COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE XPR MODEL AAM28QPN9RA1AN (PMUE3649C) (IC MODEL: PMUE3649CBMNAA) MOBILE RADIO

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Introduction

This report summarizes the computational [numerical modeling] analysis performed to document compliance of the XPR Series Model Number AAM28QPN9RA1AN (PMUE3649C) (IC MODEL: PMUE3649CBMNAA) Mobile Radio and vehicle-mounted antennas with the Innovation, Science and Economic Development (ISED) Canada and ICNIRP guidelines for human exposure to radio frequency (RF) emissions. The radio operates in the following frequency bands:

Regions	Bands	Frequency Band (MHz)
ISED Canada	LMR UHF	406.1-430, 450-470
Overall (Other regions)	LMR UHF	403-470

This computational analysis supplements the measurements conducted to evaluate the compliance of the exposure from this mobile radio with respect to applicable *reference levels*, which in the following will be referred to as *maximum permissible exposure* (MPE) limits.[1] A total of 14 test conditions that did not conform with ISED MPE limit were considered to determine whether those conditions complied with the *specific absorption rate* (SAR) limits for general public exposure (1.6 W/kg averaged over 1 gram of tissue and 0.08 W/kg averaged over the whole body) set forth in Health Canada guidelines [1]. A total of 10 test conditions did not conform with ICNIRP guideline MPE limit were considered to determine whether those

[1] This choice is made for process efficiency, since "MPE" is used in the United States. In this way, chances of making editorial mistakes that may then require extended interactions with the report examiner are reduced.

conditions complied with SAR limits set forth in, ICNIRP guidelines [4] and IEEE Std. C95.1-2019 standard [5] (2.0 W/kg averaged over 10 gram of tissue and 0.08 W/kg averaged over the whole body).

Employing SAR simulation reduction considerations [2], a total of 4 configurations (requiring a total of 8 numerical simulations) have been performed, all of them addressing the exposure of the back seat passenger to the UHF mobile radio featuring trunk-mount antennas.

For all simulations a commercial code (XFDTD™ v7.6.0, by Remcom Inc, State College, PA, USA) based on the Finite-Difference-Time-Domain (FDTD) methodology was employed to carry out the computational analysis. It is well established and recognized within the scientific community that SAR represents the *basic restriction* for RF energy exposure up to 6 GHz and that MPE limits are in fact derived from SAR limits. Accordingly, the SAR computations provide a scientifically valid and more relevant estimate of RF energy exposures.

Method

The XFDTD™ v7.6.0 computational suite enable simulating the heterogeneous full human body model defined according to the IEC/IEEE 62704-2:2017 standard and derived from the so-called Visible Human [3], discretized in 3 mm cubic-edge voxels. The IEC/IEEE 62704-2:2017 dielectric properties for 39 body tissues are automatically assigned by XFDTD™ at the specific simulation frequency. The "seated" man model representing the passenger was obtained from the standing model by modifying the articulation angles at the hips and the knees. Details of the computational method and model are provided in the Appendix A to this report. The evaluation of the computational uncertainties and results of the benchmark validations are provided in the Appendix B attached to this report. The XFDTD code validation performed by Remcom Inc. according to the IEEE/IEC 62704-2:2017 standard requirements are provided in conjunction with this report.

The car model has been imported into XFDTD™ from the CAD file of the sedan vehicle defined in the IEEE/IEC 62704-2:2017 standard, having dimensions 4.98 m (L) x 1.85 m (W) x 1.18 m (H), and discretized with the minimum resolution of 3 mm and the maximum resolution of 8 mm. Figure 1 below shows both the vehicle CAD model and a picture of the actual vehicle.

[2] SAR simulation reduction is described in the SAR Simulations Reduction Considerations section of this report.

