Engineering
RF Exposure Measurements

FOR THE

TR301, OC251 and OC301

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The test data contained in this report documents the observed testing parameters pertaining to and are relevant for only the sample equipment tested in the agreed upon operational mode(s) and configuration(s) as identified herein. Compliance assessment remains the client's responsibility. This report may not be used to claim product endorsement by A2LA or any government agencies. This test report has been authorized for release under quality control from CKC Laboratories, Inc.

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Purpose and Discussion

To demonstrate compliance with United States, Canada, Australia and/or European Union RF Exposure requirements for Mobile Equipment (devices used >20cm from the body), where MPE measurements apply.

Device and Antenna Operating Configuration:

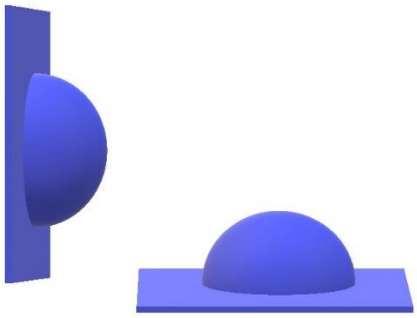
Device operating at maximum output power with continuous charging.

Test Procedure:

The EUT system consists of a transmitter module coupled with a 20 cm diameter power transmitting coil, plus a 10cm receiver coil and receiver module combination. These components are used to charge a battery wirelessly. The frequency used by the system is 6.78MHz.

The manufacturer of the charging circuit brought a typical robot chassis that is used with the device, but it is not a fully assembled system, however this system limits the proximity a person could get to the charging coil when in use, so the worst case distance will be explored with the chassis in place. The manufacturer declares the charging coil is only active while charging a device via the receiver coil and receiver module.

There are also several installation scenarios for the charging pad. The manufacturer declares the charging pad could either be installed into a wall, or installed into the ground, therefore, the manufacturer declares the "back" of the charging coil is inaccessible, and the investigation of worst case was not performed beyond the imagined surface that the coil would be installed onto. Essentially a semi-sphere was investigated opposite the installation case of a wall/floor surface.



The EUT system was set to max power and continuously transmitting during the investigation of the worst-case H field and E field. This was done by moving the probe around the semi-sphere test volume between 20cm and 1m away from either the charging coil or as limited by the robot chassis. In this region, both the E and H fields strengths were proportional to the proximity of the charging coil.

The probe was also rotated about its center in the probe XYZ axis to ensure the maximum value is reported. The worst case was found to be concentrated directly 20cm away from the edge of the charging coil. This area is able to be accessed within 20cm given the robot chassis provided by the manufacturer. This area was explored 360 degrees outside the edge of the coil, and the worst-case position was found 20cm away. This position is labeled at "20cm max."

For the magnetic field, a 5-point spatial average was then performed by increasing and decreasing the height above and below the worst case point. The manufacturer declares this represents the worst-case installation situation where the charging pad is on a wall with a person next to it. Measurements were taken at 40cm above, 80cm above, 40cm below, 80cm below the "20cm max" position. Each time the probe orientation was investigated to report the maximum observed magnetic field.

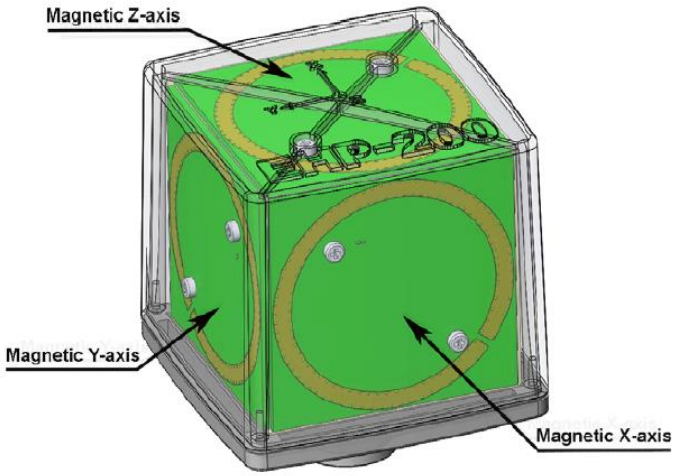
Finally, an investigation was performed to verify the behavior of the fields beyond 1 meter. A qualitative investigation was performed around a semi-sphere from 1 meter to beyond 3 meters and it was observed that in both the E and H field strengths were proportional the proximity of the charging coil. Measurements were collected by starting with "20cm max" and increasing the distance to 50cm, 100cm, 200cm, and 300cm to characterize the field strength behavior over distance. At each position the measurement probe was rotated in the XYZ axes to maximize the value reported.

This investigation was performed on 2 different EUT systems, in both cases the transmitter was model TR301. The receiver models investigated were the OC251 and OC301. It was found that the OC301 produced slightly higher field strengths in all cases, all data presented in this report was measured using the model OC301 as representative of worst case.

The following settings used by the EHP-200A software:
RBW = 10kHz
Span = 100kHz centered around fundamental frequency
Peak values are reported.

Measurement Probe Information:

Measurement probe used is a Narda EHP-200A. All distances recorded in this report are with respect to the center of the probe. The probe is approximately an 90mm cube, so from edge of the probe to the center in any axis is approximately 45mm.



EHP-200A Internal Construction

EHP-200A Dimensions

MPE Measurements

Test Equipment					
Asset	**Description**	**Manufacturer**	**Model**	**Cal Date**	**Cal Due**
03686	Field Analyzer	Narda	EHP-200A	4/26/2018	4/26/2021

Measurement Positions

Identified below are each of the specific measurement positions. Within the areas of concern, these positions are intended to represent positions with the highest likelihood of an interference potential given typical workflow patterns and understanding of safe approach distances (2).

