MOTOROLA SOLUTIONS

COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE DIGITAL VEHICULAR REPEATER (DVR 700), MOBEXCOM DVRS 700 (DQPMDVR7000P) AND COMPANION APX SERIES MODEL M37TSS9PW1AN MOBILE RADIO.

December 11, 2017

Saw Sun Hock, Giorgi Bit-Babik, Ph.D., and Antonio Faraone, Ph.D.
Motorola Solutions EME Research Lab, Plantation, Florida

Introduction

This report summarizes the computational [numerical modeling] analysis performed to document compliance of the DVR 700, model # MOBEXCOM DVRS 700 (DQPMDVR7000P) with FCC ID # LO6-DVRS700 and IC # 2098-DVRS700 interfaced with, and transmitting simultaneously with companion mobile radio, model #M37TSS9PW1AN and vehicle-mounted antennas with the US Federal Communications Commission (FCC) and the Innovation, Science and Economic Development (ISED) Canada guidelines for human exposure to radio frequency (RF) emissions. The devices operate in the following frequency bands:

Regions	Device	Bands	Frequency Band (MHz)
FCC US	DVR 700	700 MHz	769-775; 799-806
	Companion Mobile	LMR VHF	150.8 – 173.4
		LMR UHF1	406.1 – 470
		LMR UHF2	450 -512
		LMR 7/800	769-775; 799-824; 851-869
ISED Canada	DVR 700	700 MHz	769-775; 799-806
	Companion Mobile	LMR VHF	138 - 174
		LMR UHF1	406.1 – 430; 450 -470
		LMR UHF2	450 -470
		LMR 7/800	769-775; 799-824; 851-869

This computational analysis supplements the measurements conducted to evaluate the compliance of the exposure from this DRV and companion mobile radio with respect to

applicable *maximum permissible exposure* (MPE) limits. All test conditions (19 in total) that did not conform with applicable MPE limits were analyzed 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, which are based on the IEEE C95.1-1999 standard [1]. The same test conditions were also analyzed to determine compliance with the SAR limits set forth in the ICNIRP [3] guidelines and IEEE Std. C95.1-2005 standard [4] (2.0 W/kg averaged over 10 gram of tissue and 0.08 W/kg averaged over the whole body). In total 36 independent simulations had been performed addressing exposure of back seat passenger to the DVR 700 repeater with trunk-mounted antennas and Companion mobile radio (VHF, UHF R1, UHF R2 and 7/800) with roof-mount antennas.

For all simulations a commercial code based on 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 is the primary dosimetric quantity used to evaluate the human body's absorption of RF energy and that MPE limits are in fact derived from SAR. Accordingly, the SAR computations provide a scientifically valid and more relevant estimate of human exposure to RF energy.

Method

The simulation code employed is XFDTD™ v7.6.0, by Remcom Inc., State College, PA. This computational suite provides means to simulate the heterogeneous full human body model defined according to the IEC/IEEE 62704-2-2017 standard and derived from the so-called Visible Human [2], discretized in 3 mm voxels. The IEC/IEEE 62704-2-2017 standard dielectric properties of 39 body tissues are automatically assigned by XFDTD™ at any specific frequency. The "seated" man model 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 according to IEEE/IEC 62704-1 draft standard by Remcom Inc., is provided in conjunction with this report.

The car model has been imported into XFDTD™ from the CAD file of a sedan car 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 8mm. The Figure 1 below show both the CAD model and the photo of the actual car This CAD model has been incorporated into the IEC/IEEE 62704-2-2017 standard.

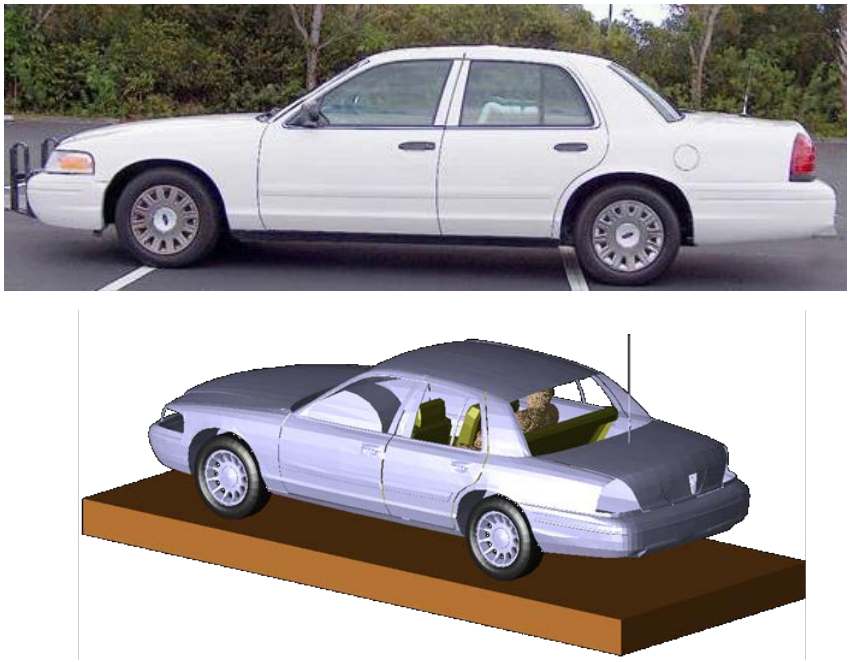
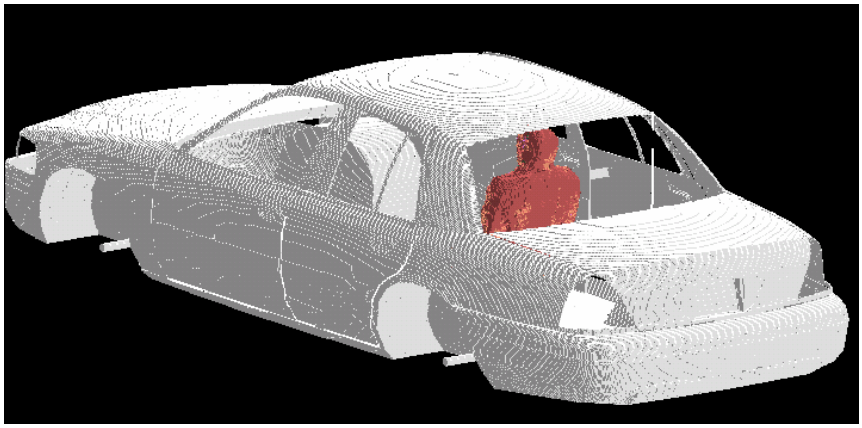


