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XPD2400

RF Exposure Report

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1 Introduction

The XPD2400A is a transceiver and, when works as a transmitter, it emits electromagnetic radiation. Since this radiation could be generated in the vicinity of human body, it is important to satisfy all the safety requirements related to RF Exposure.

In a remote system XPD2400 is used inside a remote (controller) operated by a person and inside a “receiver” (controlled device) that is installed on remote machinery. The installation on a machine qualifies as a mobile product i.e., there are not persons closer than 20 cm from the controlled device’s antenna. The installation inside a remote qualifies as a portable product that is closer to human body than 20 cm.

In a mobile product the module complies with the limits for general population/ un-controlled exposure limits.

In a portable product the mechanical design should respect the limits calculated in this RF Exposure Report to be excluded from SAR routine test. If the limits are not respected the SAR test is required.

2 RF Exposure Information

This product is intended for mobile and portable installation applications.

To comply with FCC/ISED adopted RF exposure requirements for mobile applications, installation of this transmitter system's antennas must be performed in a manner that will provide at least 8 inches (20 cm) clearance from the antenna to any user or member of the public.

The RF Exposure Evaluation showed that the maximum power density radiated by the antennas used in mobile applications (antennas 1, 2 and 3 from table 6) is well under the maximum permissible exposure (MPE) limits as specified in §1.1310 of FCC regulations and RF Field Strength Limits in RSS-102 for general population/uncontrolled exposure at 20cm. The calculations are done later in the present report.

Table 1. RF Exposure Evaluation for Mobile Products

MPE Power Density threshold for General Population/ uncontrolled Exposure FCC 47 §1.1310	RF Field Strength Power Density threshold for General Population/ uncontrolled Exposure RSS-102	Maximum Power Density created at 20 cm distance by the Maximum Gain Antenna (Type2) for a maximum duty cycle of 53%
$1.0\frac{mW}{cm^2}$	$0.547\frac{mW}{cm^2}$	$0.019\frac{mW}{cm^2}$

XPD2400’s emissions were measured for portable applications using antennas 4 and 5 from table 6. In portable applications the distance between antenna and the body or extremity is less than 20cm. If the minimum distance between the antenna and the external of the enclosure respects the thresholds presented below the product is excluded from routine SAR testing.
The distances are calculated from the maximum transmit power, the maximum duty cycle of the transmitter and the antenna gain, based on table from KDB 447498 v06 and RSS-102.

The KDB 447498 states that occupational exposure limits do not apply to consumer devices and radio services intended for supporting public networks or Part 15 unlicensed operation and such only the minimum distances for general population/ un-controlled exposure are presented.

Table 2. FCC minimum distances for SAR testing exclusion of portable products

Minimum distance between antenna and body for uncontrolled exposure KDB447498	Minimum distance between antenna and extremity for uncontrolled exposure KDB447498
$d_{min} = 15.95\ mm$	$d_{min} = 06.27\ mm$

Table 3. ISED minimum distances for SAR testing exclusion of portable products

Antenna type (portable products)	Minimum distance between antenna and body for un-controlled exposure RSS-102	Minimum distance between antenna and extremity for un-controlled exposure RSS-102	Minimum distance between antenna and body for controlled exposure RSS-102	Minimum distance between antenna and extremity for controlled exposure RSS-102
AR 010-2.4G	$d_{min} = 24.3\ mm$	$d_{min} = 16.5\ mm$	$d_{min} = 11.7\ mm$	$d_{min} = 0\ mm$
ANT7020LL05R2400A	$d_{min} = 25.7\ mm$	$d_{min} = 17.5\ mm$	$d_{min} = 12.6\ mm$	$d_{min} = 5.8\ mm$

Occupational exposure limits only apply to “work-related” use conditions. Users must be “fully aware of” and be able to “exercise control over” their exposure to qualify for the higher occupational exposure limits.

3 EUT, Transceiver Module and Antenna types

The EUT is XPD2400, a low power transceiver module, licensed in 2.4Ghz ISM band, using FHSS transmission, used in mobile and portable products.

A picture of the module is presented in fig.1.