Position*	Description
20cm max	The worst case 20cm position. This probe position developed the highest field values with center of probe 20 cm away from the edge of the charging coil. It was 20cm away directly off to the side of the charging coil. (see photo of orientation)
20cm max + 40	Start with 20cm max position, the probe is then moved up 40cm in height.
20cm max + 80	Start with 20cm max position, the probe is then moved up 80cm in height.
20cm max - 40	Start with 20cm max position, the probe is then moved down 40cm in height.
20cm max - 80	Start with 20cm max position, the probe is then moved down 80cm in height.
50cm max	Start with 20cm max position, then move away from coil an additional 30cm.
100cm max	Start with 20cm max position, then move away from coil an additional 80cm.
200cm max	Start with 20cm max position, then move away from coil an additional 180cm.
300cm max	Start with 20cm max position, then move away from coil an additional 280cm.

*NOTE: Reported measurement distances were from edge of EUT to Center of the measurement probe. Because the measurement coils are offset inside the probe, the reported “maximized” positions should be interpreted with 45mm subtracted from the declared measurement distance.

Summary of Results

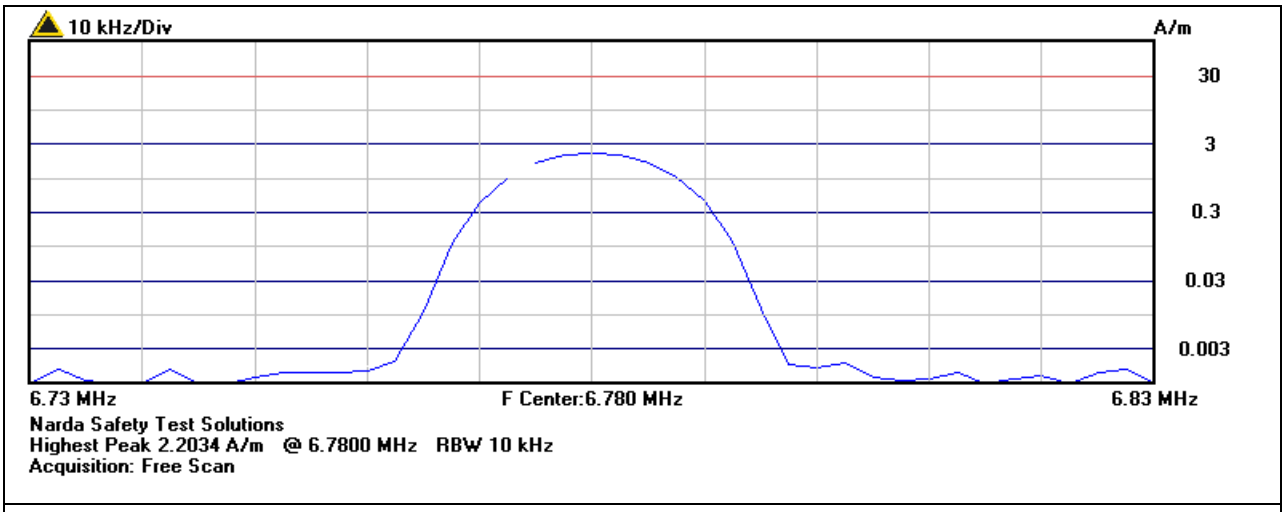
Test Summary – Worst Case 20cm position				
Method:	☒ Measurement ☐ Computation			
Limit Used is:	☐ General Population ☒ Occupational / Controlled Use Exposure			
Value	**Position**	**Measured Exposure**	**Limit**	**Result**
Electric Field Strength (V/m)	20cm max	108.65 V/m	271.7 V/m	Engineering
Magnetic Field Strength (A/m)	20cm max	2.2034 A/m	0.72 A/m	Engineering

Test Summary – Worst Case 20cm 5-point spatial average (Mag Only)				
Method:	☒ Measurement ☐ Computation			
Limit Used is:	☐ General Population ☒ Occupational / Controlled Use Exposure			
Value	**Position**	**Measured Exposure**	**Limit**	**Result**
Magnetic Field Strength (A/m)	20cm max + 80	0.0816 A/m	N/A	Engineering
Magnetic Field Strength (A/m)	20cm max + 40	0.3641 A/m	N/A	Engineering
Magnetic Field Strength (A/m)	20cm max	2.2034 A/m	N/A	Engineering
Magnetic Field Strength (A/m)	20cm max - 40	0.2703 A/m	N/A	Engineering
Magnetic Field Strength (A/m)	20cm max - 80	0.0310 A/m	N/A	Engineering
Magnetic Field Strength (A/m)	Calculated Average	0.59 A/m	0.72 A/m	Engineering