Figure 1: The photo picture of the car used in field measurements and the corresponding CAD model used in simulations

For passenger exposure, the antenna position is on the trunk and the distance of trunk mounted antenna from the passenger head when the passenger is located in the center of the back seat was set at 85 cm, to replicate the experimental conditions used in MPE measurements. Figure 2 shows some of the XFDTD™ computational models used for passenger exposure to trunk mounted antennas

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



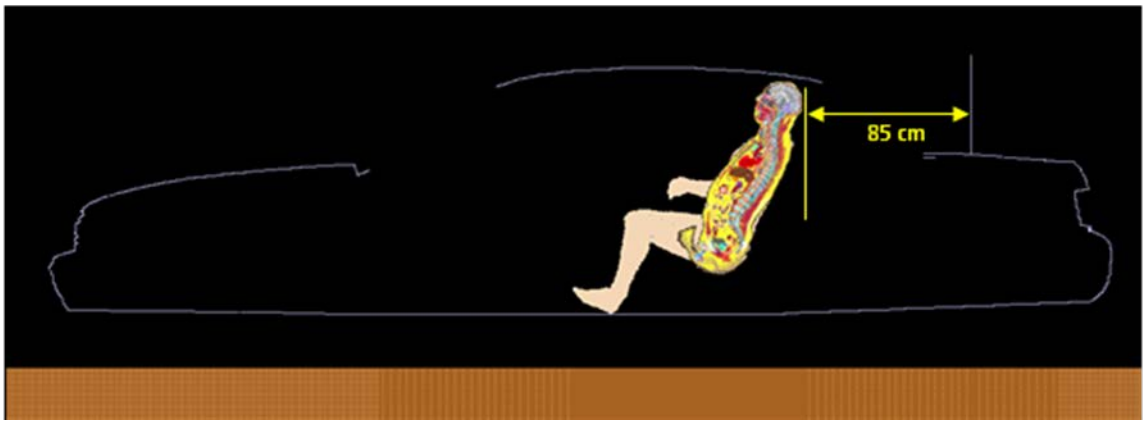

85 cm

Figure 2: Passenger 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.

The computational code employs a time-harmonic excitation to produce a steady state electromagnetic field in the exposed body. Subsequently, the corresponding SAR distribution is automatically processed in order to determine the whole-body, 1-g, and 10-g average SAR. The maximum average output power from DVR 700 repeater is 5W (764-806 MHz) and companion mobile radio antenna is 60W (136-174MHz). Since the ohmic losses in the car materials, as well as the mismatch losses at the antenna feed-point are neglected, and source-based time averaging (100% talk time) for DVR 700 repeater and (50% talk time) for companion mobile radio were employed, all computational results are normalized full to DVR 700 repeater 5W (764-806 MHz) and companion mobile radio is half of it, i.e., 30W (136-174MHz) average net output power; less the corresponding minimum insertion loss in excess of 0.5 dB of the feed cables supplied with the antennas. This power normalization is in accordance with the IEC/IEEE 62704-2 standard (2017).

Results of SAR computations for car passengers

The test conditions requiring SAR computations are summarized in Table 1 (DVR 700, 100% talk time) and Table 2 (Companion mobile, 50% talk time), together with the antenna data, the SAR results, and power density (P.D.) as obtained from the measurements in the corresponding test conditions. The conditions are for antennas mounted on the trunk (DVR 700) and side roof, offset 20cm from center of the roof (Companion mobile). The antenna length in Table 1&2 includes the 1.8 cm magnetic mount base used in measurements to position the antenna on the vehicle. The same length was used in 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 combinations reported in Table 1 & 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 (configurations exceed FCC MPE limits):
Results of the Computations and Adjusted SAR for passenger exposure of DVR 700 repeater (100% talk-time)

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	10 g	WB	1 g	10 g	WB	1 g	10 g	WB
Trunk	HAF4016A, 1/4 Wave (764-870MHz)	10.8	775.0000	0.04	Back Center	0.05	0.04	0.002	1.10	1.10	2.24	0.06	0.05	0.004
					Back Side	0.05	0.03	0.002	1.44	1.28	1.95	0.07	0.03	0.003

Table 1b (configurations exceed ISED MPE limits):
Results of the Computations and Adjusted SAR for passenger exposure of DVR 700 repeater (100% talk-time)

