MOTOROLA SOLUTIONS

COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE DIGITAL VEHICULAR REPEATER (DVR 800), MOBEXCOM DVRS 800 (DQPMDVR8000P) AND COMPANION APX SERIES MODEL M37TXS9PW1AN (HUW1001A) MOBILE RADIO.

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Introduction

This report summarizes the computational [numerical modeling] analysis performed to document compliance of the DVR 800, model # MOBEXCOM DVRS 800 (DQPMDVR8000P) with FCC ID# LO6-DVRS800 interfaced with, and transmitting simultaneously with Companion mobile radio, model # M37TXS9PW1AN (HUW1001A) and vehicle-mounted antennas with the US Federal Communications Commission (FCC) 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 800	800 MHz	806-824; 851-869
	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

This computational analysis supplements the measurements conducted to evaluate the compliance of the exposure from this DVR and Companion mobile radio with respect to applicable *maximum permissible exposure* (MPE) limits. All test conditions (108 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]. With SAR simulation reduction consideration, total 8 test conditions (with 16 independent simulations) had been performed addressing exposure of back seat passenger to the DVR 800 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 62704-1:2017 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 8 mm. 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.

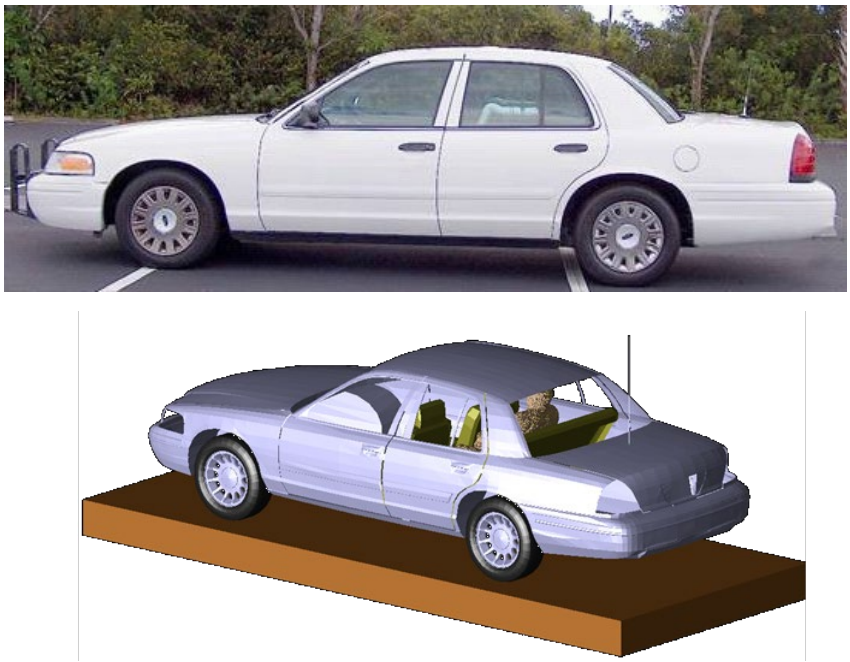


Figure 1: The photo picture of the car used in field measurements and the corresponding CAD model used in simulations

For passenger exposure, Companion mobile antenna position is on the roof and DVR 800 repeater antenna position is on the trunk. 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 stanadards 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.

