



NOVATEL WIRELESS

SA 2100 and external antenna

FCC ID: PKRNVWSA2100
IC: 3229A-SA2100

FCC/IC MPE Calculations

October 29, 2013

Rev.6

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Document Revision History

Revision	Date	Description of Change	Originator
1.0	September 10, 2013	Initial Report	Todd Gallagher
2.0	September 12, 2013	Corrections to LTE power levels	Todd Gallagher
3.0	September 24, 2013	Change in Power back off and add IC references	Todd Gallagher
4.0	October 7, 2013	Modify antenna gain in the 2400 band	Todd Gallagher
5.0	October 10, 2013	Modified antenna gain in the 1900 band.	Todd Gallagher
6.0	October 29, 2013	Updated report based on TCB comments.	Todd Gallagher

Reference Documents

The evaluations contained in this document were performed as specified in the following documents, as applicable;

- [1] KDB941225 D05 SAR test procedures for devices incorporating Long Term Evolution (LTE) capabilities
- [2] KDB447498 D01 RF Exposure Evaluation Guidance for Mobile Conditions
- [3] FCC OET Bulletin 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
- [4] RSS 102 Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)

1.0 Introduction

The Maximum Permissible Exposure (MPE) calculations demonstrate compliance with FCC CFR 47 1.1310 and 2.1091 for standalone and collocated simultaneous transmission in mobile exposure conditions. Compliance is demonstrated to RSS-102, Industry Canada regulations.

The mobile classification applies when there is 20 centimeters or more separation distance between the end user and both WWAN and WLAN transmission antennas.

The maximum conducted transmit power levels and maximum antenna gains were used in the MPE calculations to present a worst-case assessment.

1.1 Product Information

Table 1: Product Information

Product Information		
Host type	M2M Fixed Wireless Device	
Platform Code Name	SA 2100	
Marketing Name	SA 2100	
FCC ID	PKRNVWSA2100	
Antenna Type	Fixed internal antenna (with external antenna option)	
		Antenna Peak Gain (dBi)
Internal Antenna Information	GPRS/EDGE - 850MHz	-0.08
	GPRS/EDGE - 1900MHz	1.95
	WCDMA - 850MHz	-0.08
	WCDMA - 1700MHz	2.08
	WCDMA - 1900MHz	1.95
	LTE B2 - 1900MHz	1.95
	LTE Band 4 - 1700MHz	2.08
	LTE Band 5 - 850MHz	-0.08
	LTE Band 17 - 700MHz	-0.85
	WiFi 802.11 b,g,n - 2.4GHz	2.83

NOTE: Peak gains include all system losses (cable, connector, etc.).

1.2 RF Exposure Information and Limits

The FCC defines 3 different categories of transmitters in OET Bulletin 65. The categories are fixed installation, mobile and portable devices.

1. Fixed Installation

Fixed installation means that the device including antenna is physically secured at a permanent location and is not easily moved to another location. The minimum distance between the antenna and humans is 2 meters.

2. Mobile Devices

A mobile device is defined as a transmitting device used in other than fixed locations, and is normally used in such a way that the minimum separation distance between the transmitter radiating structures and the body of the user or nearby persons is 20 centimeters. Transmitters designed to be used by consumers or workers that can be easily relocated are considered mobile devices if they meet the 20 centimeter separation requirement. FCC 47 CFR 2.1091 defines the rules for evaluating mobile devices for RF compliance.

3. Portable Devices

A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is within 20 centimeters of the user's body. . FCC 47 CFR 2.1093 defines the rules for evaluating portable devices for RF compliance.

The FCC and Industry Canada categorizes the use of the device based upon the user's awareness and ability to control his or her exposure.

Occupational / Controlled Exposure

In general, occupational / controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, and have been made fully aware of the potential for exposure. Awareness of the potential for RF exposure in a workplace or similar environment can be provided through training as part of a RF safety program. If appropriate, warning signs and labels can also be used to establish such awareness by providing prominent information on the risk of potential exposure, and instructions on methods to minimize exposure risks.