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	10 g	WB	1 g	10 g	WB	1 g	10 g	WB
Trunk	HAF4016A, 1/4 Wave (764-870MHz)	10.8	770.0000	0.04	Back Center	0.06	0.05	0.002	1.12	1.12	2.25	0.07	0.05	0.004
					Back Side	0.04	0.03	0.001	1.45	1.29	1.96	0.06	0.03	0.003
			#775.0000	0.04	Back Center	0.05	0.04	0.002	1.10	1.10	2.24	0.06	0.05	0.004
					Back Side	0.05	0.03	0.002	1.44	1.28	1.95	0.07	0.03	0.003
			800.0000	0.02	Back Center **Fig 3 & 4**	0.09	0.06	0.002	1.00	1.00	2.20	0.09	0.06	0.004
					Back Side	0.05	0.02	0.002	1.40	1.20	1.90	0.07	0.03	0.003
			806.0000	0.02	Back Center	0.07	0.06	0.002	1.01	1.00	2.19	0.07	0.06	0.004
					Back Side	0.04	0.02	0.002	1.39	1.19	1.89	0.06	0.03	0.003

Note: # Same SAR simulation configuration as FCC US.

Table 2a (configurations exceed FCC MPE limits):

Results of the Computations and Adjusted SAR for passenger exposure of Companion mobile radio (50% talk-time)

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	10 g	WB	1 g	10 g	WB	1 g	10 g	WB
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	50.8	150.8000	0.18	Back Center	0.12	0.11	0.003	1.21	1.01	2.01	0.15	0.11	0.006
					Back Side	0.27	0.23	0.004	1.00	1.00	1.50	0.27	0.23	0.006

Table 2b (configurations exceed ISED MPE limits):

Results of the Computations and Adjusted SAR for passenger exposure of Companion mobile radio (50% talk-time)

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	10 g	WB	1 g	10 g	WB	1 g	10 g	WB
Roof	HAD4016A, 1/4 Wave (136-162MHz)	53.1	144.0000	0.11	Back Center	0.16	0.14	0.006	1.18	1.00	1.91	0.19	0.14	0.011
					Back Side	0.27	0.23	0.006	1.00	1.00	1.49	0.27	0.23	0.008
			150.8000	0.12	Back Center	0.12	0.11	0.003	1.21	1.01	2.01	0.15	0.11	0.006
					Back Side	0.27	0.23	0.004	1.00	1.00	1.50	0.27	0.23	0.006
			156.4000	0.13	Back Center	0.12	0.10	0.003	1.26	1.06	2.06	0.15	0.11	0.005
					Back Side	0.17	0.14	0.002	1.02	1.03	1.53	0.17	0.14	0.004
Roof	HAD4017A, 1/4 Wave (146-174MHz)	48.0	158.0125	0.12	Back Center	0.08	0.07	0.002	1.27	1.07	2.07	0.11	0.08	0.005
					Back Side	0.14	0.12	0.002	1.02	1.03	1.53	0.15	0.12	0.003
Roof	HAD4021A, 1/4 Wave (136-174MHz)	53.5	144.0000	0.14	Back Center	0.16	0.13	0.006	1.18	1.00	1.91	0.19	0.13	0.011
					Back Side	0.27	0.23	0.006	1.00	1.00	1.49	0.27	0.23	0.008
			158.0125	0.14	Back Center	0.08	0.07	0.002	1.27	1.07	2.07	0.11	0.08	0.005
					Back Side	0.14	0.12	0.002	1.02	1.03	1.53	0.14	0.12	0.003
Roof	HAD4006A, 1/4 Wave (136-144MHz)	53.8	140.0000	0.19	Back Center **Fig 5 & 6**	0.26	0.19	0.006	1.17	1.00	1.86	0.30	0.19	0.010
					Back Side	0.27	0.18	0.007	1.00	1.00	1.49	0.27	0.18	0.011
			144.0000	0.15	Back Center	0.16	0.13	0.006	1.18	1.0	1.91	0.19	0.13	0.011
					Back Side	0.27	0.23	0.006	1.00	1.00	1.49	0.27	0.23	0.009
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	50.8	144.0000	0.15	Back Center	0.16	0.13	0.006	1.18	1.00	1.91	0.19	0.13	0.011
					Back Side	0.27	0.23	0.006	1.00	1.00	1.49	0.27	0.23	0.008
			#150.8000	0.18	Back Center	0.12	0.11	0.003	1.21	1.01	2.01	0.15	0.11	0.006
					Back Side	0.27	0.23	0.004	1.00	1.00	1.50	0.27	0.23	0.006

Note: # Same SAR simulation configuration as FCC US.

Table 2b continued (configurations exceed ISED MPE limits):
Results of the Computations and Adjusted SAR for passenger exposure of Companion mobile radio (50% talk-time)

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	10 g	WB	1 g	10 g	WB	1 g	10 g	WB
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	47.3	150.8000	0.17	Back Center	0.12	0.11	0.003	1.21	1.01	2.01	0.15	0.11	0.006
					Back Side	0.27	0.23	0.004	1.00	1.00	1.50	0.27	0.23	0.006
			156.4000	0.17	Back Center	0.12	0.10	0.003	1.26	1.06	2.06	0.15	0.11	0.005
					Back Side	0.17	0.14	0.002	1.02	1.03	1.53	0.18	0.14	0.004
			162.0000	0.18	Back Center	0.03	0.02	0.001	1.31	1.11	2.11	0.04	0.02	0.003
					Back Side	0.11	0.09	0.002	1.03	1.05	1.55	0.11	0.10	0.003
Roof	HAD4009A, 1/4 Wave (162-174MHz)	44.85	162.0000	0.16	Back Center	0.08	0.07	0.002	1.31	1.11	2.11	0.11	0.08	0.005
					Back Side	0.14	0.12	0.002	1.03	1.05	1.55	0.15	0.12	0.003
			165.0125	0.14	Back Center	0.16	0.13	0.006	1.34	1.14	2.14	0.21	0.15	0.012
					Back Side	0.27	0.23	0.006	1.04	1.07	1.56	0.28	0.25	0.009

The SAR distribution in the exposure condition that gave highest adjusted 1-g SAR for DVR 700 is reported in Figure 3 (800.0000 MHz, passenger on the center of the back seat, HAF4016A antenna).