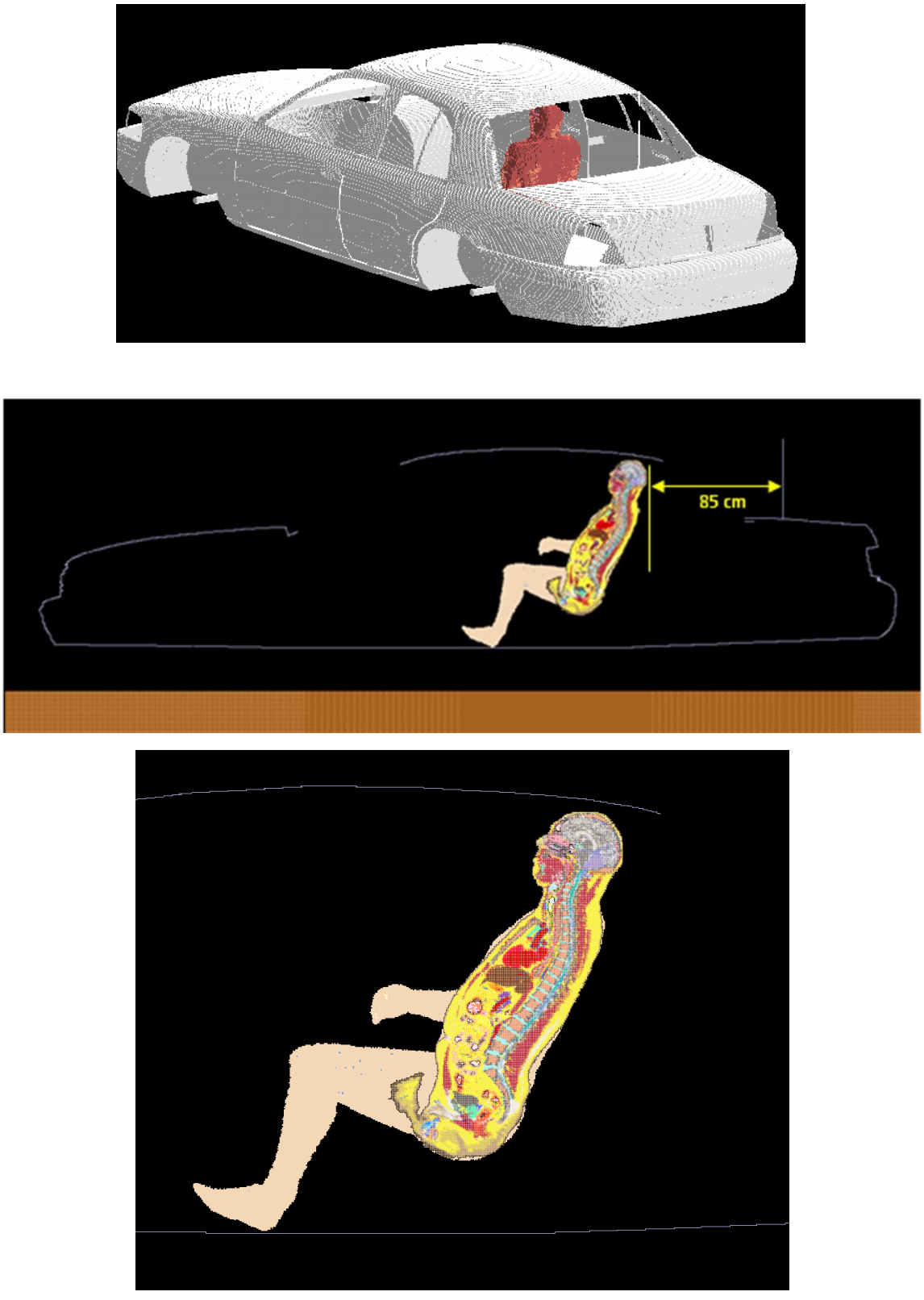


Figure 2: Passenger model exposed to a trunk-mount antenna: XFDTD geometry.

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 and 1-g average SAR. The maximum average output power from DVR 800 repeater is 10W (806-825MHz; 851-870MHz) and Companion mobile radio antenna 120W (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 800 repeater and (50% talk time) for Companion mobile radio were employed, all computational results are normalized full to DVR 800 repeater 10W (806-825MHz; 851-870MHz) and Companion mobile radio is half of it, i.e., 60W (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 62704-2-2017 standard.

