^{0.6834}$ W (adjusted for tune-up tolerance), where f is in MHz;
• at or above 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 5 W (adjusted for tune-up tolerance).

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

$S = E \wedge 2 / 3770$

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(mW) = P (W) / 1000 and d (cm) =100 * d (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/cm^2

Substituting the logarithmic form of power and gain using: P (mW) = 10 ^ (P (dBm) / 10) and
G (numeric) = 10 ^ (G (dBi) / 10)
yields

$$d = 0.282 * 10 \wedge ((P + G) / 20) / \sqrt{S}$$ Equation (1)
$$S = 0.0795 * 10 \wedge ((P + G)/10)/ d\wedge 2$$ Equation (2)

where
d = MPE distance in cm
P = Power in dBm
G = Antenna Gain in dBi
S = Power Density Limit in mW/cm^2

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 Exposure for separation >= 20cm

FCC: From §1.1310 Table 1 (B), for Public S = 1.0 mW/cm^2 ; for Professional, S = 5.0 mW/cm^2
IC: With formula of 1.31 x 10^{-2} $f^{0.6834}$ W, more restricted EIRP limit value are 1.37W at 902MHz, 2.67W at 2400MHz.

SAR Exclusion Thresholds for separation ≤5~40cm:

FCC : Use Formular in FCC § 1.1307(b)(3)(i)(B) & KDB 447498 D04
IC: Use RSS-102 Table1
Apply duty cycle factor & 2.5 factor for extremity or limb-worn devices

RESULTS

No non-compliance noted.

For GPR UWB Transmitter:

1-mW Test Exemption:
Per § 1.1307(b)(3)(i)(A), a single RF source is exempt RF device (from the requirement to show data demonstrating compliance to RF exposure limits, as previously mentioned) if the available maximum time-averaged power is no more than 1 mW, regardless of separation distance. This exemption applies to all operating configurations and exposure conditions, for the frequency range 100 kHz to 100 GHz, regardless of fixed, mobile, or portable device exposure conditions.

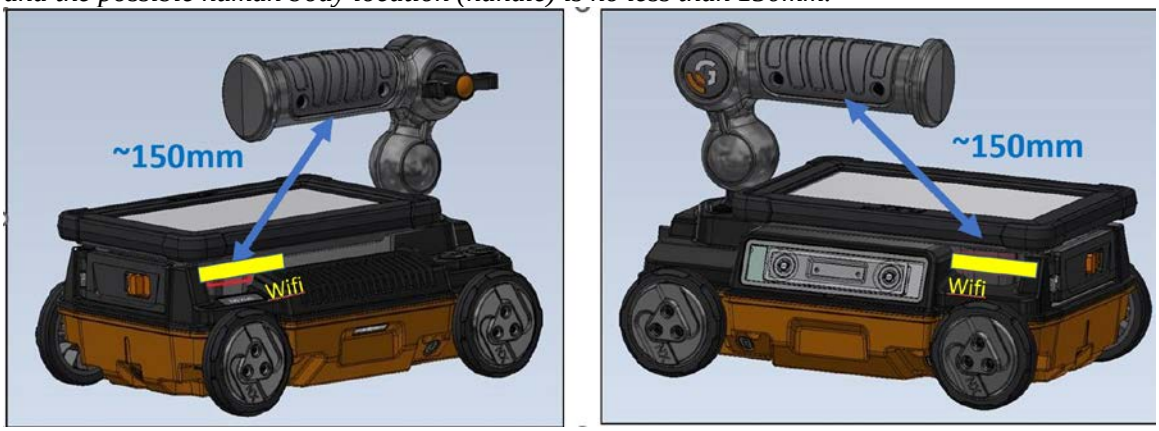
For this EUT, max emission level is under the 0dBm limit set in Part 15F: -4.4dBm (0.363mW). No RF hazard need to be concerned.

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

WiFi Module Information:
Chip Module: Marvell / NXP/ W8997-M1216/FCC ID: UAY-W8997-M1216
Modular: AzureWave /AW-CM276NF with max. RF power: 18.5dBm at 2.4GHz band, 15dBm at 5GHz band.
Antenna: Molex /2042811100 / 2.562dBi for 2.4GHz band & 3.904dBi for 5GHz band.
Max. duty cycle factor is close to 100%.

Minimum separation distance: 150mm (15cm).

On FlexNX, the WIFI module uses the AzureWave AW-CM276NF wireless module which comes with Apalis iMX8 module.
AW-CM276NF is 2x2 MU-MIMO Wlan&BT module which adopts NXP SOC-88W8997.
There are two Wifi antennas (Molex 2042811300) are inside FlexNX, they are inside and at two front-side of the module (shown as the following diagram), the distance between the Wifi antenna and the possible human body location (handle) is no less than 150mm.



Worst Case Scenario: GPR and WiFi Transmitting Simultaneously

	GPR	WiFi 2.4G	WiFi 5GHz	GPR+WiFi 2.4G	GPR+WiFi 5G
Frequency (MHz)	400-5160	2.4GHz Band	5GHz Band		
Antenna Gain		2.562	3.904		
Conducted Power (dBm)		18.5	15		
EIRP (dBm/mW)	-4.4/ 0.363	21.062/127.7	18.904 /77		
Total Combined Power (mW)				**128.063mW**	**77.363mW**

---For FCC:
Using the formula in 1.1307(b)(3)(i)(B), ERP_{20cm}=3060mW, min. $x=-\log_{10}(60/(3060\sqrt{2.4}))=1.9$ corresponding to the lowest frequency of 2.4GHz & 5GHz bands.
Then the most restricted P_{th}= 3060 $(15/20)^{1.9}$=1771mW.

The max. combined power of the EUT is 128.063mW for GPR+ WiFi 2.4G mode, which is under calculated P_{th}. So the SAR test exclusion condition is met.

--- For IC:
With the max. combined power calculated above, considering a factor of 2.5 for 10-g extremity SAR, the power value used to compare Table 1 threshold is

128.063/2.5=51.23mW for 2.4GHz Band, which is under the limit of 309mW at separation distance of ≥50mm.

77.363/2.5=30.95mW for 5GHz Band, which is under the limit of 106mW at separation distance of ⩾50mm.

Conclusion: This module is used limited portable application (Handheld/limb-worn) with minimum 15mm separation distance from antenna to user's hand/wrist, which meets the requirement for SAR test exclusion.