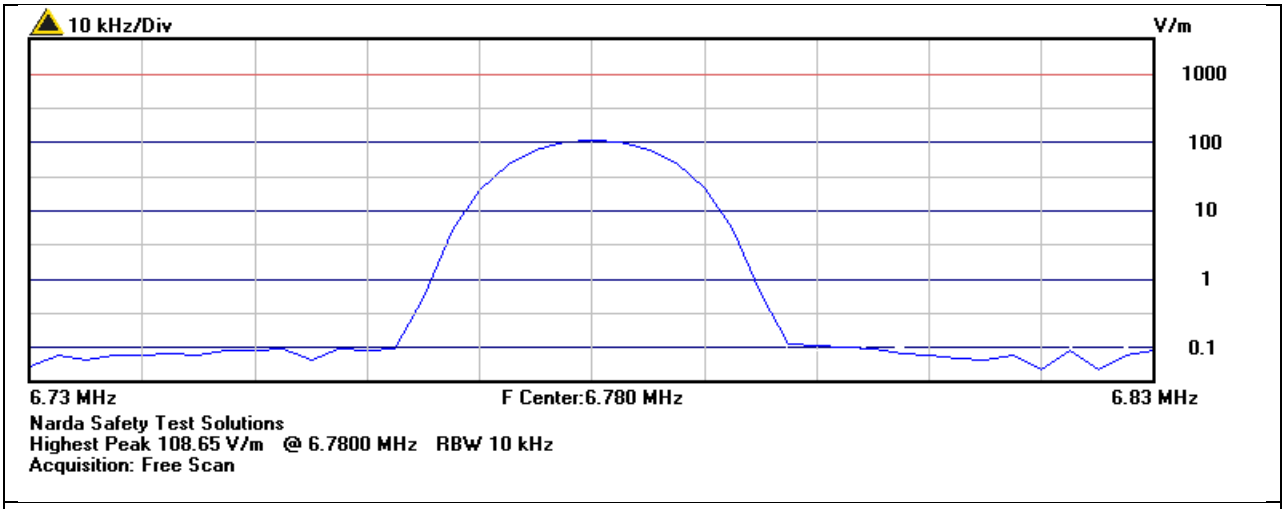
Test Summary – H field vs distance measurements				
Method:	☒ Measurement ☐ Computation			
Limit Used is:	☐ General Population ☒ Occupational / Controlled Use Exposure			
Value	**Position**	**Measured Exposure**	**Limit**	**Result**
Magnetic Field Strength (A/m)	20cm max	2.2034 A/m	0.72 A/m	Engineering
Magnetic Field Strength (A/m)	50cm max	0.1306 A/m	0.72 A/m	Engineering
Magnetic Field Strength (A/m)	100cm max	0.0230 A/m	0.72 A/m	Engineering
Magnetic Field Strength (A/m)	200cm max	0.0032 A/m	0.72 A/m	Engineering
Magnetic Field Strength (A/m)	300cm max	0.0019 A/m	0.72 A/m	Engineering

Test Summary – E field vs distance measurements				
Method:	☒ Measurement ☐ Computation			
Limit Used is:	☐ General Population ☒ Occupational / Controlled Use Exposure			
Value	**Position**	**Measured Exposure**	**Limit**	**Result**
Electric Field Strength (V/m)	20cm max	108.65V/m	271.7 V/m	Engineering
Electric Field Strength (V/m)	50cm max	18.996V/m	271.7 V/m	Engineering
Electric Field Strength (V/m)	100cm max	6.0218V/m	271.7 V/m	Engineering
Electric Field Strength (V/m)	200cm max	1.3540V/m	271.7 V/m	Engineering
Electric Field Strength (V/m)	300cm max	0.4433V/m	271.7 V/m	Engineering