Results of SAR computations for car passengers

The test conditions requiring SAR computations are summarized in Table 1 (DVR 800, 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 800) and on 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 800 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	WB	1 g	WB	1 g	WB
Trunk	HAF4016A, 1/4 Wave (764-870MHz)	10.8	815.0000	0.06	Back Center	0.09	0.003	1.02	2.18	0.09	0.007
					Back Side **Fig 3 & 4**	0.10	0.003	1.37	1.89	**0.14**	0.005

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

Table 2 (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	WB	1 g	WB	1 g	WB
Roof	AN000131A01, 1/4 wave (136-870MHz)	57.5	158.0125	0.37	Back Center	0.26	0.005	1.33	1.90	0.34	0.010
					Back Side **Fig 5 & 6**	0.56	0.005	1.02	2.41	**0.57**	0.012
Roof	HAD4021A, 1/4 Wave (136-174MHz)	53.5	158.0125	0.33	Back Center	0.17	0.004	1.33	1.90	0.22	0.008
					Back Side	0.28	0.004	1.02	2.41	0.29	0.010
Roof	HAD4017A, 1/4 Wave (146-174MHz)	48.0	165.0125	0.42	Back Center	0.05	0.003	1.37	1.89	0.07	0.005
					Back Side	0.18	0.004	1.04	2.43	0.19	0.010
Roof	HAD4016A, 1/4 Wave (136-162MHz)	53.1	162.0000	0.34	Back Center	0.06	0.003	1.35	1.90	0.08	0.006
					Back Side	0.21	0.004	1.03	2.42	0.22	0.009
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	50.8	150.8000	0.37	Back Center	0.25	0.006	1.30	1.90	0.32	0.012
					Back Side	0.53	0.008	1.00	2.40	0.54	0.020
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	47.3	162.0000	0.36	Back Center	0.06	0.003	1.35	1.90	0.08	0.006
					Back Side	0.22	0.004	1.03	2.42	0.22	0.009
Roof	HAD4009A, 1/4 Wave (162-174MHz)	44.8	165.0125	0.35	Back Center	0.05	0.003	1.37	1.89	0.07	0.005
					Back Side	0.18	0.004	1.04	2.43	0.19	0.010

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

The SAR distribution in the exposure condition that gave highest adjusted 1-g SAR for DVR 800 is reported in Figure 3 (815.0000 MHz, passenger on the side of the back seat, HAF4016A antenna).