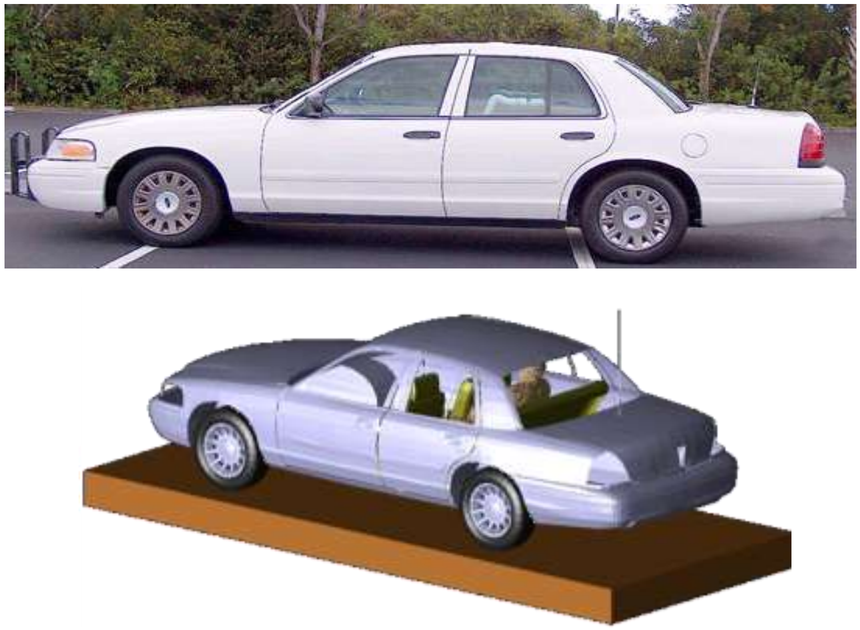


Figure 1: Picture of the vehicle and corresponding CAD model used in XFDTD™ simulations

For back seat passenger exposures, the antenna is positioned on the trunk at 85 cm distance from the passenger model head when the passenger model is located in the center of the back seat, replicating the experimental conditions used in MPE measurements. Figure 2 and shows the XFDTD™ computational models used for passenger exposure to trunk mount antennas.

According to the IEC/IEEE 62704-2:2017 standard a lossy dielectric slab featuring 30 cm thickness, relative dielectric constant 8 and conductivity 0.01 S/m has been introduced in the computational model to properly account for the effect of the ground (pavement) on exposure.

The computational code employs a time-harmonic field excitation to produce a steady-state electromagnetic field in the exposed body model. Subsequently, the corresponding SAR distribution is automatically processed in order to determine the whole-body SAR and peak spatial average SAR distribution.