General Population / Uncontrolled Exposure

General population / uncontrolled exposure limits apply to situations in which the general public may be exposed, or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential to exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment related (for example, in the case where a wireless transmitter exposes persons in the vicinity). Warning labels placed on low power consumer devices are not considered sufficient to allow the device to be considered under the occupational / controlled exposure category.

FCC Rules:

According to CFR 47 1.1310, the criteria in Table 2 shall be used to evaluate the environmental impact of human exposure to radio frequency radiation specified in 1.1307(b).

Table 2: Limits for Maximum Permissible Exposure (MPE)

Frequency Range (MHz)	E-field Strength (V/m)	H-field Strength (A/m)	Power Density (mW/cm ²)	Average Time (minutes)
(A) Limits for Occupational / Controlled Exposure (f = frequency)				
30-300	61.4	0.163	1.0	6
300-1500	-	-	f/300	6
1500-100,000	-	-	5.0	6
(B) Limits for General Population / Uncontrolled Exposure (f = frequency)				
30-300	27.5	0.073	0.2	30
300-1500	-	-	f/1500	30
1500-100,000	-	-	1.0	30

Industry Canada Rules:

Industry Canada sets the requirements and measurement techniques in RSS 102 used to evaluate radio frequency (RF) exposure compliance of radiocommunication apparatus. The criteria in Table 3 shall be used to evaluate the environmental impact of human exposure to radio frequency radiation.

Table 3: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)

Frequency Range (MHz)	E-field Strength (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/cm ²)	Average Time (minutes)
0.003-1	280	2.19	-	6
1-10	280/f	2.19/f	-	6
10-30	28	2.19/f	-	6
30-300	28	0.073	2*	6
300-1500	1.585 f ^{0.5}	0.0042 f ^{0.5}	f/150	6
1500-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	616000/f ^{1.2}
150000-300000	1.585 f ^{0.5}	4.21x10 ⁻⁴ f ^{0.5}	6.67x10 ⁻⁵ f	616000/f ^{1.2}

Note: f is frequency in MHz.

* Power density limit is applicable at frequencies greater than 100 MHz.

2.0 Product Declarations

2.1 Product Transmitters:

The following tables summarize transmitter parameters associated with the MPE evaluation. The WWAN modes of operation reflect the applicable technologies and bands within the scope of the FCC and Industry Canada rules.

The maximum conducted transmit power levels and maximum antenna gains were used in the MPE calculations to present a worst-case assessment.

Note that in the case of more than 1 antenna manufacturer, the manufacturer’s antenna that had the highest gain in a frequency range was used in the MPE calculations to present a worst-case assessment.

Table 4: WWAN Transmitter Declarations

Mode	Equipment Category	Band Name	Transmitter Frequency Range (MHz)	Maximum Conducted Power		Maximum Antenna Gain (dBi)	Duty Cycle
				dBm	Watts		
GPRS/EDGE	GPRS Cat 10/ EDGE Cat 12	850 MHz – US Cellular	824-849	34.00	2.51	-0.08	0.25
		1900 MHz – US PCS	1850-1910	31.00	1.26	1.95	0.25
WCDMA	R7 HSDPA Cat 10 R6 HSUPA Cat 6	Band II – 1900MHz	1850-1900	24.00	0.251	1.95	1.00
		Band IV – 1700MHz	1710 - 1755	24.00	0.251	2.08	1.00
		Band V – 850MHz	824-849	24.00	0.251	-0.08	1.00
LTE	LTE	Band 2	1850-1910	24.00	0.251	1.95	1.00
		Band 4	1710-1755	24.00	0.251	2.08	1.00
		Band 5	824-849	24.00	0.251	-0.08	1.00
		Band 17	704-716	24.00	0.251	-0.85	1.00

Table 5: WLAN Transmitter Declarations

Mode	Equipment Category	Transmitter Frequency Range (MHz)	Maximum Conducted Power		Maximum Antenna Gain (dBi)	Duty Cycle
			dBm	Watts		
WLAN	802.11 b/g/n	2400	17.5	0.056	2.83	1.00

Table 6: Antenna transmission configurations.