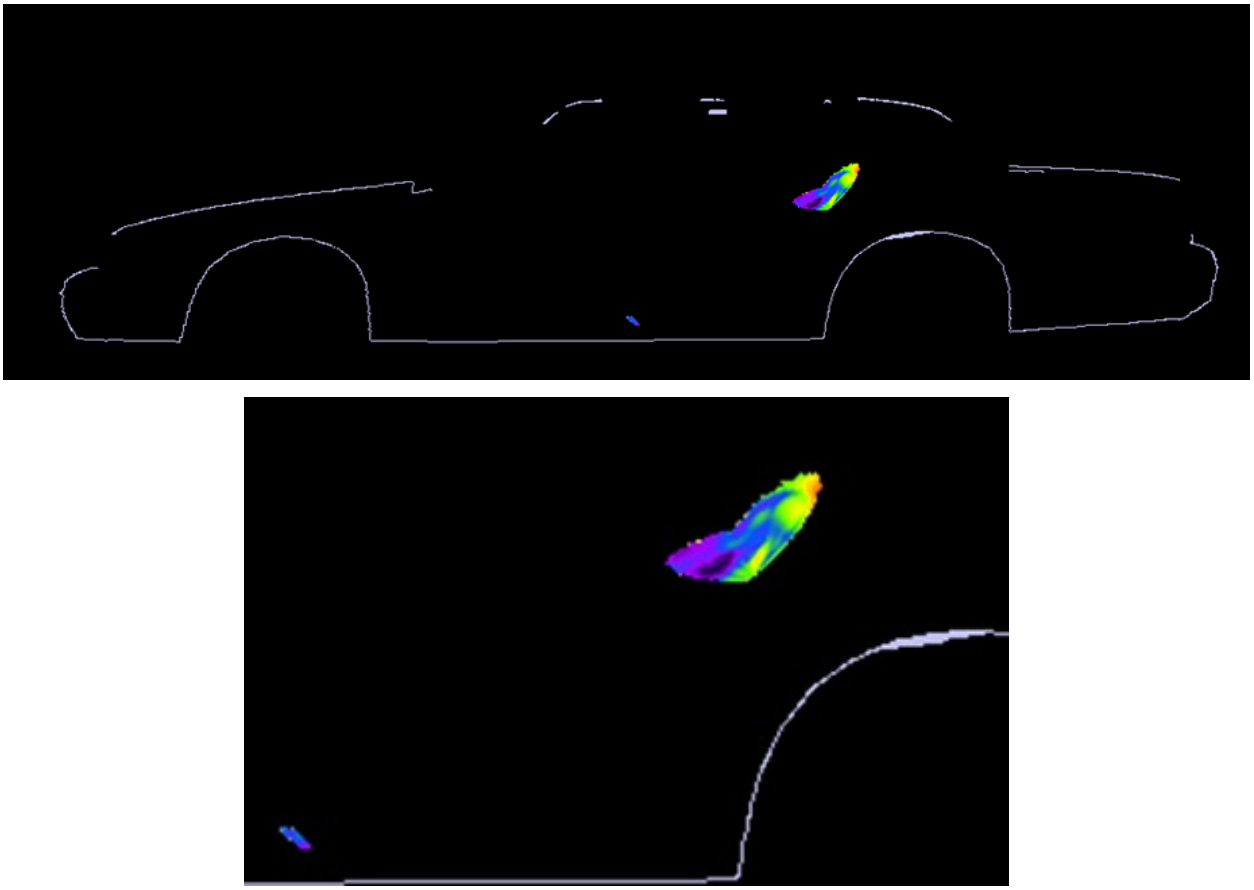
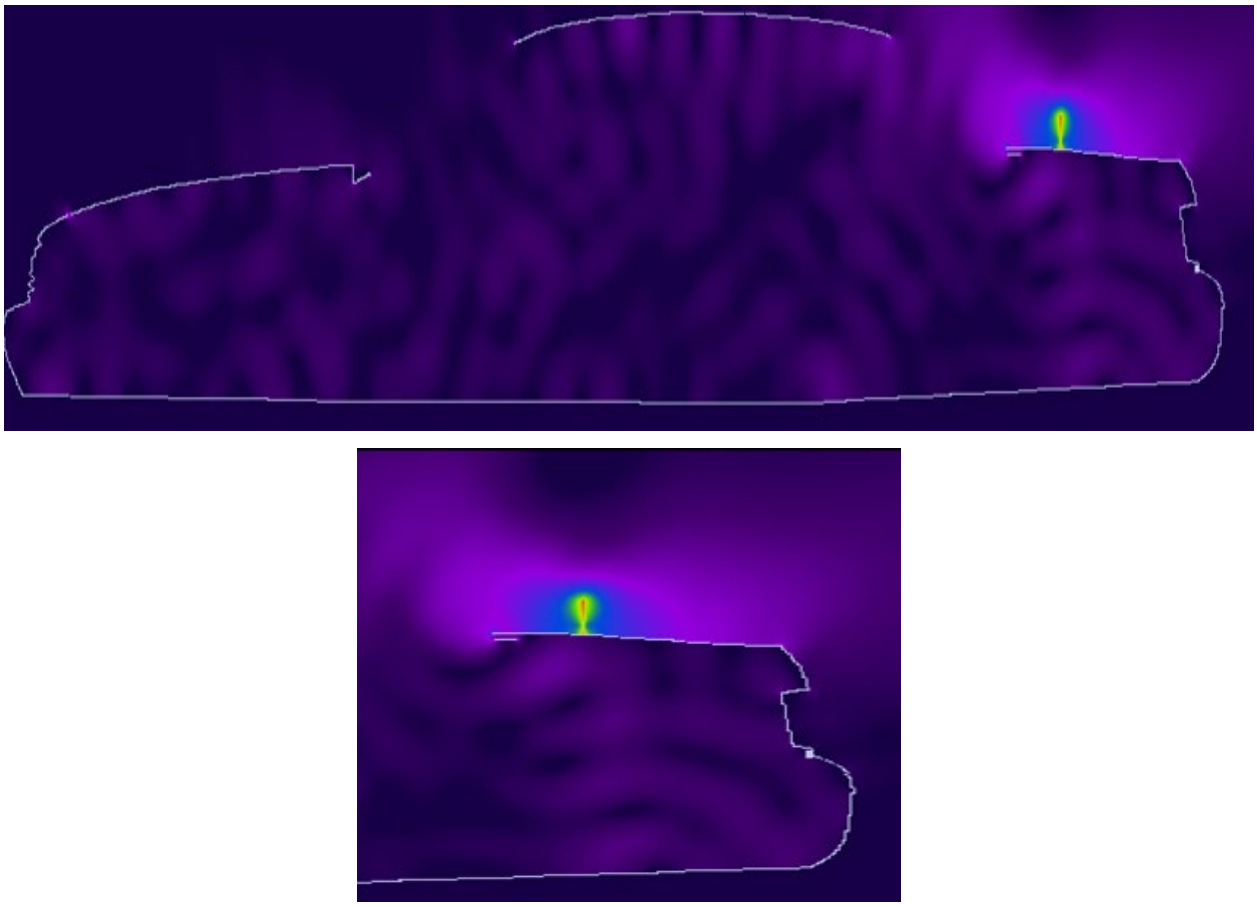
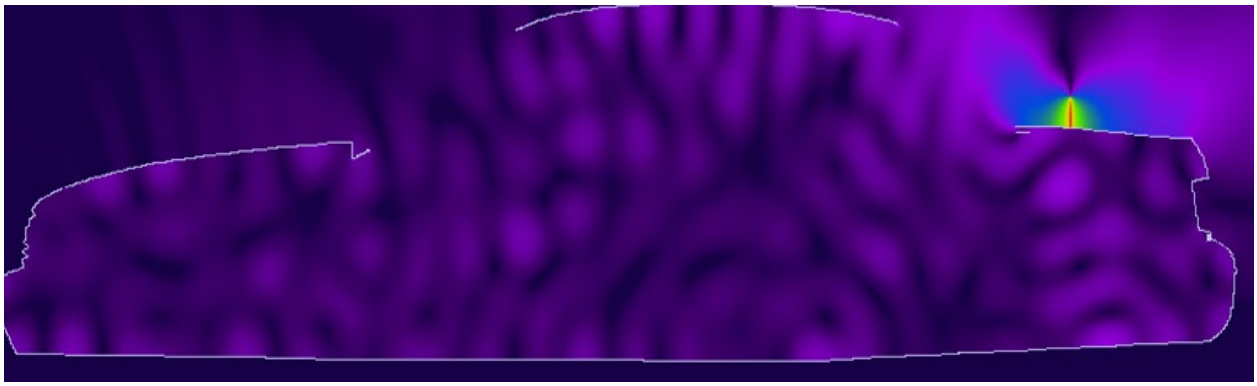