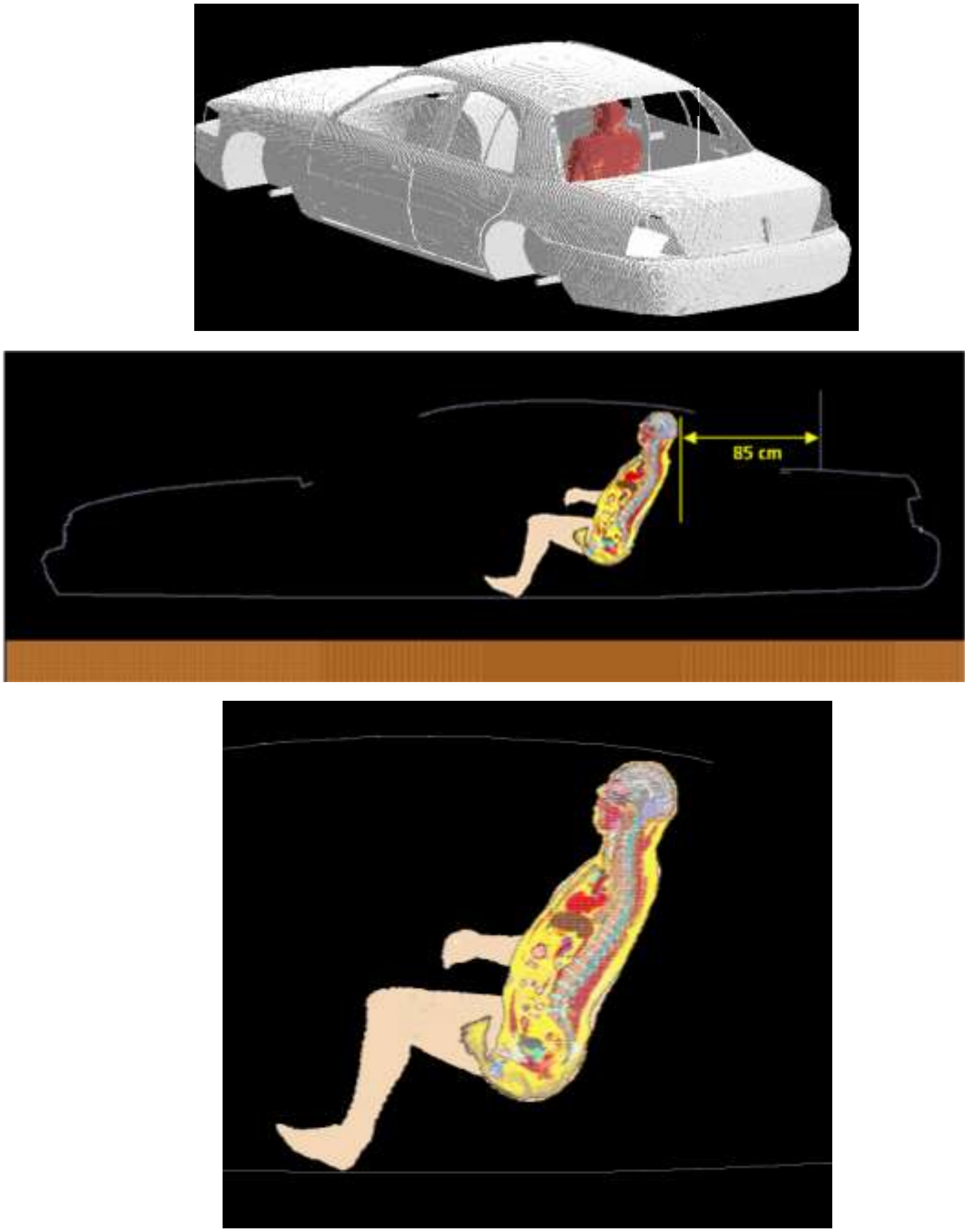


Figure 2: Passenger (back seat) model exposed to a trunk-mount antenna: XFDTD™ geometry. The antenna is installed at 85 cm from the passenger located in the center of the back seat.

The maximum average output power from mobile radio antenna is 48W (403-470 MHz). Since the ohmic losses in the vehicle materials, as well as the mismatch losses at the antenna feed-point are neglected, while source-based time averaging (50% talk time for to push-to-talk operation) for the UHF mobile radio were employed, all computational results are normalized to half of the UHF mobile radio maximum average net output power, i.e., 24W (403-470 MHz), minus the corresponding minimum insertion loss in excess of 0.5 dB of the feed cables supplied with the antennas, in accordance with the IEC/IEEE 62704-2:2017 standard provisions.

Results of SAR computations for car passengers

The test conditions requiring SAR computations are summarized in Table 1 (Passengers), together with the antenna data, the SAR results, and power density (P.D.) as obtained from the MPE measurements in the corresponding test conditions. The conditions are for antennas mounted on the center of the trunk. The antenna length listed in the tables includes the height of the 1.8 cm magnetic mount base used in MPE measurements to position the antenna on the vehicle. The same length was then used in the corresponding simulation model.

The passenger is located in the center or on the side of the rear seat corresponding to the respective configurations defined in the IEC/IEEE 62704-2-2017 standard.

All the transmit frequency, antenna length, and passenger location reported in Table 1 have been simulated individually. These tables also include the interpolated adjustment factor and corresponding SAR scaled values following requirement of the IEC/IEEE 62704-2-:2017 standard.

Table 1a: Computed and adjusted SAR results for Passengers exposure

(Configurations exceeding ISED MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computed SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Trunk	HAE6022A, 1/2 Wave (403-527 MHz)	29.6	453.0125	0.27	Back Center	0.23	0.015	2.39	2.795	0.55	**0.042**
					Back Side	0.28	0.013	1.99	2.594	0.56	0.035
Trunk	HAE6029A, 1/2 Wave (403-527 MHz)	29.8	419.9875	0.26	Back Center	0.19	0.010	2.35	2.760	0.44	0.028
					Back Side	0.26	0.012	2.22	2.640	0.57	0.032
Trunk	PMAE4040A, 1/4 Wave (406-420 MHz)	37.8	419.9875	0.26	Back Center	0.18	0.009	2.35	2.760	0.42	0.026
					Back Side	0.23	0.011	2.22	2.640	0.52	0.030
Trunk	PMAE4042A, 5/8 Wave (450-470 MHz)	32.8	450.0125	0.22	Back Center **(Figure 3 & 4)**	0.26	0.014	2.40	2.800	**0.63**	0.039
					Back Side	0.26	0.012	2.00	2.600	0.52	0.032

Notes:
Bold Blue – the highest adjusted SAR results for the respective frequency band.