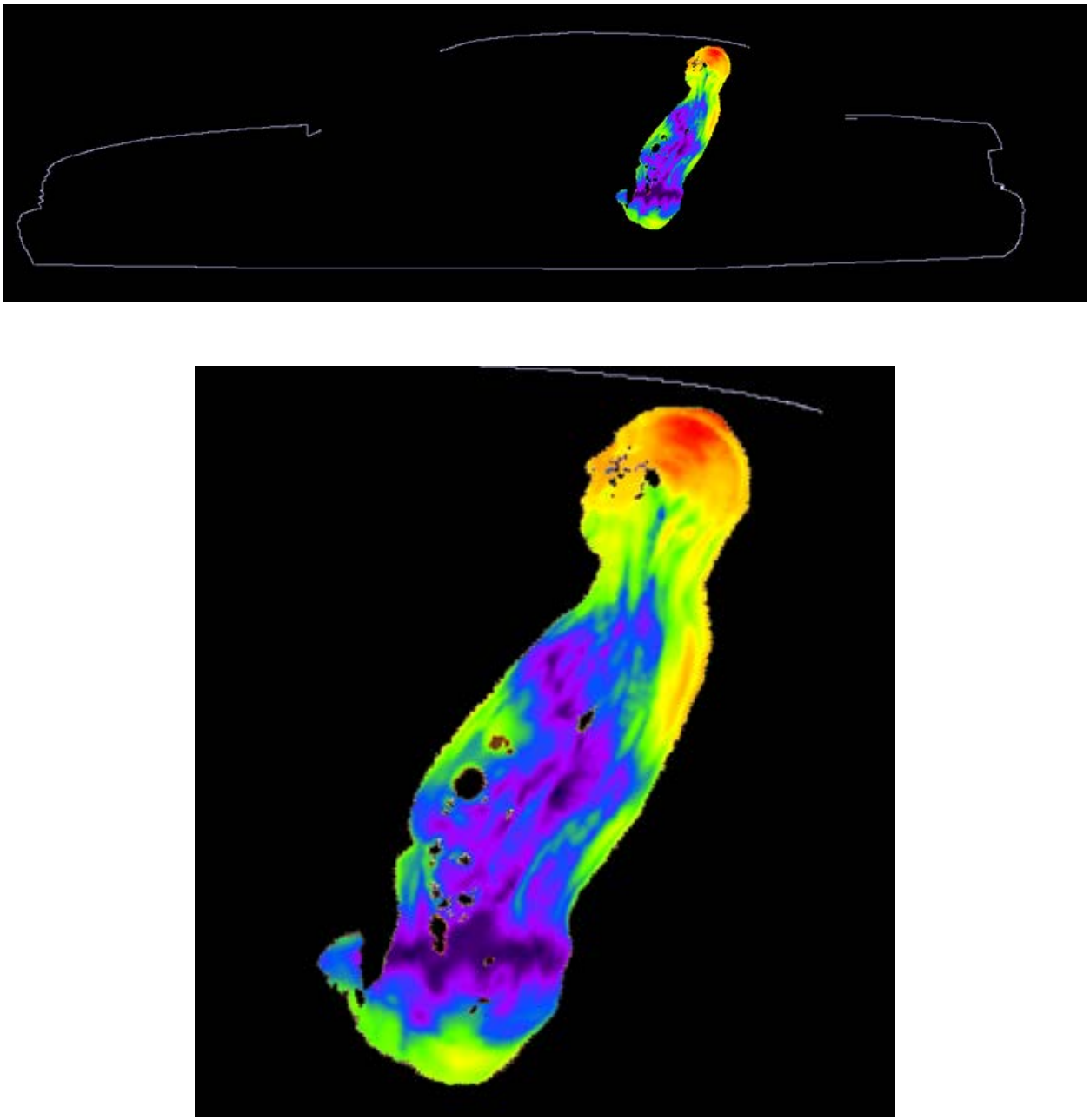
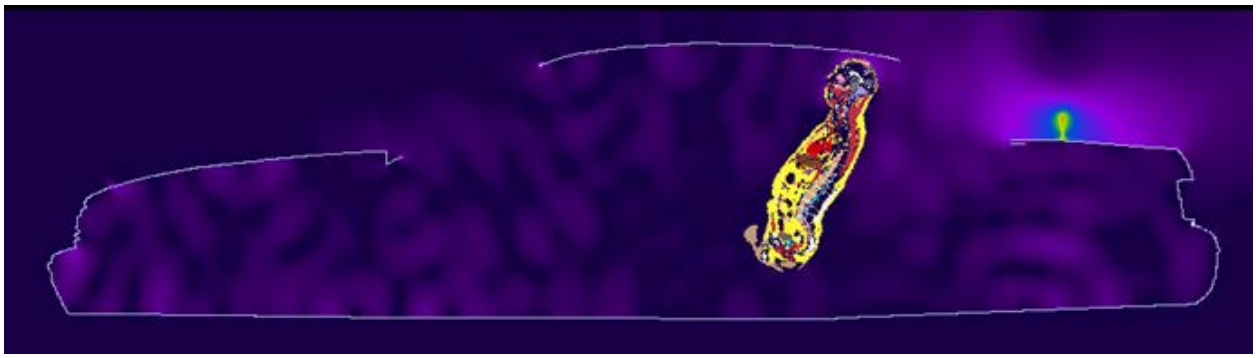
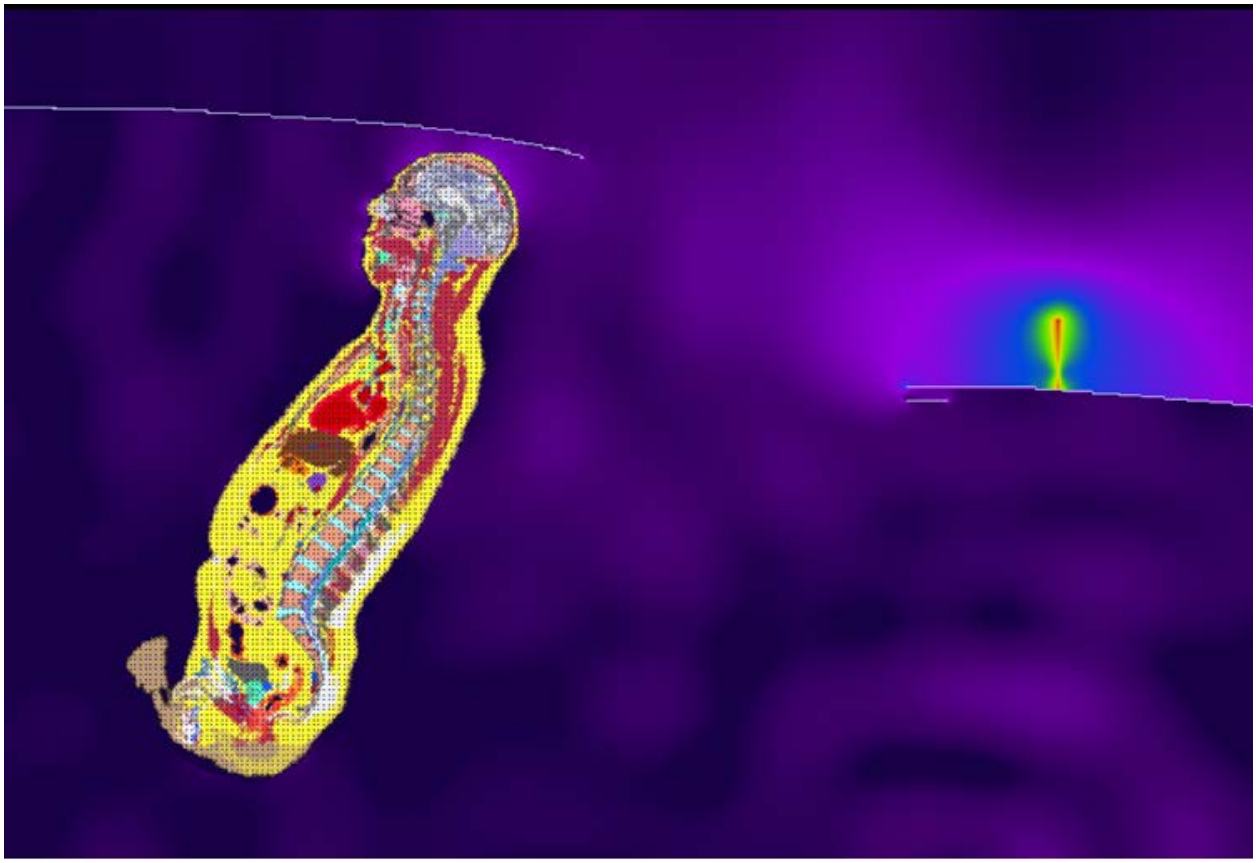