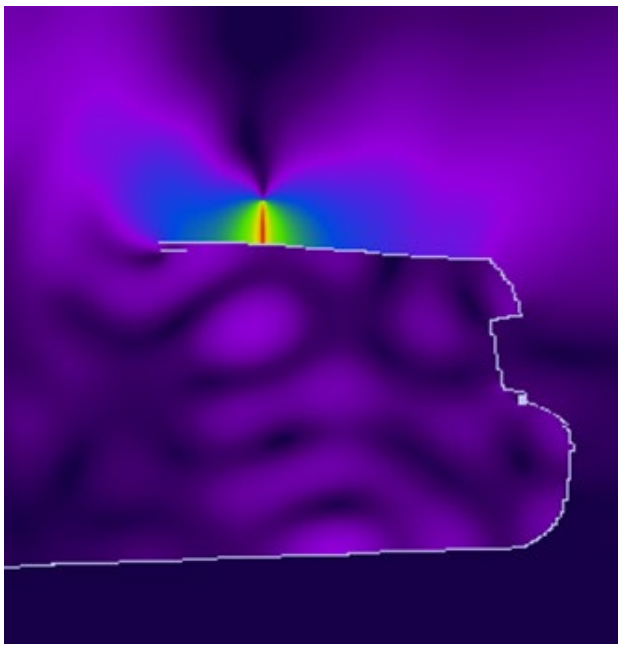
Figure 3. SAR distribution at 815.0000 MHz in the passenger model located on the side of the back seat, produced by the trunk-mount HAF4016A antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

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 SAR distribution in the exposure condition that gave highest adjusted 1-g SAR for Companion mobile radio VHF Band is reported in Figure 5 (158.0125 MHz, passenger on the side of the back seat, AN000131A01 antenna).

