COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE APX SERIES MODEL M25SSS9PW1BN (PMUE5756A) MOBILE RADIO.

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Introduction

This report summarizes the computational [numerical modeling] analysis performed to document compliance of the APX Series Model Number M25SSS9PW1BN (PMUE5756A) Mobile Radio and vehicle-mounted antennas with the US Federal Communications Commission (FCC), 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)
FCC US	LMR UHF R2	450 -512
ISED Canada	LMR UHF R2	450 -470
Overall (Other regions)	LMR UHF R2	450 - 520

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 2 test conditions that did not conform with FCC MPE limit and 6 test conditions 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 FCC guidelines [2] and Health Canada guidelines [1]. A total of 8 test conditions did not conform with ICNIRP

[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.

guideline MPE limit were considered to determine whether those 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 3 configurations (requiring a total of 6 numerical simulations) have been performed, all of them addressing the exposure of the bystander and back seat passenger to the UHF R2 mobile radio featuring trunk-mount and roof-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 related IEC/IEEE 62704-2:2017 standard numerical uncertainty budget for exposure simulations with vehicle mounted wire antennas operating in UHF band is summarized in the table on page 25 of Appendix B. The XFDTD code validation performed by Remcom Inc. according to the IEEE/IEC 62704-2:2017 standard requirements is also 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

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

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.

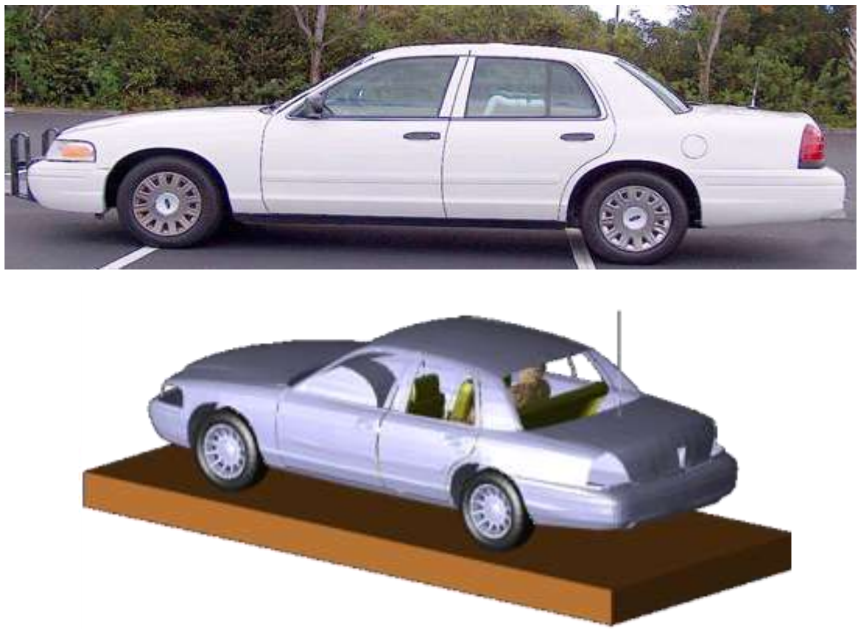


Figure 1: Picture of the vehicle and corresponding CAD model used in XFDTD™ simulations

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 shows some of the XFDTD™ computational models used for passenger exposure to trunk mounted antennas.

For bystander exposure, the antenna position is in the center of the trunk, as to replicate the experimental conditions used in MPE measurements. Figure 3 shows some for the XFDTD™ computational models used for bystander exposure configurations.

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.