Plots of 20cm Data

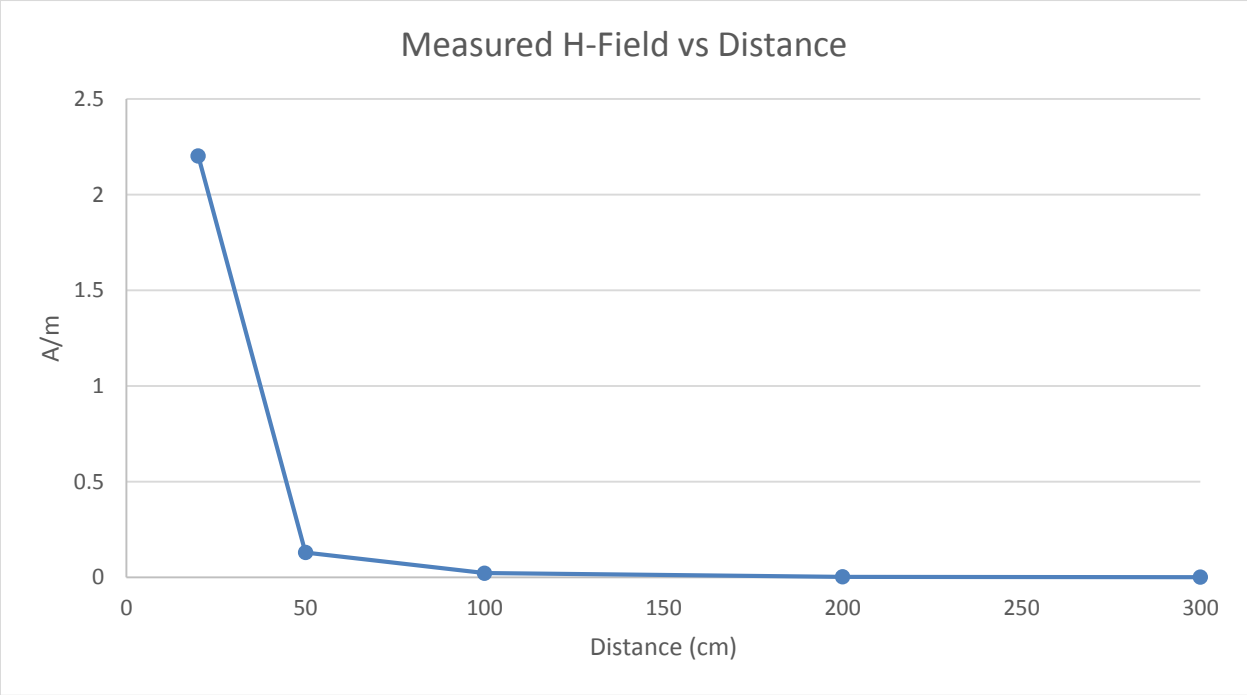


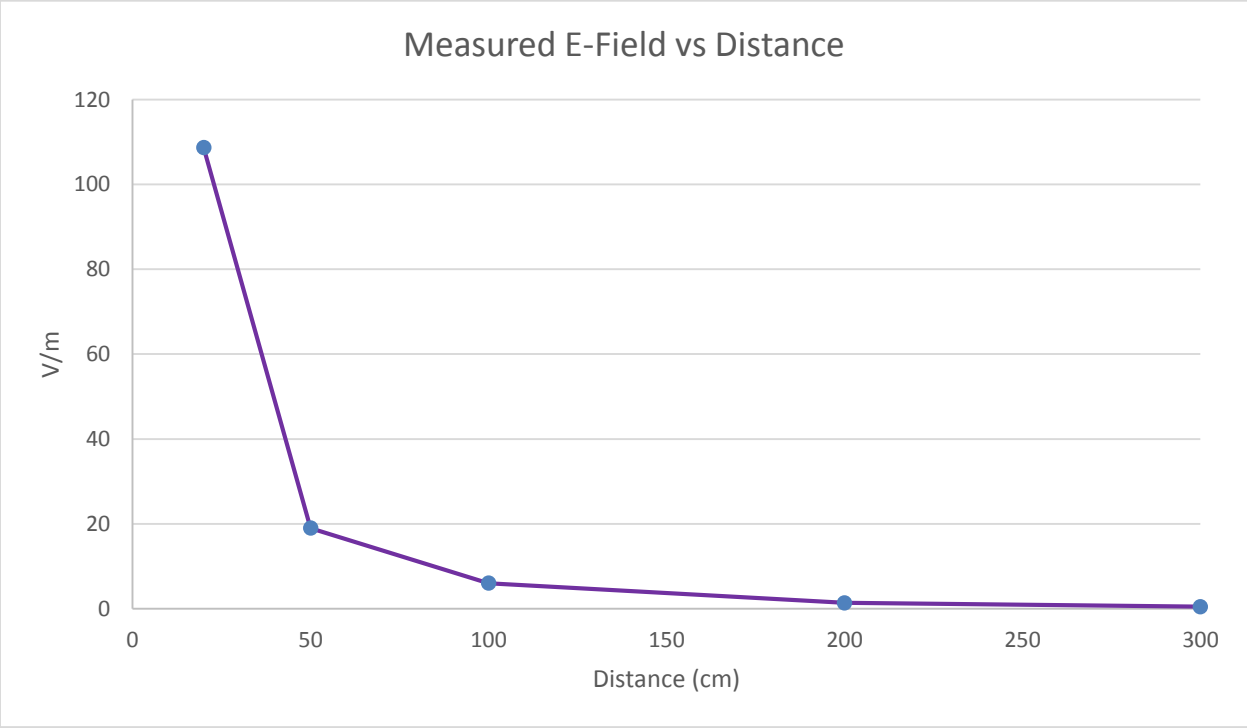
H Field 20cm max



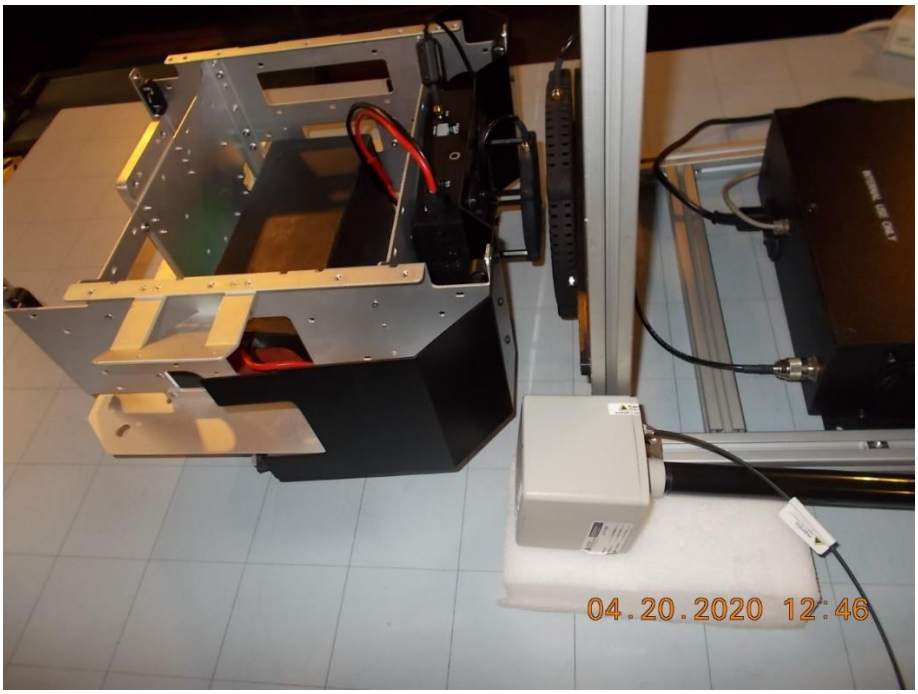
E Field 20cm max

Plots of Field Falloff

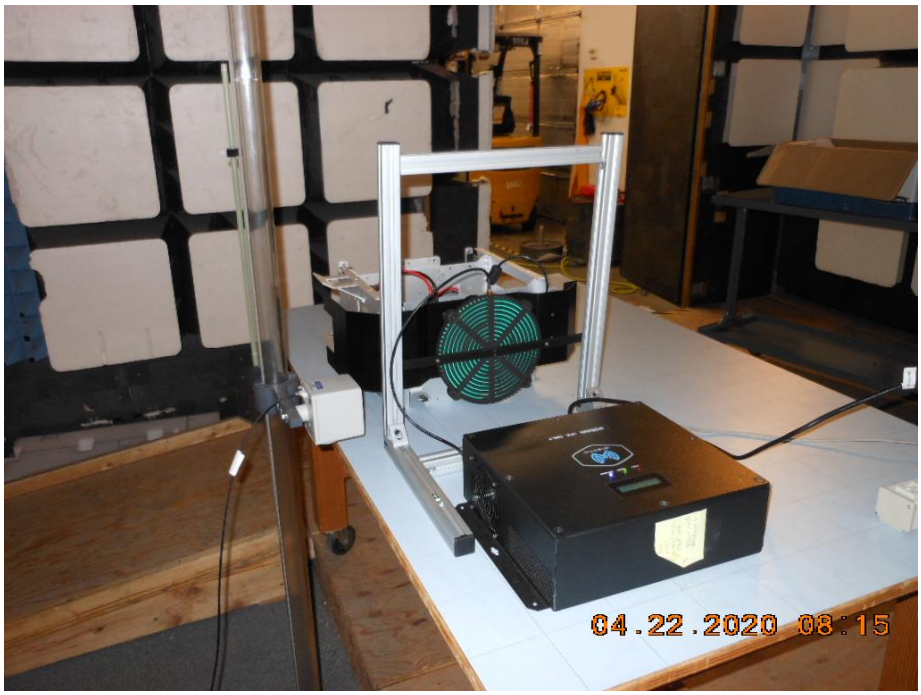




Setup Photos

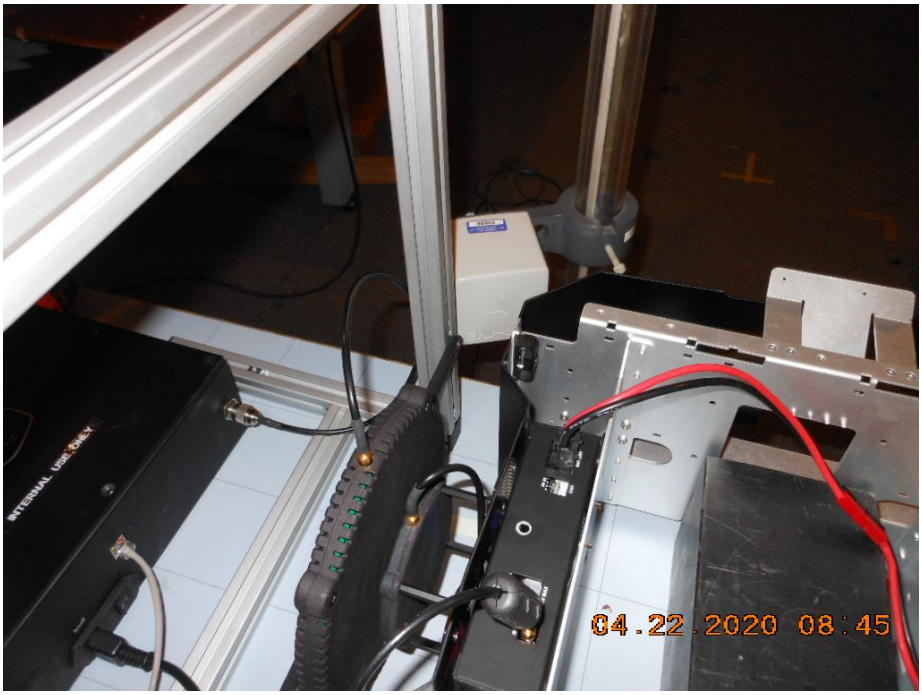