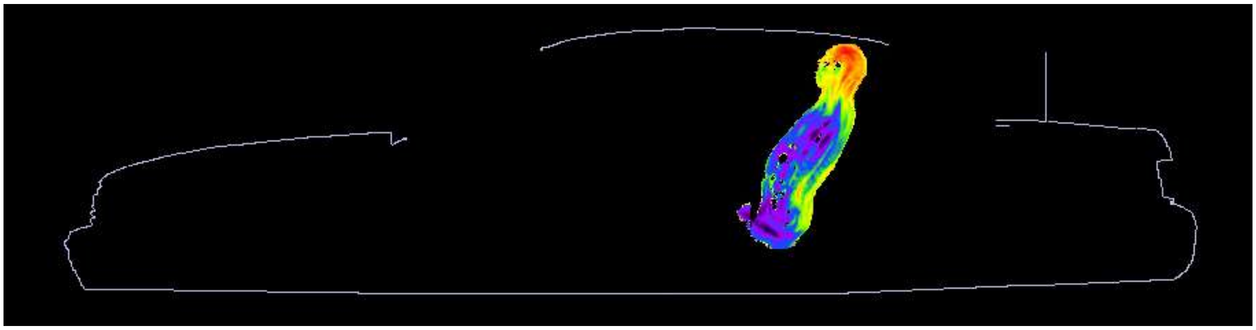
Table 1b: Computed and adjusted SAR results for Passengers exposure

(Configurations exceeding ICNIRP MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computed SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						10 g	WB	10 g	WB	10 g	WB
Trunk	HAE6022A, 1/2 Wave (403-527 MHz)	29.6	453.0125	0.27	Back Center	0.17	0.015	2.39	2.794	0.40	**0.042**
					Back Side	0.18	0.013	2.29	2.594	0.41	0.035
Trunk	HAE6029A, 1/2 Wave (403-527 MHz)	29.8	419.9875	0.26	Back Center	0.13	0.010	2.36	2.760	0.32	0.028
					Back Side **(Figure 5 & 6)**	0.18	0.012	2.51	2.640	**0.46**	0.032
Trunk	PMAE4040A, 1/4 Wave (406-420 MHz)	37.8	419.9875	0.26	Back Center	0.13	0.009	2.36	2.760	0.30	0.026
					Back Side	0.16	0.011	2.51	2.640	0.41	0.030

Notes:
Bold Blue – the highest adjusted SAR results for the respective frequency band.

The SAR distribution in the passenger exposure condition that gave the highest adjusted 1-g SAR (UHF mobile radio) for ISED is reported in Figure 3. (450.0125 MHz, passenger on the center of the back seat, PMAE4042A antenna installed on the trunk).