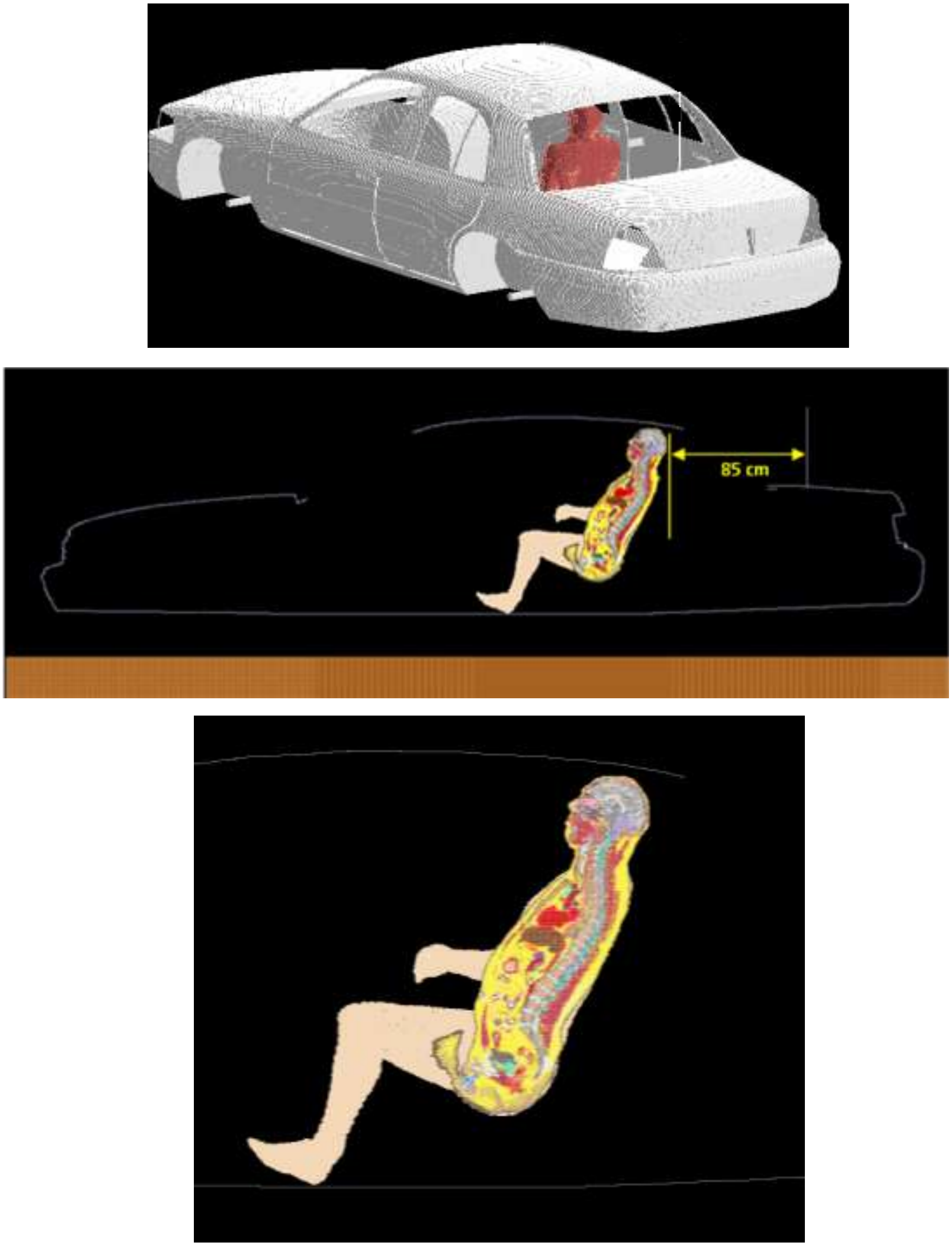


Figure 2: Passenger (back seat) model exposed to a trunk-mount antenna: XFDTD geometry. The antenna is mounted at 85 cm from the passenger located in the center of the back seat.

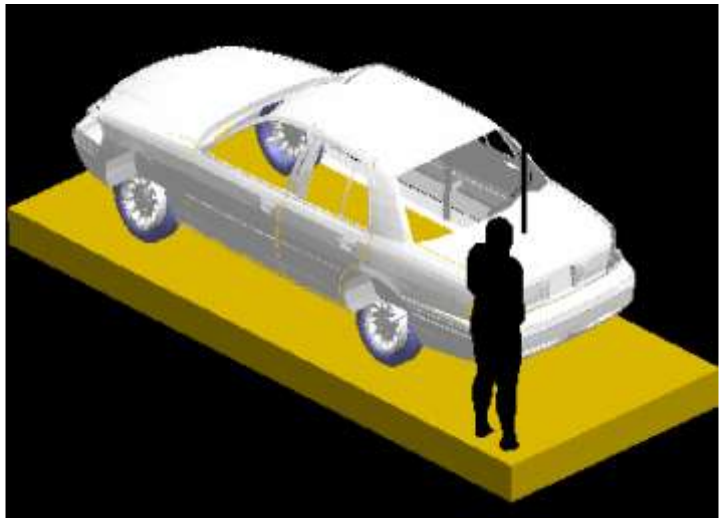


Figure 3: Bystander model exposed to a trunk-mount antenna: XFDTD geometry. Bystander is located at the back corner of the car replicating the measurement conditions.