General Setup Photo 1

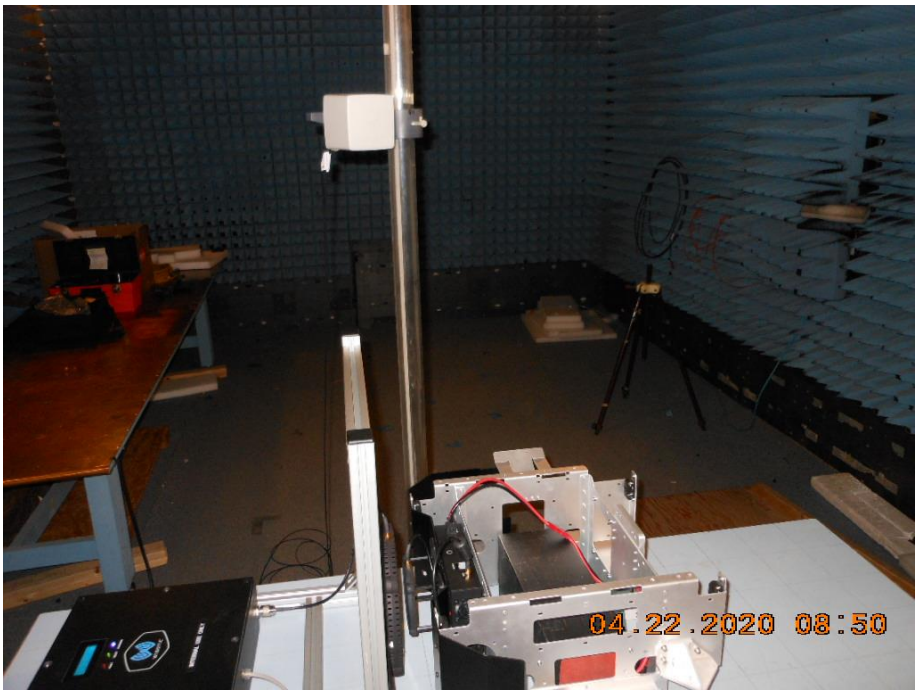


General Setup Photo 2

Worst Case 20cm position photo 1



Worst Case 20cm position photo 2



Example Position for Spatial Average – “20cm max + 80” position shown

Check field against distance beyond 1 meter

Summary

MPE Measurement Results:

Equipment demonstrating compliance with MPE measurement have been evaluated for use under mobile RF exposure configurations as identified herein. Additional configurations including collocation or simultaneous transmission with other transmitters (including necessary separation distances) are subject to further assessment. It is assumed that the manufacturer shall design the equipment such that the minimum separation distance of 20cm (or greater, as listed above) is met or that the manufacturer provides a protection guide (e.g. installation instructions) to the end user such that the antenna(s) may be installed in accordance with the manufacturer's instructions in such a manor to maintain the minimum separation distance.

General Comments:

The absorption and distribution of Electromagnetic energy in the body is a very complex phenomena that depends on the mass, shape and physiological condition of the body; the orientation of the body with respect to the fields; and, the electrical properties of the body and the environment. Variables that may play a substantial role in possible biological effects are those that characterize the environment (including but not limited to: ambient temperature, air velocity, relative humidity and body insulation); and those that characterize the individual (including but not limited to: age, gender, activity level and existing debilitation or disease). Because innumerable factors may interact to determine specific biological effects of exposure to electromagnetic fields, any protection guide should consider both intended and unintended operational environments and provide guidance for installation and use of the product such that proper separation distances can be maintained. (ANSI C95.1)

APPENDIX A - Assessment Procedure

TEST CONFIGURATION

The EUT antenna is placed in a configuration typical of normal installation. Where antenna mounting is required, non-conductive materials are used for support structures. In the special case of magnetically mounted vehicle antennas, a reference ground plane is used to simulate actual installation. In order to limit external interference effects, the test is performed in a semi-anechoic chamber. The EUT equipment is setup in a configuration representative of normal use. Support equipment for the measurement instruments are located outside of the testing area.

TEST PROCEDURE

Measurements are performed using a broadband detector with three orthogonal measurement axes. Values recorded are RMS based on the maximum measurements. To determine the direction of the maximum measurement, the detector is moved throughout the RF field generated by the transmit antenna. The detector is positioned at a minimum of 12 radials and at varying distances from the antenna along each radial. The area of maximum RF energy determined during preliminary investigation shall be used for the remainder of the tests. In the case where a transmitter may have multiple frequency bands, the preliminary investigation shall be repeated for each band.

For time varying fields, the appropriate averaging time is used. For spatially uniform fields, the measurement height is selected based on maximum preliminary measurements.

For spatially non-uniform fields (e.g. distances close to a magnetically mounted vehicle antenna), spatial averaging may be performed. The method for performing spatially averaged measurements is as follows:

1. Determine the direction of the maximum measurement.
2. At a specific distance measure vertically from the floor 5 points comprising a linear cross section of an adult human body, beginning at 0.2m and at each 40cm up to 1.8m.
3. Calculate the average of the measurements and compare with the established limit.

Since the applicable limits exist in several different measurement units, the following outlines the most common calculations used for determining the spatially averaged field.

Case 1: Where limits are applied in electric field strength (V/m), the spatially averaged electric field strength along a grid of *n* points is calculated using:

$$E = \left[\frac{1}{n} \sum_{i=1}^{n} E_i^2 \right]^{\frac{1}{2}}$$

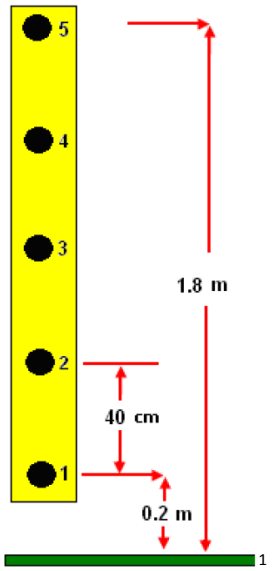
Case 2: Where limits are applied in units of power density (mW/cm^2), assuming measurements are made in the far field, where the E and H vectors are mutually orthogonal, power density is first calculated using:

$$S = \frac{E^2}{3770}$$

And the spatially averaged power density along a grid of n points is calculated using:

$$S = \frac{1}{n} \sum_{i=1}^{n} S_i$$

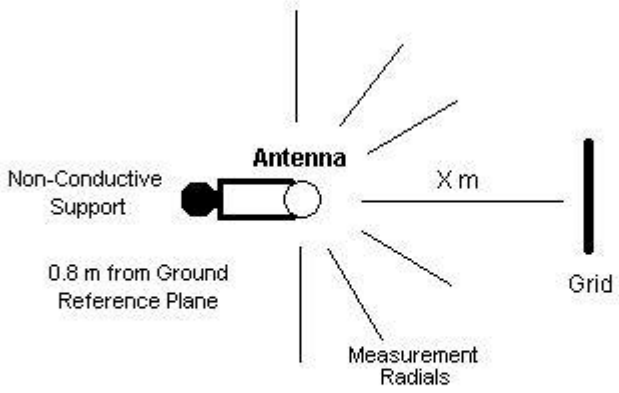
The following diagram is an example of the grid used to perform local measurements for RF exposure evaluation over a whole-body spatial average.