Figure 1 XPD2400, Top view.

Table 4. EUT

Transceiver module	**2.4 GHz Hopping Frequency Spread Spectrum Transceiver**
Manufacturer	**Cooper Industries (Electrical) Inc**
FCC ID	**IA9XPD2400A**
ISED IC	**1338B-XPD2400A**
Product Marketing Name	**XPD2400**
HVIN (Model)	**TPCB3499-01**
FVIN	**363001R48123**
Serial No	**1E065874**

Table 5. EUT RF Information

Product	XPD2400
Frequency	2403.1 MHz to 2479.8MHz
Channel Spacing	100 kHz
Max Transmit Power	57.94 mW
Channel Bandwidth	25 kHz
Method of transmission	Frequency Hopping Digital Modulation
Digital Modulation	2-level FSK
Data Rate	10416 bauds

The module's emissions were measured with 5 different antennas, the first three antennas are used in mobile applications, where the distance between the person and the antenna is greater than 20cm, and the last 2 antennas are used in portable products.

The antennas and their characteristics are summarized in the table below.

Item	Description	Manufacturer	Model	Gain
1	2.4-2.5GHz 1/2⅄ Dipole	Laird	TRA24003NP	3dBi
2	2.4-2.5 Dual Closed Coil Whip	Pulse	NMO5E2400B	5dBi
3	2.4-2.5GHz Edge Inverted L	Cooper	ACAB-2683-07	5.06 dBi
4	2.4-2.5GHz 1/2⅄ Dipole	Wellshow	AR010-2.4G	2 dBi
5	2.4-2.5GHz SMD Ceramic	Yageo	ANT7020LL05R2400A	2.62dBi

Table 6. Antennas' characteristics

Antenna Information

Antenna 1

Manufacturer	Laird
Model	TRA24003NP
Type	Dome
Centre Frequency	2.45 GHZ
Bandwidth	100MHz
Height	58.42 mm
Gain	3dBi
Connection	N Female
Impedance	50 Ohm

Antenna 2

Manufacturer	Larsen/Pulse
Model	NMO5E2400B
Type	Whip
Centre Frequency	2.45 GHZ
Bandwidth	100MHz
Height	217 mm
Gain	5 dBi
Connection	NMO
Impedance	50 Ohm

Antenna 3

Manufacturer	Cooper Industries
Model	ACAB-2683-07
Type	Inverted L
Centre Frequency	2.45 GHZ
Bandwidth	80MHz
Height	70 mm Total length
Gain	5.06 dBi
Connection	Soldered
Impedance	50 ohm includes matching circuit on the host

Antenna 4

Manufacturer	Wellshow
Model	AR010-2.4G
Type	Rubber Duck
Centre Frequency	2.45 GHZ
Bandwidth	100MHz
Height	68 mm
Gain	2 dBi
Connection	UFL
Impedance	50 Ohm

Antenna 5

Manufacturer	Yageo
Model	ANT7020LL05R2400A
Type	Ceramic Chip Antenna
Centre Frequency	2.45 GHZ
Bandwidth	500MHz
Height	7 x 2 mm
Gain	2.62 dBi
Connection	Soldered
Impedance	50 ohm includes matching circuit on the host

4 Applicable Standards and Limits

Devices that have a radiating element normally operating at or below 6 GHz, with a separation distance of up to 20 cm between the user and/or bystander and the device, shall undergo a SAR evaluation. Devices that have a radiating element normally operating at or below 6 GHz, with a separation distance greater than 20 cm between the user and/or bystander and the device shall undergo an RF exposure evaluation. For devices that operate at larger distances from persons, where there are minimal RF coupling interactions between a device and the user or nearby persons, the more complex SAR evaluation can be avoided by evaluating RF exposure compliance using MPE limits.

4.1 MPE Limits

The Standards used are:

- FCC 47 §1.1310 Radiofrequency radiation exposure limits.
- KDB 447498 v06 RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices
- RSS-102 issue 5 Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus

4.1.1 FCC

Table 1. LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
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

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (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

Occupational exposure limits only apply to “work-related” use conditions. Users must be “fully aware of” and be able to “exercise control over” their exposure to qualify for the higher occupational exposure limits. Occupational exposure limits do not apply to consumer devices and radio services intended for supporting public networks or Part 15 unlicensed operations.