The maximum average output power from mobile radio antenna is 54W (450-485 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 R2 mobile radio were employed, all computational results are normalized to half of the UHF R2 mobile radio maximum average net output power, i.e., 27W (450-485 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 and bystanders

The test conditions requiring SAR computations are summarized in Table 1 (Passengers) and Table 2 (Bystanders), 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 in the center of the trunk and roof. 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. The bystander is located at the measurement distance from the transmit antenna as described in the MPE report and assessed for front and rear exposure.

All the transmit frequency, antenna length, and passenger/bystander location reported in Table 1 and Table 2 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 back seat passenger exposure

(Configurations exceeding FCC MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Trunk	HAE6031A, 380-520MHz	29.8	450.0125	0.33	Back Center **(Figure 4 & 5)**	0.31	0.016	2.40	2.80	**0.73**	**0.044**
					Back Side	0.29	0.014	2.00	2.60	0.58	0.036

Note:
Bold Blue – the highest SAR results computed for the respective frequency bands

Table 1b: Computed and adjusted SAR results for back seat passenger exposure

(Configurations exceeding ISED MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^ 2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Trunk	HAE6031A, 380-520MHz	29.8	#450.0125	0.33	Back Center **(Figure 4 & 5)**	0.31	0.016	2.40	2.80	**0.73**	**0.044**
					Back Side	0.29	0.014	2.00	2.60	0.58	0.036
Trunk	HAE6013A, 380-470MHz	30.8	450.0125	0.27	Back Center	0.30	0.016	2.40	2.80	0.73	0.044
					Back Side	0.29	0.014	2.00	2.60	0.58	0.036

Note:
Bold Blue – the highest SAR results computed for the respective frequency bands
- Same SAR simulation configuration as Table 1a

Table 1c: Computed and adjusted SAR results for back seat passenger exposure

(Configurations exceeding ICNIRP MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						10g	WB	10g	WB	10g	WB
Trunk	HAE6031A, 380-520MHz	29.8	450.0125	0.33	Back Center **(Figure 4 & 5)**	0.21	0.016	2.40	2.80	**0.50**	**0.044**
					Back Side	0.18	0.014	2.30	2.60	0.40	0.036
Trunk	HAE6013A, 380-470MHz	30.8	450.0125	0.27	Back Center	0.21	0.016	2.40	2.74	0.50	0.036
					Back Side	0.18	0.014	2.30	2.66	0.40	0.031

Note:
Bold Blue – the highest SAR results computed for the respective frequency bands

Table 2a: Computed and adjusted SAR results for Bystander exposure

(Configurations exceeding ISED MPE limits)

Mount Location	Antenna Kit#	Antenna Length (cm)	Freq (MHz)	P.D. (mW/cm^2)	Exposure Location	Computations SAR (W/kg)		Interpolated Adjustment Factors		Adjusted SAR Results (W/kg)	
						1 g	WB	1 g	WB	1 g	WB
Trunk	HAE6031A, 380-520MHz	29.8	469.9875	0.18	45 Deg. Front **(Figure 6 & 7)**	0.23	0.007	1.49	1.33	**0.34**	**0.010**
					45 Deg. Rear	0.17	0.007	1.49	1.33	0.25	0.010

Note:
Bold Blue – the highest SAR results computed for the respective frequency bands

The SAR distribution in the passenger exposure condition that gave highest adjusted 1-g SAR (UHF R2 mobile radio) for FCC. ISED and ICNIRP is reported in Figure 4. (450.0125 MHz, passenger in the center of the back seat, HAE6031A antenna installed on the trunk).