The following diagram is an example of the setup used for most tests, excluding magnetically mounted vehicle antennas.

Setup Used for RF Evaluation Measurements

(excluding magnetically mounted vehicle antennas)

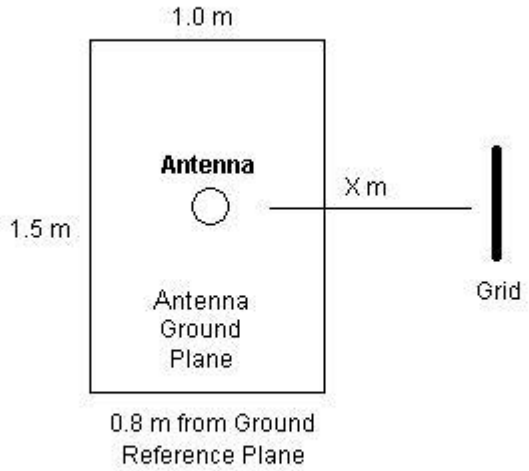


Top View

[1] Source: IC GL-01

The following diagram is an example of the setup used for vehicle-mounted antennas. In the case where vehicle glass mounted antennas are used, this setup shall not apply. The letter X represents the test distance used for RF exposure measurements. The distance X is measured from the phase center of the transmitting antenna to the volumetric center of the measurement instrument. In order to more accurately simulate normal installation, the antenna ground plane is not bonded to the ground reference plane. The transmitting antenna is placed in the center of the antenna ground plane.

Setup Used for Vehicle-Mounted Antennas



Top View

APPENDIX B - RF Exposure Limits

United States Compliance Requirements (1.1310):

RF Exposure Evaluation Limits
Occupational / Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (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	6
300-1500	---	---	f/300	6
1500-100,000	---	---	5.0	6

RF Exposure Evaluation Limits
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	*($180/f^2$)	30
30-300	27.5	0.073	0.2	30
300-1500	---	---	f/1500	30
1500-100,000	---	---	1.0	30

** Plane wave equivalent power density*
Limit is calculated based on the mid-band frequency used in the operating frequency range.

Stand-Alone Evaluation Exemption Levels:
In accordance with KDB 447498 D01 v05r02

	Max Output Power at Exemption Limit (mW)	
Frequency (MHz)	*d ≤ 50mm*	*50mm < d ≤ 20cm*
<100	$\frac{1}{2}\cdot\left(\frac{R\cdot 50}{\sqrt{0.1}}\right)\cdot\left(1+LOG\left(\frac{100}{f_{MHz}}\right)\right)$	$\left(\frac{R\cdot 50}{\sqrt{0.1}}+(d-50)\frac{100}{150}\right)\cdot\left(1+LOG\left(\frac{100}{f_{MHz}}\right)\right)$
100-1500	$\left(\frac{R\cdot d}{\sqrt{f_{GHz}}}\right)$	$\left(\frac{R\cdot 50}{\sqrt{f_{GHz}}}+(d-50)\frac{f_{MHz}}{150}\right)$
1500-6000		$\left(\frac{R\cdot 50}{\sqrt{f_{GHz}}}+(d-50)\cdot 10\right)$

R is the allowed ratio: 3 for 1-g SAR and 7.5 for 10-g extremity SAR.
d is distance in mm, rounded to the nearest mm.

Canadian Compliance Requirements (RSS-102):

RF Exposure Evaluation Limits
Occupational / Controlled Exposure:

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.003-10	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	$129.8 / f^{0.5}$	$0.3444 / f^{0.25}$	$44.72 / f^{0.5}$	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
15000-150,000	137	0.364	50	$616000/ f^{1.2}$
150,000-300,000	$0.354 f^{0.5}$	$9.40x10^{-4} f^{0.5}$	$3.33x10^{-4} f$	$616000/ f^{1.2}$

RF Exposure Evaluation Limits
General Population / Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.003-10	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
15000-150,000	61.4	0.163	10	$616000/ f^{1.2}$
150,000-300,000	$0.158 f^{0.5}$	$4.21x10^{-4} f^{0.5}$	$6.67x10^{-5} f$	$616000/ f^{1.2}$