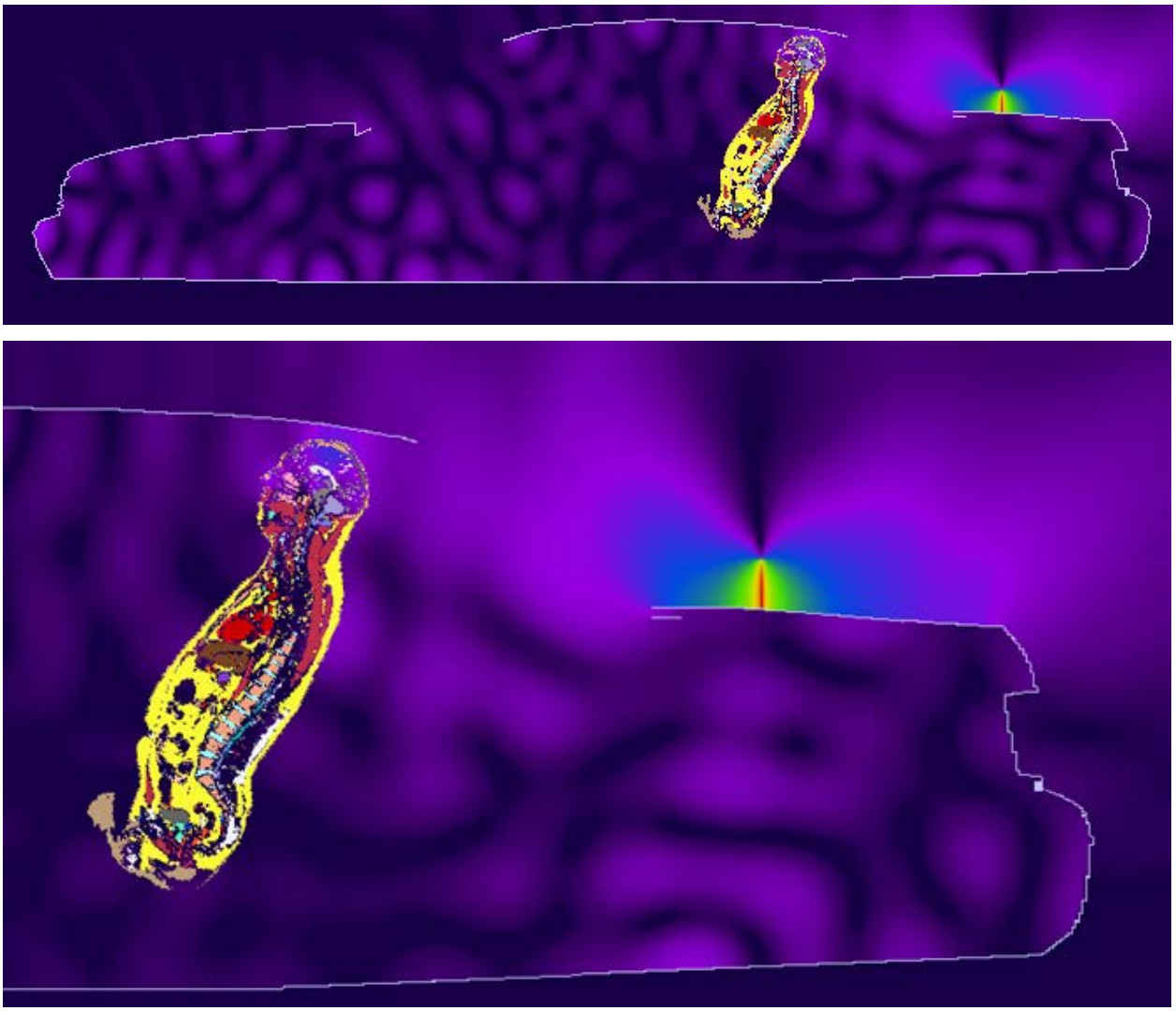
Figure 3. SAR distribution at 800.0000 MHz in the passenger model located on the center of the back seat, produced by the trunk-mount HAF4016A antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The two pictures below in Figure 4 show the E and H field distributions in the plane of the antenna corresponding to the condition 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 highest adjusted 1-g SAR was produced in the passenger exposure condition with HAF4016A antenna at 800.0000 MHz (passenger on the center of the back seat).