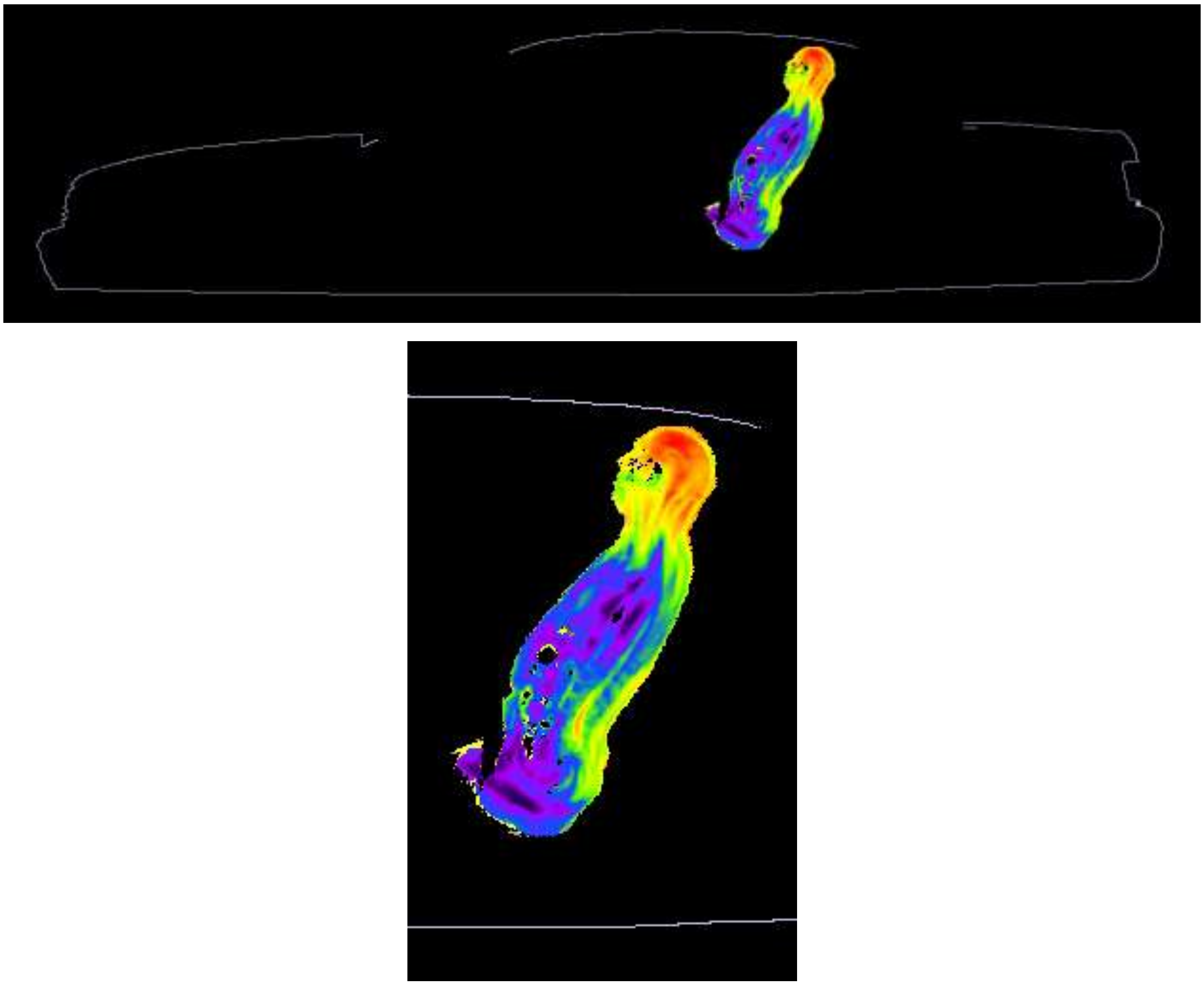
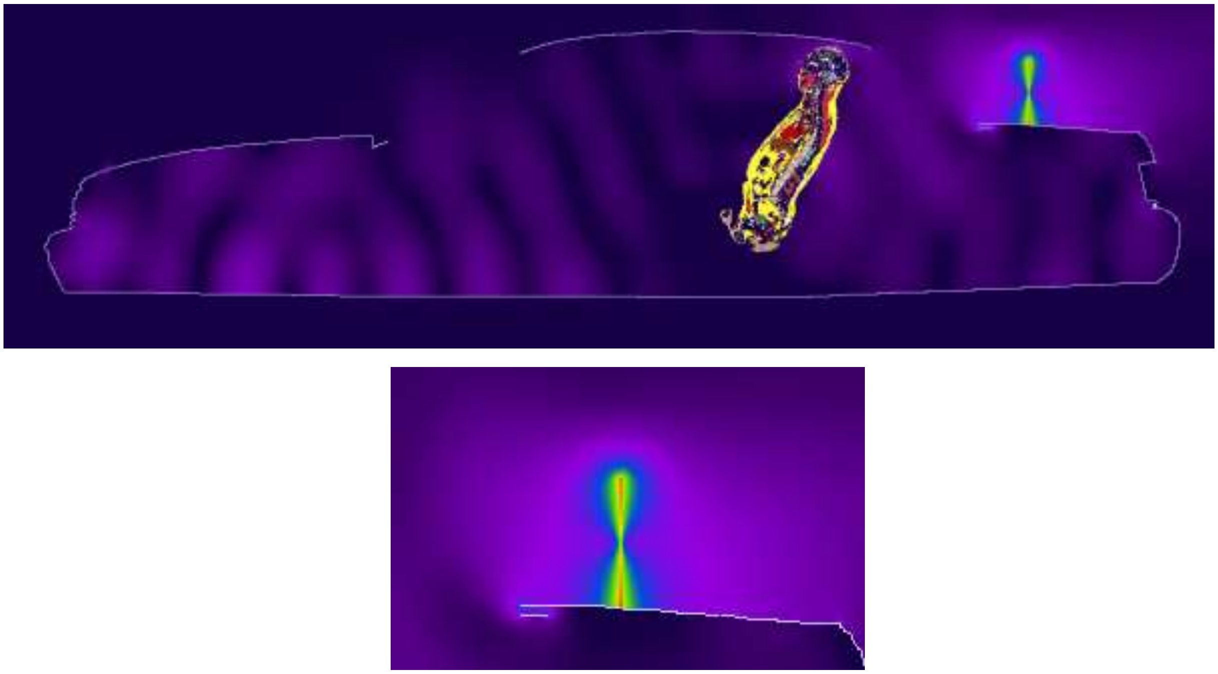