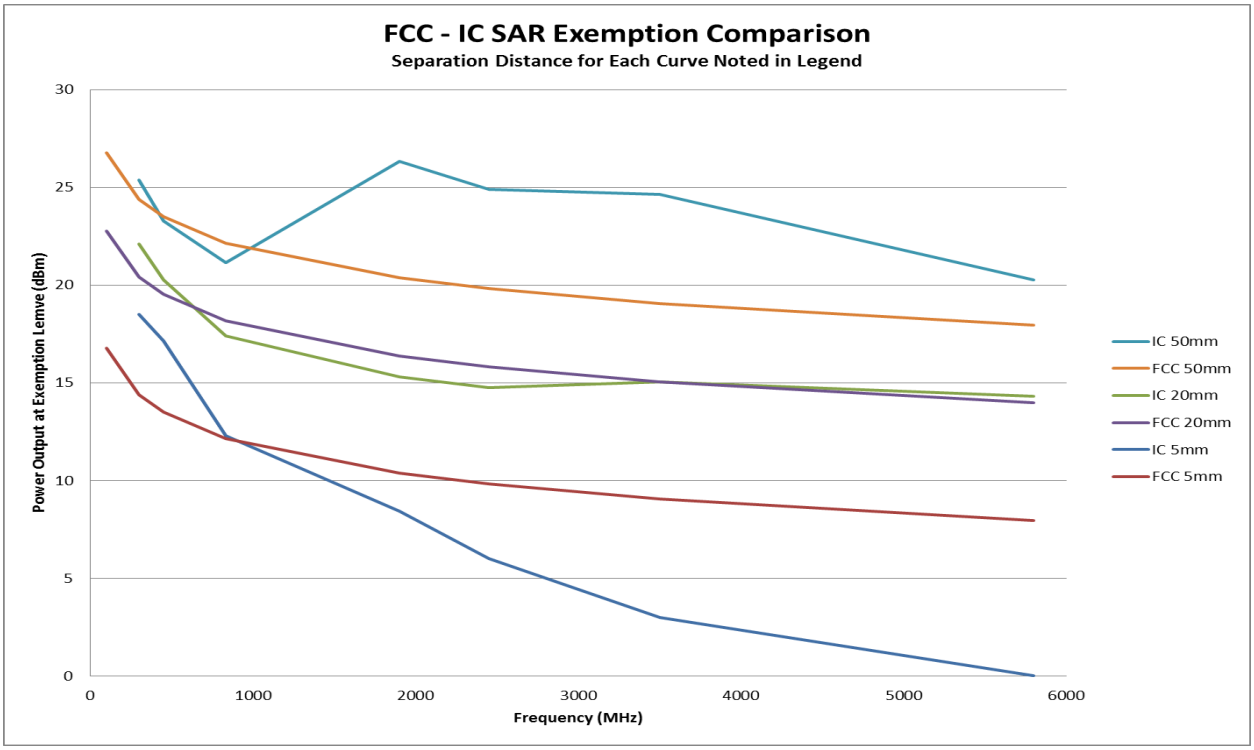
Stand-Alone Evaluation Exemption Levels:

Exemption Limits (mW) at Separation Distance (mm)										
Freq(MHz)	**≤5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**≥50**
≤300	71	101	132	162	193	223	254	284	315	345
450	52	70	88	106	123	141	159	177	195	213
835	17	30	42	55	67	80	92	105	117	130
1900	7	10	18	34	60	99	153	225	316	431
2450	4	7	15	30	52	83	123	173	235	309
3500	2	6	16	32	55	86	124	170	225	290
5800	1	6	15	27	41	56	71	85	97	106

Stand-Alone Evaluation Exemption Levels:

Frequency (MHz)	RF Exposure Exemption Limit (mW)
<20	1000
20-48	$22480 / f^{0.5}$
48-300	600
300-6000	$1310\ f^{0.6834}$
≥6000	5000

General[2] Comparison of FCC and IC Exemption Limits



[2] Non-Exhaustive

Australian Radiation Protection and Nuclear Safety Agency Requirements (ARPANSA):

RF Exposure Evaluation Limits
Occupational / Controlled Exposure:

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.1 – 1.0	614	1.63/f	---	6
1.0-10	614/f	1.63/f	$1000/f^2$	6
10-400	61.4	0.163	10	6
400-2000	$3.07 * f^{0.5}$	$0.00814 * f^{0.5}$	f/40	6
2000-10,000	137	0.36	50	6
10,000 – 300,000	137	0.36	50	$9.6x10^4 / f^{1.05}$

RF Exposure Evaluation Limits
General Population / Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.10-0.15	86.8	4.86	---	6
0.150-1.0	86.8	0.729/f	--	6
1.0-10	$86.8/f^{0.5}$	0.729/f	---	6
10-400	27.4	0.0729	2	6
400-2000	$1.37 f^{0.5}$	$0.00364*f^{0.5}$	f/200	6
2000-10,000	61.4	0.163	10	6
10,000 – 300,000	61.4	0.163	10	$9.6x10^4 / f^{1.05}$

**Power density limit applicable >100MHz*

Stand-Alone Evaluation Exemption Levels:

Occupational Exposure: 100mW
Portable - General Public: 20mW
Mobile – General Public: Separation distance >20cm and power < ARPANSA RPS3 Table S2
Or according to ARPANSA RPS3 Table S1

Table S2

Operating Frequency (MHz)	Nominal Mean Power Output (W)
0.1-450	7
450-2500	3150 / f

European Union Compliance Requirements (ICNIRP):

RF Exposure Evaluation Limits
Occupational / Controlled Exposure:

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.00082-0.065	610	24.4	---	6
0.065-1.0	610	1.6/f	---	
1.0-10	610/f	1.6/f	---	6
10-400	61	0.16	10	6
400-2000	$3.0 * f^{0.5}$	$0.008 * f^{0.5}$	f/40	6
2000-300,000	137	0.36	50	6

RF Exposure Evaluation Limits
General Population / Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
0.003-0.150	87	5.0	---	6
0.150-1.0	87	0.73/f	--	6
1.0-10	$87/f^{0.5}$	0.73/f	---	6
10-400	28	0.073	2	6
400-2000	$1.375\ f^{0.5}$	$0.0037*f^{0.5}$	f/200	6
2000-300,000	61	0.16	10	6

**Power density limit applicable >100MHz*

Stand-Alone Evaluation Exemption[3] Levels:

Head / Body: 20mW
Extremity: 40mW

[3] EN 62479 Annex A, General Public

APPENDIX C - References

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11. Industry Canada RSS-102 Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands), Issue 5, March 2015.
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14. European Committee for Electrotechnical Standardization. European Normative, EN 62479 Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz), 2010.
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