4.1.2 ISED

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	$3.142f^{0.3417}$	$0.008335f^{0.3417}$	$0.02619f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158f^{0.5}$	$4.21 \times 10^{-4}f^{0.5}$	$6.67 \times 10^{-5}f$	$616000/f^{1.2}$

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

Table 6: RF Field Strength Limits for Controlled Use Devices (Controlled 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[23]	170	180	-	Instantaneous*
0.1-10	-	$1.6/f$	-	6**
1.29-10	$193/f^{0.5}$	-	-	6**
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	$15.60f^{0.25}$	$0.04138f^{0.25}$	$0.6455f^{0.5}$	6
6000-15000	137	0.364	50	6
15000-150000	137	0.364	50	$616000/f^{1.2}$
150000-300000	$0.354f^{0.5}$	$9.40 \times 10^{-4}f^{0.5}$	$3.33 \times 10^{-4}f$	$616000/f^{1.2}$

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

4.2 Exception Limits for Routine Evaluation - SAR Evaluation

4.2.1 FCC

***SAR Test Exclusion Thresholds* for 100 MHz – 6 GHz and ≤ 50 mm**

Approximate SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances are illustrated in the following Table. The equation and threshold in 4.3.1 must be applied to determine SAR test exclusion.

MHz	5	10	15	20	25	mm
150	39	77	116	155	194	*SAR Test Exclusion Threshold* (mW)
300	27	55	82	110	137	
450	22	45	67	89	112	
835	16	33	49	66	82	
900	16	32	47	63	79	
1500	12	24	37	49	61	
1900	11	22	33	44	54	
2450	10	19	29	38	48	
3600	8	16	24	32	40	
5200	7	13	20	26	33	
5400	6	13	19	26	32	
5800	6	12	19	25	31	

MHz	30	35	40	45	50	mm
150	232	271	310	349	387	*SAR Test Exclusion Threshold* (mW)
300	164	192	219	246	274	
450	134	157	179	201	224	
835	98	115	131	148	164	
900	95	111	126	142	158	
1500	73	86	98	110	122	
1900	65	76	87	98	109	
2450	57	67	77	86	96	
3600	47	55	63	71	79	
5200	39	46	53	59	66	
5400	39	45	52	58	65	
5800	37	44	50	56	62	

Note: 10-g Extremity SAR Test Exclusion Power Thresholds are 2.5 times higher than the 1-g *SAR Test Exclusion Thresholds* indicated above. These thresholds do not apply, by extrapolation or other means, to occupational exposure limits.

In KDB447498 is specified: Depending on the operating frequency and required antenna test separation distance, antenna gain usually does not apply to portable exposure conditions. Near-field exposure conditions can be highly dependent on the RF current distribution characteristics of individual transmitters, antennas, and host device configurations, which are not directly related to the far-field antenna gain.

4.2.2 ISED

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

In RSS-102 is specified: Output power level shall be the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power. For controlled use devices where the 8 W/kg for 1 gram of tissue applies, the exemption limits for routine evaluation in Table 1 are multiplied by a factor of 5. 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. If the operating frequency of the device is between two frequencies located in Table 1, linear interpolation shall be applied for the applicable separation distance. For test separation distance less than 5 mm, the exemption limits for a separation distance of 5 mm can be applied to determine if a routine evaluation is required

5 RF Exposure Evaluation

5.1 MPE verification for mobile products

The first three antennas from Table 6.1 are antennas used only for mobile products

The FCC MPE power density limit at 20 cm for General Population/Uncontrolled Exposure is:

$$S_{limit}\left(\frac{mW}{cm^2}\right) = 1\left(\frac{mW}{cm^2}\right)$$

The ISED power density limit at 20 cm for General Population/Uncontrolled Exposure is:

$$S_{limit}\left(\frac{mW}{cm^2}\right) = 0.002619 * f(MHz)^{0.6834} = 0.547\left(\frac{mW}{cm^2}\right)$$