Antenna port	GPRS/EDGE/WCDMA		LTE (Band 4/13)		802.11 b/g/n		GPS
	TX	RX	TX	RX	TX	RX	RX
#1 WWAN (Main)	Yes	Yes	Yes	Yes	No	No	No
#2 WLAN Main	No	No	No	No	Yes	Yes	No
#3 Diversity/GPS	No	Yes	No	Yes	No	No	Yes

2.2 Simultaneous Transmission Table

Table 7: Antenna simultaneous transmission configurations.

TX Modes	GPRS/EDGE/WCDMA/LTE	802.11 b/g/n
1	ON*	ON

*The device is only capable of transmitting a single WWAN technology (GPRS/EDGE/WCDMA/LTE) at one time.

3.0 MPE Calculations

3.1 Individual MPE Calculations - Definitions:

The individual Maximum Permissible Exposure (MPE) calculations are given by:

$$P_d = \frac{P_{out} \times G}{4\pi R^2}$$

Where,

- P_d = power density (mW/cm²)
- P_{out} = output power to antenna (mW) x Duty Cycle (%)
- G = gain of antenna in linear scale
- R = distance between observation point and center of the radiator (cm)

The following table shows duty cycles for typical technologies.

Table 8: Technology Duty Cycles for MPE Calculations

Technology	Duty Cycle
GPRS/EDGE	12.5%
GPRS/EDGE	25%
WCDMA	100%
LTE	100%
WLAN	100%

3.2 Simultaneous transmission - Definitions

Collocated Power density –

Simultaneous transmitters = Fractional MPE ratio (WWAN) + Fractional MPE ratio (WLAN) ≤ 1

3.3 MPE Calculations - Router

The power density calculations for standalone transmitters at an exposure separation distance of 20 cm are shown in the following table per the WWAN transmitter powers and antenna gains declared in Table 4 and 5.

The WLAN power levels shown represent worst-case values for the given frequency ranges.

Table 9: WWAN and WLAN Standalone MPE Calculations

Technology	Frequency (MHz)	Maximum Antenna Gain (dBi)	Maximum Conducted Power		Peak Radiated Power		Duty Cycle (%)	Average Radiated Power		Power Density @ 20cm (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	FCC/IC MPE Margin (mW/cm ²)
			dBm	W	EIRP (dBm)	EIRP (W)		EIRP (dBm)	EIRP (W)			
GPRS (1UL)	824	-0.08	34.00	2.51	33.92	2.466	12.5	24.89	0.308	0.061	0.549	0.488
GPRS (2UL)	824	-0.08	34.00	2.51	33.92	2.466	25	27.89	0.617	0.123	0.549	0.426
GPRS (1UL)	1850	1.95	31.00	1.26	32.95	1.972	12.5	23.92	0.247	0.049	1.000	0.951
GPRS (2UL)	1850	1.95	31.00	1.259	32.95	1.972	25	26.93	0.493	0.098	1.00	0.902
WCDMA	824	-0.08	24.00	0.251	23.92	0.247	100	23.92	0.247	0.049	0.549	0.500
WCDMA	1700	2.08	24.00	0.251	26.08	0.406	100	26.08	0.406	0.081	1.000	0.919
WCDMA	1850	1.95	24.00	0.251	25.95	0.394	100	25.95	0.394	0.078	1.000	0.922
LTE (Band 2)	1850	1.95	24.00	0.251	25.95	0.394	100	25.95	0.394	0.078	1.000	0.922
LTE (Band 4)	1710	2.08	24.00	0.251	26.08	0.406	100	26.08	0.406	0.081	1.000	0.919
LTE (Band 5)	824	-0.08	24.00	0.251	23.92	0.247	100	23.92	0.247	0.049	0.549	0.500
LTE(Band 17)	704	-0.85	24.0	0.251	23.15	0.207	100	23.15	0.207	0.041	0.469	0.428
WLAN	2400	2.83	17.50	0.056	20.33	0.108	100	20.33	0.108	0.021	1.000	0.979