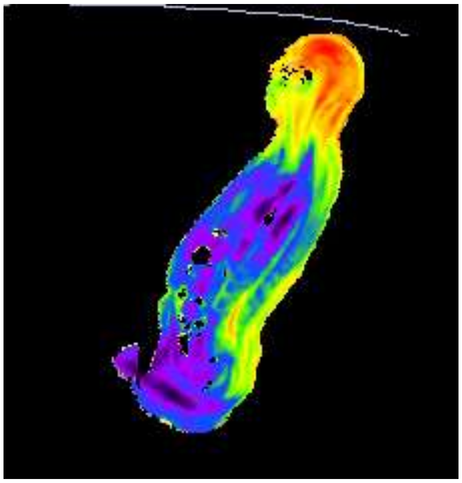
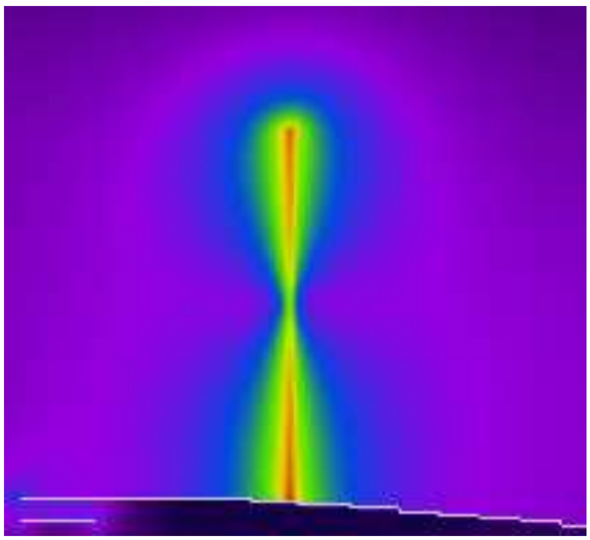
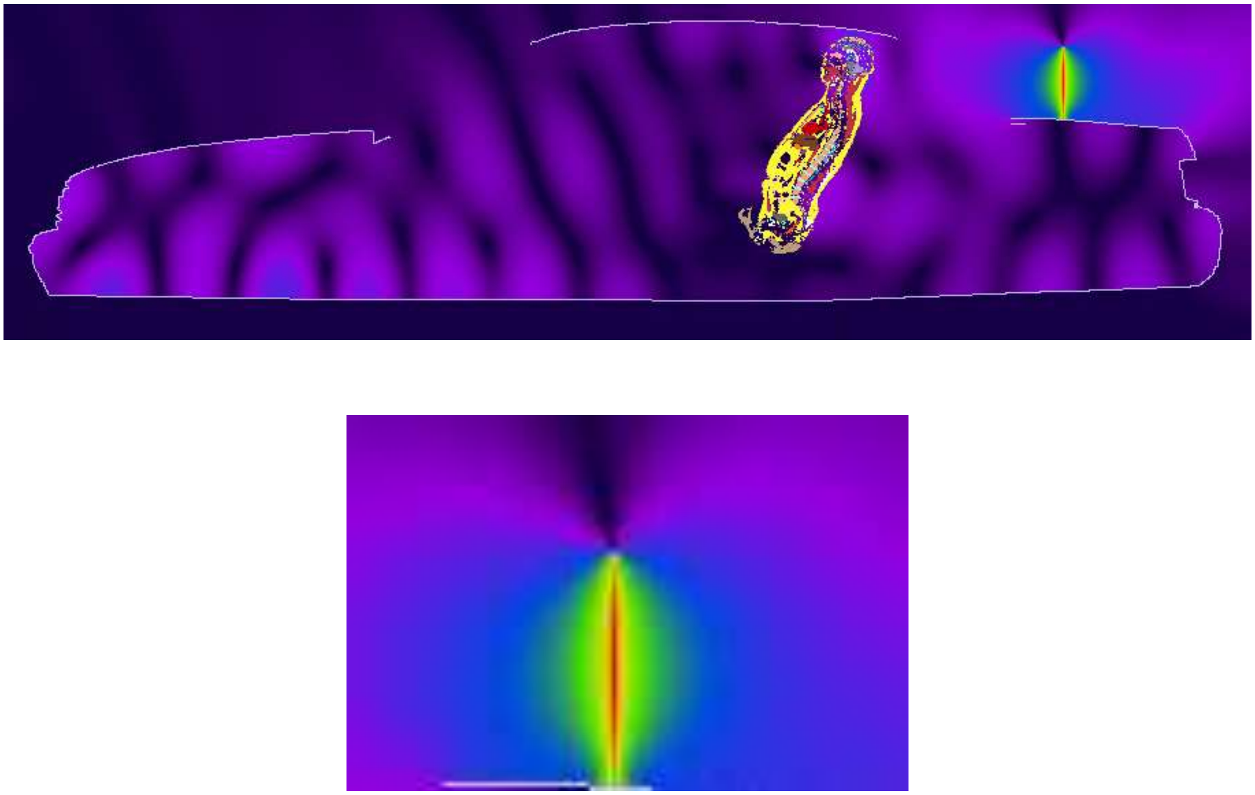


Figure 3. SAR distribution 450.0125 MHz in the passenger model located on the center of the back seat, produced by the trunk-mount PMAE4042A antenna. The SAR distribution plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The plots in Figure 4 illustrate the E and H field distributions in the plane of the antenna corresponding to the exposure condition resulting in the SAR distribution in Figure 3.



a)



b)

Figure 4. (a) E-field magnitude distribution corresponding to exposure condition of Figure 3, and (b) H-field magnitude distribution corresponding to exposure condition of Figure 3.

The SAR distribution in the passenger exposure condition that gave the highest adjusted 1-g SAR (UHF mobile radio) for ICNIRP is reported in Figure 5. (419.9875 MHz, passenger on the side of the back seat, HAE6029A antenna installed on the trunk).