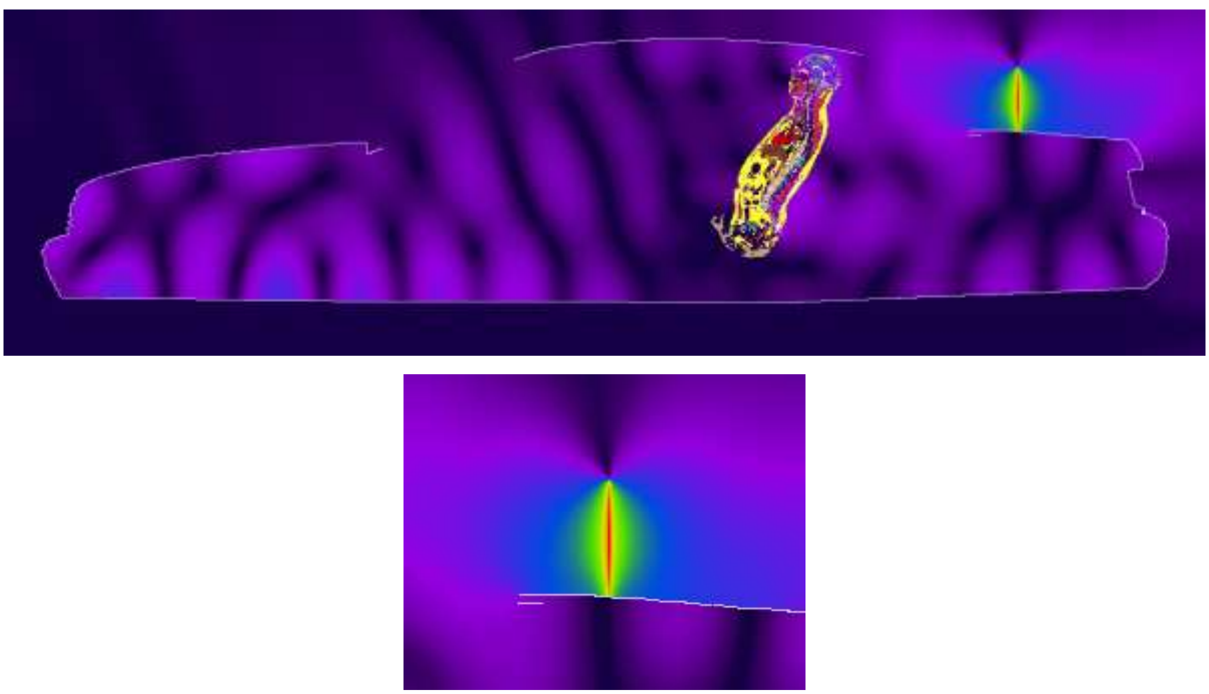