Table 10: Power Density (Fractional Calculations) – Individual

Technology	Band	WWAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WWAN P _d / MPE Limit
LTE (Band 2)	1850	0.078	1.000	0.078
LTE (Band 4)	1710	0.081	1.000	0.081
LTE (Band 5)	824	0.049	0.549	0.089
LTE (Band 17)	704	0.041	0.469	0.087
Technology	Band	WWAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WWAN P _d / MPE Limit
GPRS (1UL)	850MHz	0.061	0.549	0.111
GPRS (2UL)	850MHz	0.123	0.549	0.224
GPRS (1UL)	1900MHz	0.049	1.000	0.049
GPRS (2UL)	1900MHz	0.098	1.000	0.098
Technology	Band	WLAN Pd (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WLAN Pd / MPE Limit
WCDMA	850MHz	0.049	0.549	0.089
WCDMA	1700MHz	0.081	1.000	0.081
WCDMA	1900MHz	0.078	1.000	0.078
Technology	Band	WLAN Pd (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WLAN Pd / MPE Limit
WLAN	2.4 GHz	0.021	1.000	0.021

Table 11: Power Density (Fractional Calculations) – Worst Case Simultaneous

Band	Frequency (MHz)	WWAN Pd / MPE Limit	WLAN Pd / MPE Limit (ROUTER)	WWAN Fraction +WLAN Fraction	FCC/IC Limit	Pass/Fail
GPRS (2UL)	850	0.224	-	0.224	-	-
WLAN	2400	-	0.021	0.021	-	-
Total				0.245	1	Pass

4.0 External Antenna

4.1 Antenna location

Table 12: Antenna transmission configurations.

External Antenna port	GPRS/EDGE/WCDMA		LTE (Band 2/4/5/13)		802.11 b/g/n		GPS
	TX	RX	TX	RX	TX	RX	RX
Port #1	Yes	Yes	Yes	Yes	No	No	No
Port #2	No	Yes	No	Yes	No	No	No

4.2 Simultaneous Transmission Table

Table 13: External antenna simultaneous transmission configurations.

TX Modes	GPRS/EDGE/WCDMA/LTE	802.11 b/g/n
1 – External Antenna with router WiFi	ON	ON

*The device is only capable of transmitting a single WWAN technology (GPRS/EDGE/WCDMA/LTE) at one time.

5.0 MPE Calculations

5.1 Individual MPE Calculations - Definitions:

The individual Maximum Permissible Exposure (MPE) calculations are given by:

$$P_d = \frac{P_{out} \times G}{4\pi R^2}$$

Where,

- P_d = power density (mW/cm²)
- P_{out} = output power to antenna (mW) x Duty Cycle (%)
- G = gain of antenna in linear scale
- R = distance between observation point and center of the radiator (cm)

The following table shows duty cycles for typical technologies.

Table 14: Technology Duty Cycles for MPE Calculations

Technology	Duty Cycle
GPRS/EDGE	12.5%
GPRS/EDGE	25%
WCDMA	100%
LTE	100%

5.2 Simultaneous transmission - Definitions

Collocated Power density –

Simultaneous transmitters = Fractional MPE ratio (WWAN) + Fractional MPE Ratio (WLAN) ≤ 1

Note: When the external antenna is connected to the router the internal main WWAN antenna will disconnect.

5.3 MPE Calculations – External Antenna

The power density calculations for standalone transmitters at an exposure separation distance of 20 cm are shown in the following table per the WWAN transmitter powers and antenna gains declared in Table 4 and 5.

The WLAN power levels shown represent worst-case values for the given frequency ranges.