The ISED power density limit at 20 cm for Occupational/Controlled Exposure is:

$$S_{limit}\left(\frac{mW}{cm^2}\right) = 0.06455 * f(MHz)^{0.5} = 3.215\left(\frac{mW}{cm^2}\right)$$

The second antenna has the highest gain and we are going to verify only for this antenna that the maximum power density generated is below the threshold when is transmitting at maximum EIRP power. The maximum EIRP power is dependent on the max transmit power, duty cycle and antenna gain. The maximum duty cycle is 53%. The maximum gain is 5dBi, i.e. it is 3.16.

The maximum transmit power was measured in conducted and recorded in the Test Report as 17.63 dBm which is 57.94 mW. The power density at 20 cm is calculated as:

$$S_{max}\left(\frac{mW}{cm^2}\right) = \frac{Pmax * D * G}{4 * \pi * d^2} = \frac{57.94 * 0.53 * 3.16}{4 * \pi * 20^2} = 0.019\left(\frac{mW}{cm^2}\right)$$

As can be seen, XPD2400A has the maximum power density much lower than the thresholds at 20cm for both FCC and ISED for general population.

5.2 Minimum distance for routine SAR testing exclusion

5.2.1 FCC

The maximum time-averaged power is:

$$P_{SAR} = Pmax * D = 57.94 * 0.53 = 30.71mW$$

If we apply a linear interpolation using the data from the table in 5.2.1 we would determine the minimum distance from the body as:

$$d_{min} = 15 + \frac{30.71 - 29}{\frac{38 - 29}{20 - 15}} = 15.95\ mm$$

For extremities the values from the table in 5.2.1 are multiplied with 2.5 and the minimum distance for SAR exclusion routine test is:

$$d_{min} = 5 + \frac{30.71 - 25}{\frac{47.5 - 25}{10 - 5}} = 6.27\ mm$$

5.2.2 ISED

For ISED we need to consider the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power. Because the antenna gain is above one the maximum time-averaged power for antenna 4 is:

$$P_{SAR\_4} = Pmax * D * G_4 = 57.94 * 0.53 * 1.58 = 48.672mW$$

And for antenna 5 is:

$$P_{SAR\_5} = Pmax * D * G_5 = 57.94 * 0.53 * 1.83 = 56.14\,mW$$

If we apply a linear interpolation using the data from the table in 5.2.2, we determine the minimum distance from the body as:

$$d_{\min\ \_4} = 20 + \frac{48.672 - 30}{\frac{52 - 30}{25 - 20}} = 24.244\,mm$$

$$d_{\min\ \_5} = 25 + \frac{56.14 - 52}{\frac{83 - 52}{25 - 20}} = 25.7mm$$

For extremities the values from table 5.2.2 are going to be multiplied by 2.5 and the minimum distance is:

$$d_{\min\ \_4} = 15 + \frac{48.672 - 37.5}{\frac{75 - 37.5}{20 - 15}} = 16.5\,mm$$

$$d_{\min\ \_5} = 15 + \frac{56.14 - 37.5}{\frac{75 - 37.5}{20 - 15}} = 17.5\,mm$$

For occupational/controlled exposure the values from table 5.2.2 are going to be multiplied by 5 and the minimum distance from the body is:

$$d_{\min\ \_4} = 10 + \frac{48.672 - 35}{\frac{75 - 35}{15 - 10}} = 11.7\,mm$$

$$d_{\min\ \_5} = 10 + \frac{56.14 - 35}{\frac{75 - 35}{15 - 10}} = 12.6\,mm$$

For occupational/controlled exposure for extremities the values from the table 5.2.2 are going to be multiply with 12.5 and the minimum distance is zero for antenna 4 and for antenna 5 is.

$$d_{min} = 5 + \frac{56.14 - 50}{\frac{87.5 - 50}{10 - 5}} = 5.8\,mm$$

6 Revision History

Revision	Author	Date	Description
D0.1	Radu Oprea	2022-10-20	Create document.
D0.2	Radu Oprea	2022-11-03	Revised document.