Figure 4. SAR distribution at 450.0125 MHz in the passenger model located in the center of the back seat, produced by the trunk-mount HAE6031A antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The pictures below show the E and H field distributions in the plane of the antenna corresponding to the condition in Figure 4.



a)

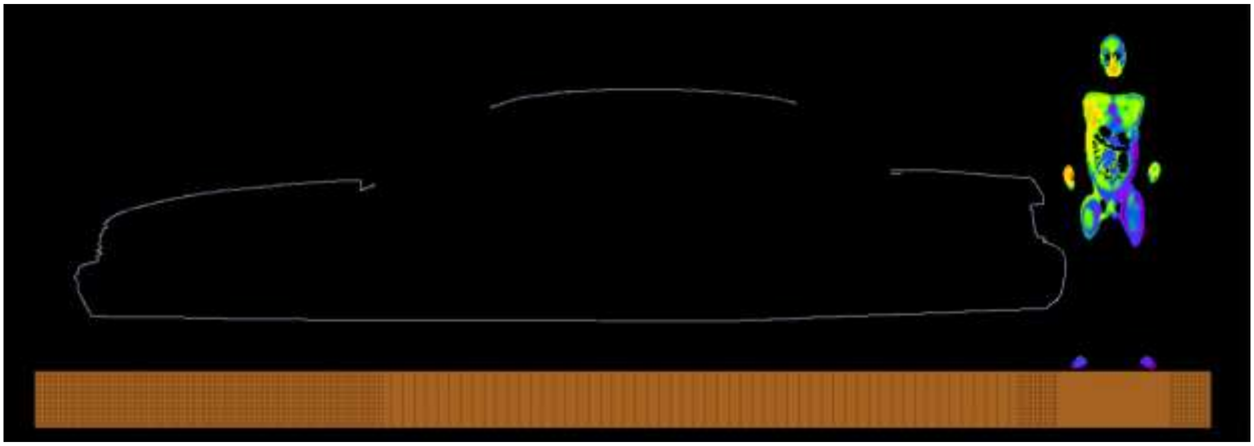


b)

Figure 5. (a) E-field magnitude distribution corresponding to exposure condition of Figure 4, and (b) H-field magnitude distribution corresponding to exposure condition of Figure 4.

The highest adjusted 1-g SAR was produced in the passenger exposure condition with HAE6031A antenna at 450.0125 MHz (passenger in the center of the back seat).

The SAR distribution in the bystander exposure condition that gave highest adjusted 1-g SAR is reported in Figure 6. (469.9875 MHz, bystander front at the 45 degree angle of the vehicle trunk, HAE6031A antenna installed on the trunk).