Table 15: WWAN and WLAN Standalone MPE Calculations

Technology	Frequency (MHz)	Maximum Antenna Gain (dBi)	Maximum Conducted Power		Peak Radiated Power		Duty Cycle (%)	Average Radiated Power		Power Density @ 20cm (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	FCC/IC MPE Margin (mW/cm ²)
			dBm	W	EIRP (dBm)	EIRP (W)		EIRP (dBm)	EIRP (W)			
GPRS (1UL)	824	4.0	34.00	2.51	38.00	6.31	12.5	28.97	0.789	0.157	0.549	0.392
GPRS (2UL)	824	4.0	34.00	2.51	38.00	6.31	25	31.98	1.577	0.314	0.549	0.235
GPRS (1UL)	1850	2.0	31.00	1.26	33.00	1.99	12.5	23.97	0.249	0.050	1.000	0.950
GPRS (2UL)	1850	2.0	31.00	1.26	33.00	1.99	25	26.98	0.499	0.099	1.000	0.901
WCDMA	824	4.0	24.00	0.251	28.00	0.631	100	28.00	0.631	0.126	0.549	0.423
WCDMA	1700	3.5	24.00	0.251	27.50	0.562	100	27.50	0.562	0.112	1.000	0.888
WCDMA	1850	2.0	24.00	0.251	26.00	0.398	100	26.00	0.398	0.079	1.000	0.921
LTE (Band 2)	1850	2.0	24.00	0.251	26.00	0.398	100	26.00	0.398	0.079	1.000	0.921
LTE (Band 4)	1710	3.5	24.00	0.251	27.50	0.562	100	27.50	0.562	0.112	1.000	0.888
LTE (Band 5)	824	4.0	24.00	0.251	28.00	0.631	100	28.00	0.631	0.126	0.549	0.423
LTE(Band 17)	704	3.5	24.0	0.251	27.50	0.562	100	27.50	0.562	0.112	0.469	0.357

Table 16: Power Density (Fractional Calculations) – Individual

Technology	Band	WWAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WWAN P _d / MPE Limit
LTE (Band 2)	1850	0.079	1.000	0.079
LTE (Band 4)	1710	0.112	1.000	0.112
LTE (Band 5)	824	0.126	0.549	0.230
LTE (Band 17)	704	0.112	0.469	0.239
Technology	Band	WWAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WWAN P _d / MPE Limit
GPRS (1UL)	850MHz	0.157	0.549	0.286
GPRS (2UL)	850MHz	0.314	0.549	0.572
GPRS (1UL)	1900MHz	0.050	1.000	0.050
GPRS (2UL)	1900MHz	0.099	1.000	0.099
Technology	Band	WWAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WWAN P _d / MPE Limit
WCDMA	850MHz	0.126	0.549	0.230
WCDMA	1700MHz	0.112	1.000	0.112
WCDMA	1900MHz	0.079	1.000	0.079
Router*	Band	WLAN P _d (mW/cm ²)	FCC/IC MPE Limit (mW/cm ²)	WLAN P _d / MPE Limit
WLAN	2.4 GHz	0.021	1.000	0.021

*WLAN data is calculated from the router (page 13). The LTE and CDMA antennas on the router are disconnected when the external antenna is attached.

Table 17: Power Density (Fractional Calculations) – Worst Case Simultaneous

Band	Frequency (MHz)	WWAN P _d / MPE Limit	WLAN P _d / MPE Limit (ROUTER)	WWAN Fraction +WLAN Fraction	FCC/IC Limit	Pass/Fail
GPRS (2UL)	850	0.572		0.572	-	-
WLAN*	2400	-	0.021	0.021		-
Total				0.593	1	Pass

5.4 External antenna summary

Based on the calculations above the maximum antenna gains cannot exceed the following values to comply with the FCC and Industry Canada RF Exposure requirements for mobile device. The SA 2100 will be sold exclusively with the Pulse (Part No.: WA700/2700SMA) antenna. The maximum gain including cable loss will not exceed the values shown in table 18.

Table 18 Maximum Permissible Exposure Summary Table

Frequency	Maximum Antenna Gain (dBi)
704 - 716	3.5
824 - 849	4.0
1710-1755	3.5
1850 - 1910	2.0