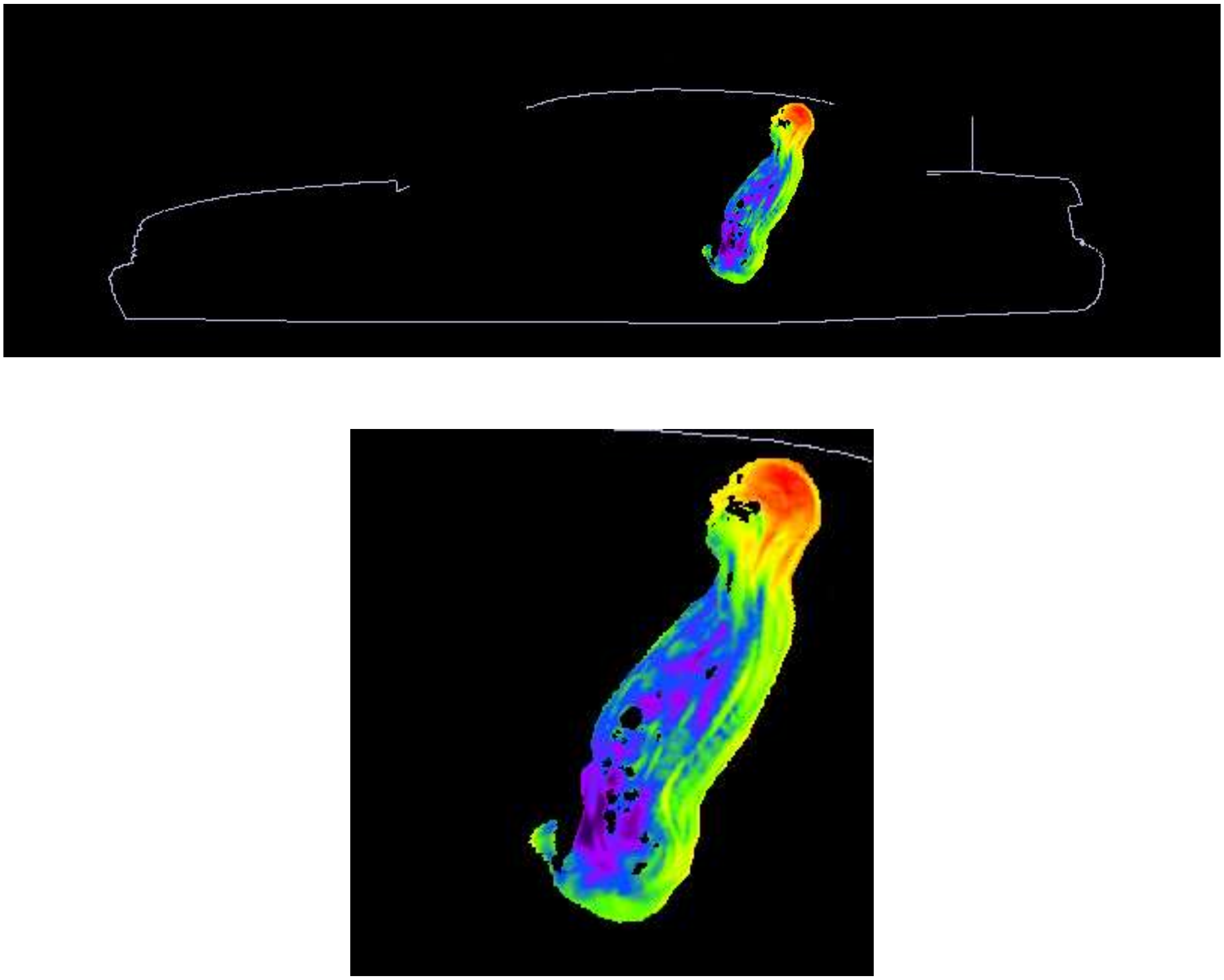
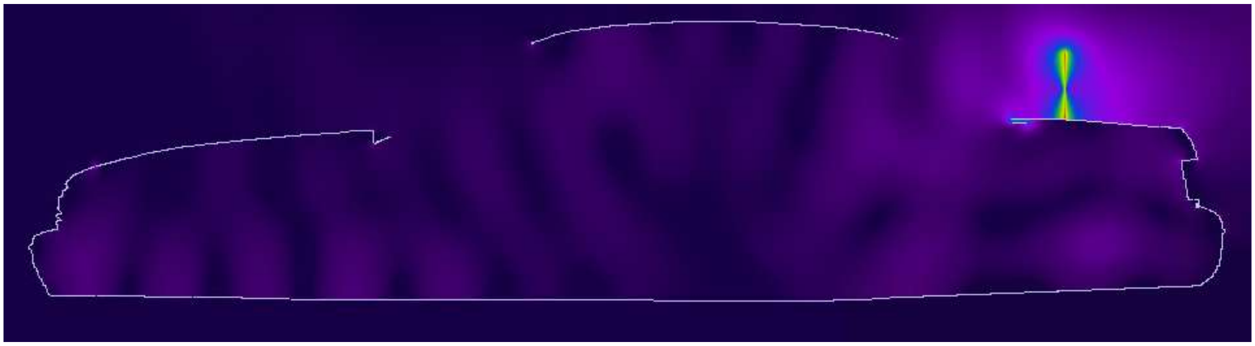
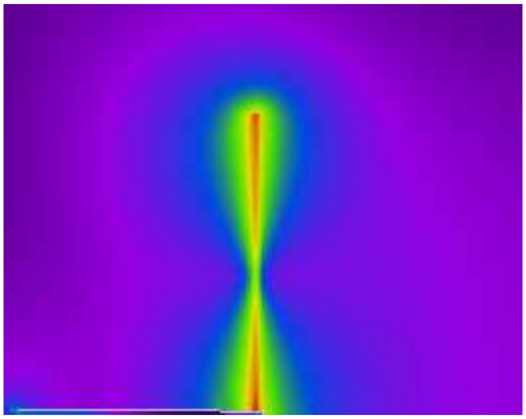