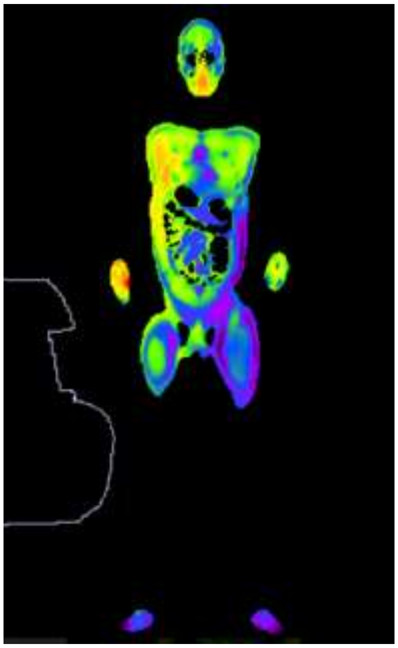
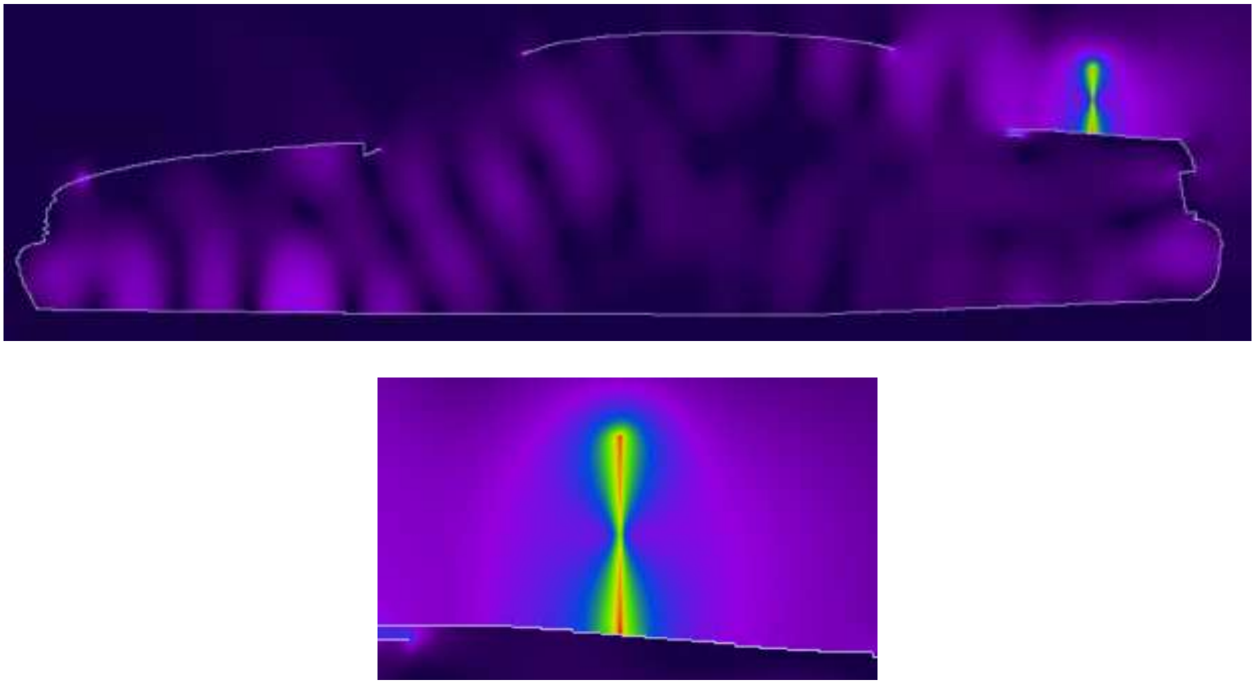
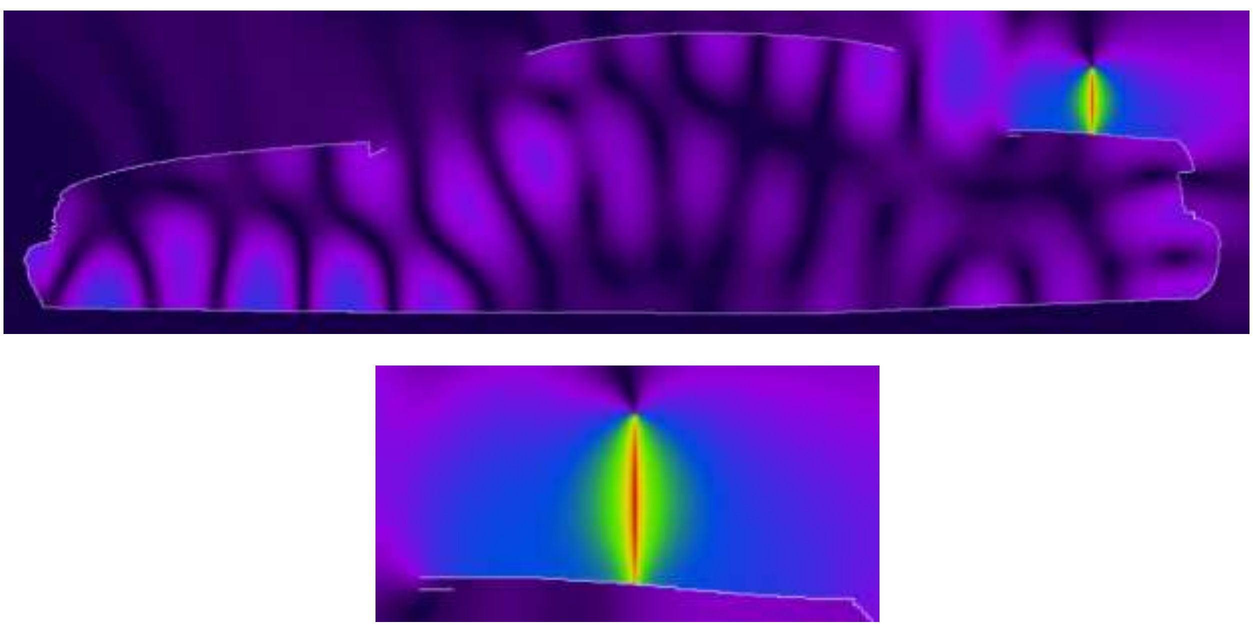