The SAR distribution in the exposure condition that gave highest adjusted 1-g SAR for Companion mobile radio VHF Band is reported in Figure 5 (140.0000 MHz, passenger on the center of the back seat, HAD4006A antenna).

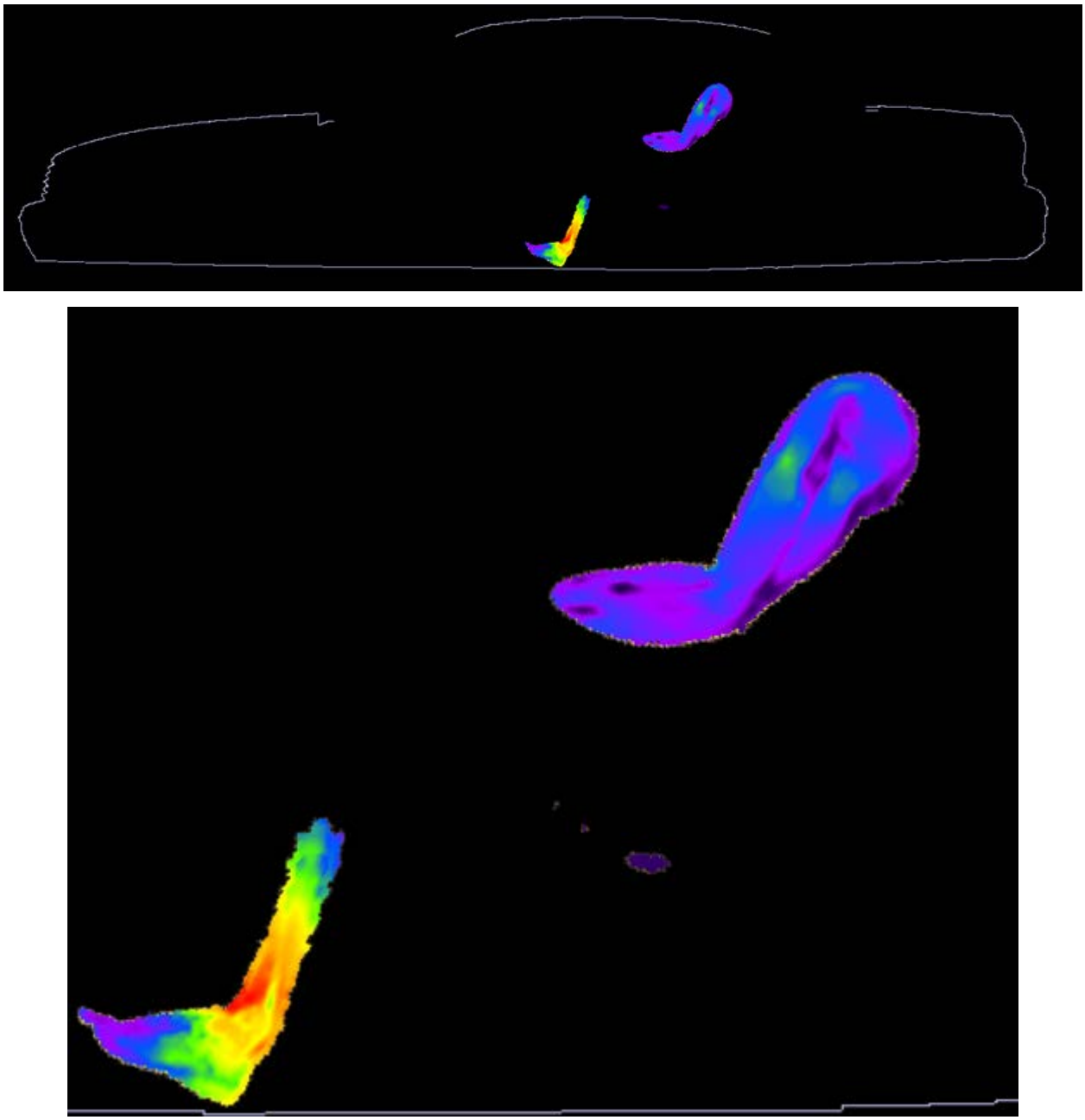
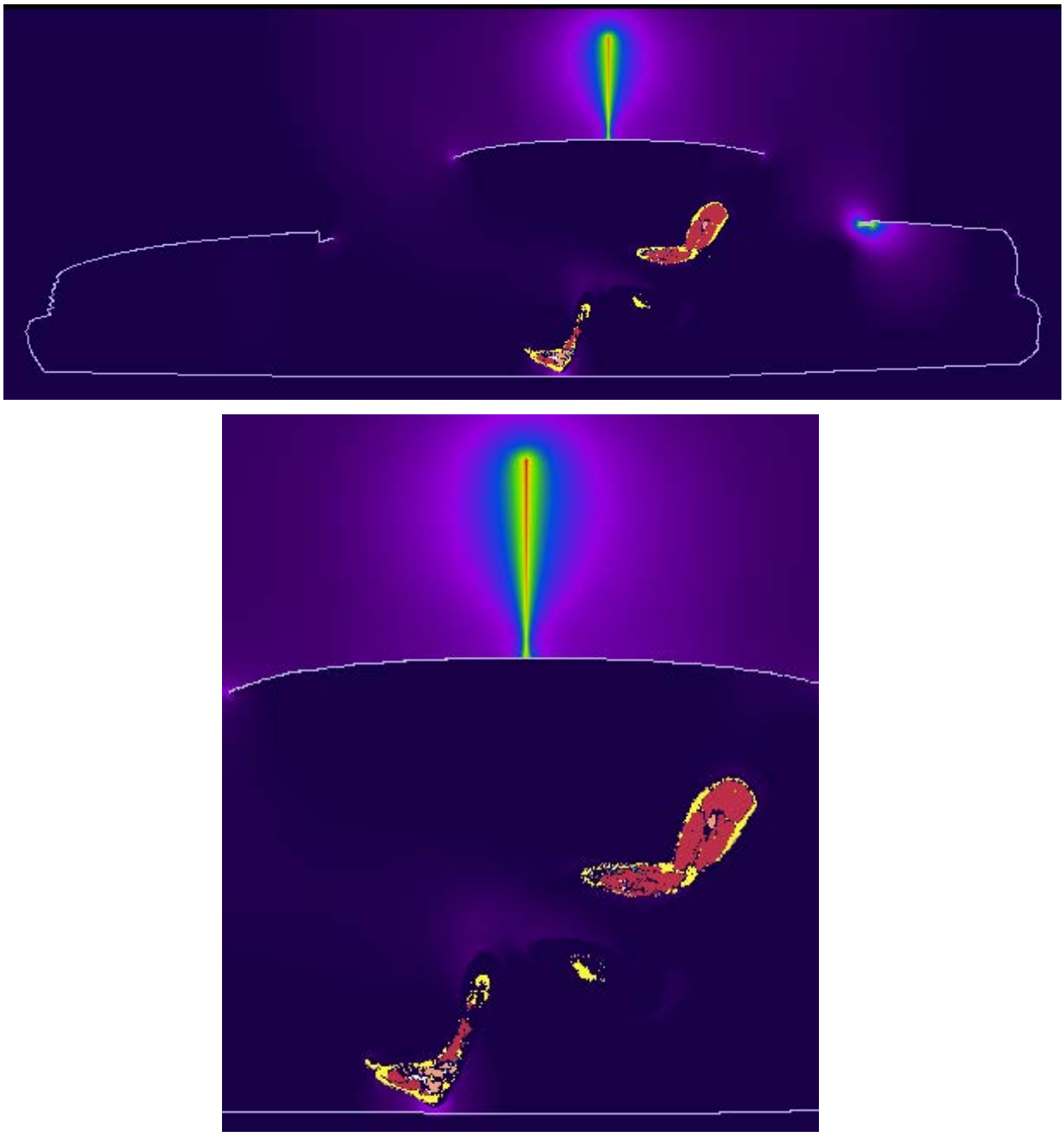
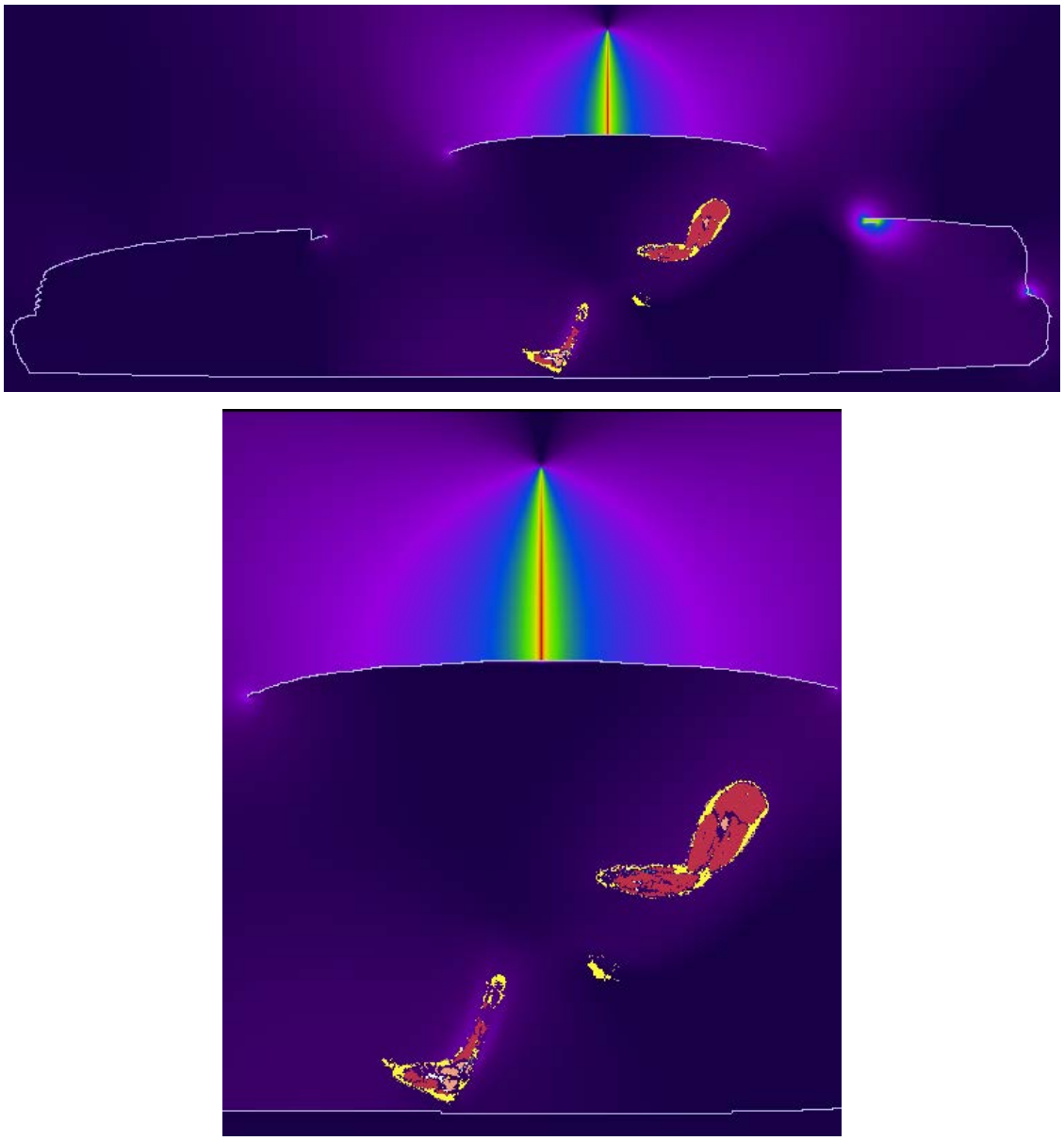