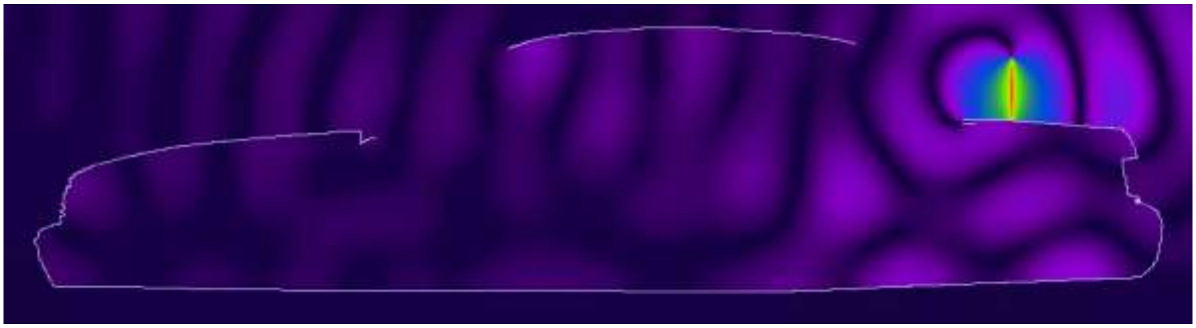
Figure 5. SAR distribution 419.9875 MHz in the passenger model located on the side of the back seat, produced by the trunk-mount HAE6029A antenna. The SAR distribution plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

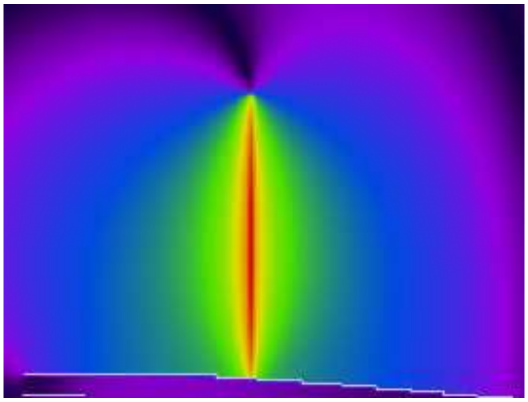
The plots in Figure 6 illustrate the E and H field distributions in the plane of the antenna corresponding to the exposure condition resulting in the SAR distribution in Figure 5.





a)





b)

Figure 6. (a) E-field magnitude distribution corresponding to exposure condition of Figure 5, and (b) H-field magnitude distribution corresponding to exposure condition of Figure 5.

SAR Simulation Reduction Considerations

For a particular antenna that has more than one configuration which exceeds the MPE limit, SAR evaluations shall begin with the highest MPE configuration (mount location and frequency channel). If the SAR value is less than 50% of the SAR limit, no further SAR evaluation is needed for that antenna.