Figure 6. SAR distribution at 469.9875 MHz in bystander model located at the 45 degree angle of the vehicle trunk, produced by the trunk-mount HAE6031A antenna. The SAR distribution plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The plots in Figure 7 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 6.



a)



b)

Figure 7. (a) E-field magnitude distribution corresponding to exposure condition of Figure 6, and (b) H-field magnitude distribution corresponding to exposure condition of Figure 6.

SAR Simulation Reduction Considerations

Per Response to Inquiry to FCC (Tracking Number 528198), for a particular antenna that has more than one configuration which exceeds the MPE limit, SAR simulation shall begin with the worst case configuration (mount location and frequency channel). If the SAR value is less than 50% of the limit, no further SAR evaluation is needed for that antenna.

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

Table 3 and Table 4 below list all the configurations that did not conform to applicable MPE limits (ranked in descending MPE percentage to limit) and apply SAR simulation reduction consideration as mentioned above.

Table 3a: SAR Simulation Reduction Considerations for Passenger (back seat) (FCC US)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ISED Limit (mW/cm^2)	% To ISED Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Trunk	HAE6031A, 380-520MHz	450.0125	0.33	0.30	110.7	Back Center	0.73	0.044	
						Back Side	0.58	0.036	
		482.5000	0.34	0.32	104.4				The highest MPE configuration has SAR below 50% of the limit.

Table 3b: SAR Simulation Reduction Considerations for Passenger (back seat) (ISED Canada)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ICNIRP Limit (mW/cm^2)	% To ICNIRP Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Trunk	HAE6031A, 380-520MHz	450.0125	0.33	0.17	194.9	Back Center	0.73	0.044	
						Back Side	0.58	0.036	
		469.9875	0.31	0.18	176.9				The highest MPE configuration has SAR below 50% of the limit.
Trunk	HAE6013A, 380-470MHz	450.0125	0.27	0.17	159.6	Back Center	0.73	0.044	
						Back Side	0.58	0.036	
		469.9875	0.27	0.18	156.2				The highest MPE configuration has SAR below 50% of the limit.
		460.0000	0.24	0.17	141.3				

Table 3c: SAR Simulation Reduction Considerations for Passenger (back seat) (ICNIRP)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ISED Limit (mW/cm^2)	% To ISED Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							10 g	WB	
Trunk	HAE6031A, 380-520MHz	450.0125	0.33	0.23	147.6	Back Center	0.50	0.044	
						Back Side	0.40	0.036	
		482.5000	0.34	0.24	139.2				The highest MPE configuration has SAR below 50% of the limit.
		469.9875	0.31	0.23	132.1				
		496.5000	0.31	0.25	124.0				
		511.9875	0.29	0.26	113.3				
Trunk	HAE6013A, 380-470MHz	450.0125	0.27	0.23	120.8	Back Center	0.50	0.044	
						Back Side	0.40	0.036	
		469.9875	0.27	0.23	116.6				The highest MPE configuration has SAR below 50% of the limit.
		460.0000	0.24	0.23	106.2				

Table 4a: SAR Simulation Reduction Considerations for Bystander
(ISED Canada)

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	ISED Limit (mW/cm^2)	% To ISED Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Trunk	HAE6031A, 380-520MHz	469.9875	0.18	0.30	110.7	Back Center	0.34	0.010	
						Back Side	0.25	0.010	

Results of SAR Computations

From all simulated results the worst case peak SAR values were identified. The overall adjusted maximum peak 1-g SAR is 0.73 W/kg, less than the 1.6 W/kg limit, while the overall adjusted maximum peak 10-g SAR is 0.50 W/kg, less than the 2.0 W/kg limit. The adjusted maximum whole-body average SAR for is 0.044 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 FCC and 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) .