Figure 5. SAR distribution at 140.0000 MHz in the passenger model located on the center of the back seat, produced by the roof-mount HAD4006A antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The pictures below in Figure 6 show the E and H field distributions in the plane of the antenna corresponding to the condition 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.

The highest adjusted 1-g SAR was produced in the passenger exposure condition with HAD4006A antenna at 140.0000 MHz (passenger on the center of the back seat).

Results of SAR computations for combined exposure

From all simulated results the worst case peak SAR values were identified for both DVR 700 and Companion mobile radio VHF band exposure and then combined to produce the composite peak SAR value in corresponding locations of the human body model. Table 3 and Table 4 present the worst case composite peak SAR value.

Table 3: Worst case peak 1-g average SAR for passenger exposure conditions and composite 1-g average SAR from simultaneous exposure.

	Passenger location	DVR 700 [W/kg]	VHF mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.06	0.15	0.21
	Back Side	0.07	0.27	0.34
ISED Canada	Back Center	0.09	0.30	0.39
	Back Side	0.07	0.28	0.35

Table 4: Worst case peak whole body average SAR for passenger exposure conditions and composite whole body average SAR from simultaneous exposure.

	Passenger location	DVR 700 [W/kg]	VHF mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.004	0.006	0.010
	Back Side	0.003	0.006	0.009
ISED Canada	Back Center	0.004	0.012	0.016
	Back Side	0.003	0.011	0.014

From Table 3 and Table 4 the maximum combined peak 1-g SAR is 0.39 W/kg, less than the 1.6 W/kg limit, while the maximum combined whole-body average SAR is 0.016 W/kg, less than the 0.08 W/kg limit.

In addition, the overall maximum combined peak 10-g SAR is 0.28 W/kg, less than the 2.0 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 these mobile radio products, the present analysis shows that the computed SAR values are compliant with the FCC US and ISED Canada exposure limits for the general public as well as with the corresponding ICNIRP and IEEE Std. C95.1-2005 SAR limits.

References

[1] IEEE Standard C95.1-1999. *IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields*, 3 kHz to 300 GHz.

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

[3] 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.

[4] IEEE. 2005. *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz*, IEEE Std C95.1-2005

[5] Simon,W., Bit-Babik, G., “Effect of the variation in population on the whole-body average 1379 SAR of persons exposed to vehicle mounted antennas W. Simon”, ICEAA September 2-7, 2012, Cape 1380 Town.