If the highest MPE configuration SAR value is above 50% of the SAR limit, a subsequent SAR simulation shall be performed on the subsequent highest MPE configuration (ranked in descending percentage of the MPE limit). If the subsequent adjusted SAR value is below 75% of the limit, no further SAR evaluation is needed for that antenna, otherwise further SAR simulations for the remaining antenna configurations shall continue until the adjusted SAR value is below 75% of the SAR limit.

Table 3 and Table 4 below list all the configurations that did not conform to applicable MPE limits (ranked in descending percentage of the MPE limit), to which the aforementioned SAR simulation reduction considerations were applied.

Table 3a: SAR Simulation Reduction Considerations for Passenger (ISED Canada)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ISED Limit (mW/cm^2)	% To ISED Spec Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1g	WB	
Trunk	HAE6022A, 1/2 Wave (403-527 MHz)	453.0125	0.27	0.17	158.2	Back Center	0.55	0.042	
						Back Side	0.57	0.035	
		469.9875	0.26	0.18	147.1	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		419..9875	0.21	0.16	129.1	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		406.1250	0.2	0.16	123.0	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
Trunk	HAE6029A, 1/2 Wave (403-527 MHz)	419.9875	0.26	0.16	159.4	Back Center	0.44	0.028	
						Back Side	0.57	0.032	
		469.9875	0.26	0.18	151.0	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		406.1250	0.22	0.16	138.4	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		453.0125	0.21	0.17	124.6	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
Trunk	PMAE4040A, 1/4 Wave (406-420 MHz)	419.9875	0.26	0.16	157.9	Back Center	0.42	0.026	
						Back Side	0.52	0.030	
		406.1250	0.22	0.16	138.3	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		413.0125	0.22	0.16	134.5	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
Trunk	PMAE4042A, 5/8 Wave (450-470 MHz)	450.0125	0.22	0.17	126.9	Back Center	0.63	0.039	
						Back Side	0.52	0.032	
		469.9875	0.21	0.18	120.5	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		460.0125	0.19	0.17	109.8	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			

Table 3b: SAR Simulation Reduction Considerations for Passenger (ICNIRP)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ICNIRP Limit (mW/cm^2)	% To ICNIRP Spec Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							10g	WB	
Trunk	HAE6022A, 1/2 Wave (403-527 MHz)	453.0125	0.27	0.23	119.5	Back Center	0.40	0.042	
						Back Side	0.41	0.035	
		469.9875	0.26	0.23	109.8	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		436.5000	0.24	0.22	108.9	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
Trunk	HAE6029A, 1/2 Wave (403-527 MHz)	419.9875	0.26	0.21	123.3	Back Center	0.32	0.028	
						Back Side	0.46	0.032	
		436.5000	0.26	0.22	119.1	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		469.9875	0.26	0.23	112.8	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		406.1250	0.22	0.20	108.2	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
Trunk	PMAE4040A, 1/4 Wave (406-420 MHz)	419.9875	0.26	0.21	122.2	Back Center	0.30	0.026	
						Back Side	0.41	0.030	
		406.1250	0.22	0.20	108.2	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			
		413.0125	0.22	0.21	104.7	Back Center			The highest MPE configuration has SAR below 50% of the limit
						Back Side			

Results of SAR Computations

From all simulated results, the highest peak 1-g, peak 10-g and whole-body average SAR values were identified. The maximum peak 1-g SAR is 0.63 W/kg, less than the 1.6 W/kg limit, the maximum peak 10-g SAR is 0.46 W/kg, less than the 2.0 W/kg limit, and the maximum whole-body average SAR for is 0.042 W/kg, less than the 0.08 W/kg limit.

Conclusions

Under the test conditions described for evaluating passenger exposure to the RF electromagnetic fields emitted by vehicle-mounted antennas used in conjunction with this product, the present analysis shows that the computed SAR values are compliant with the ISED Canada exposure limits for the general public as well as with the corresponding ICNIRP and IEEE Std. C95.1-2019 SAR limits.

References

[1] Health Canada Safety Code 6 (2015). Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz.

[2] United States Federal Communication Commission, “Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields,” OET Bulletin 65 (Ed. 97-01), August 1997.

[3] http://www.nlm.nih.gov/research/visible/visible_human.html

[4] ICNIRP (International Commission on Non-Ionising Radiation Protection) 1998. *Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)*. Health Phys. 74:494–522.

[5] IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz. IEEE Std C95.1-2019 (Revision of IEEE Std C95.1-2005/ Incorporates IEEE Std C95.1-2019/Cor 1-2019) .