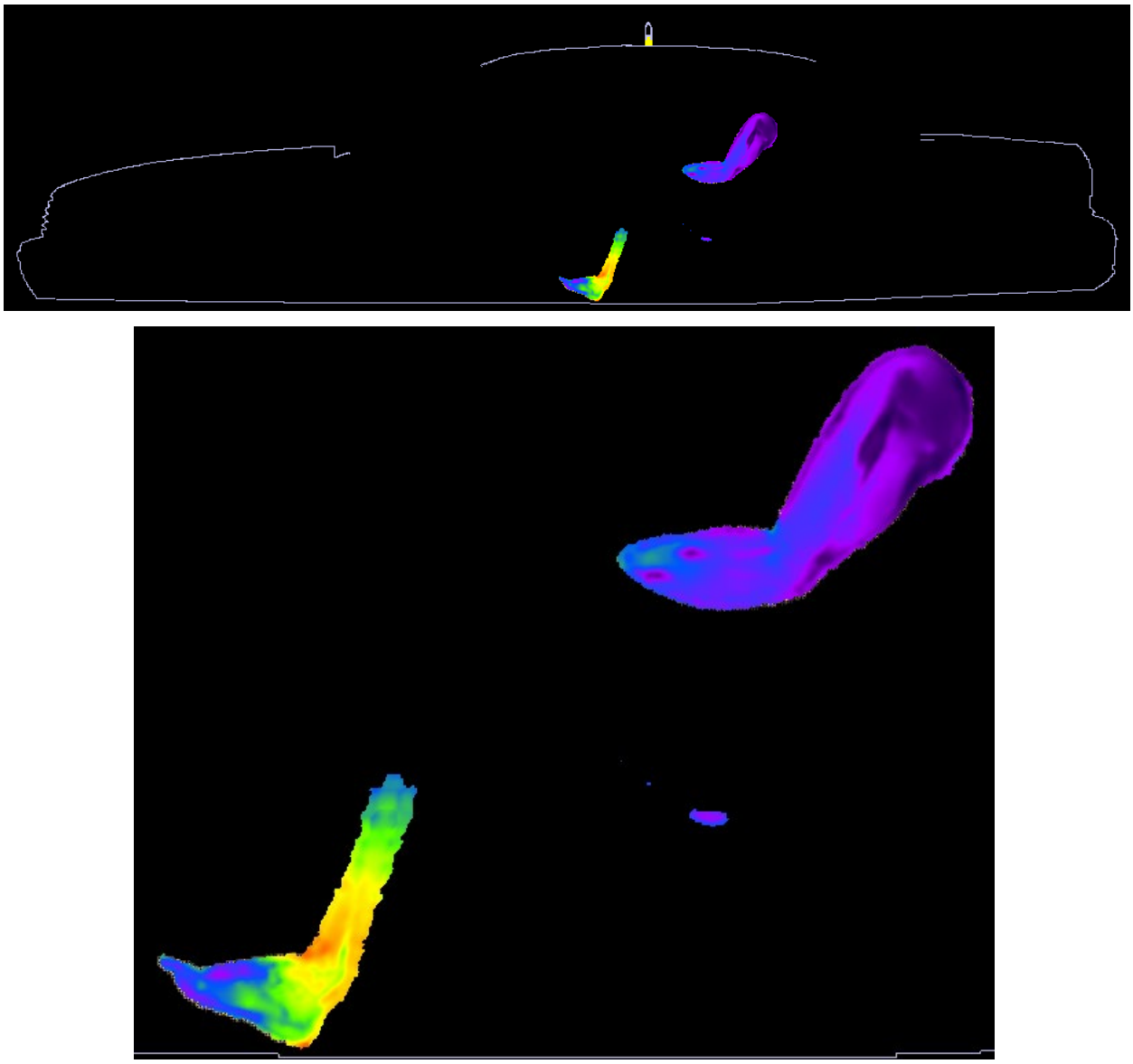
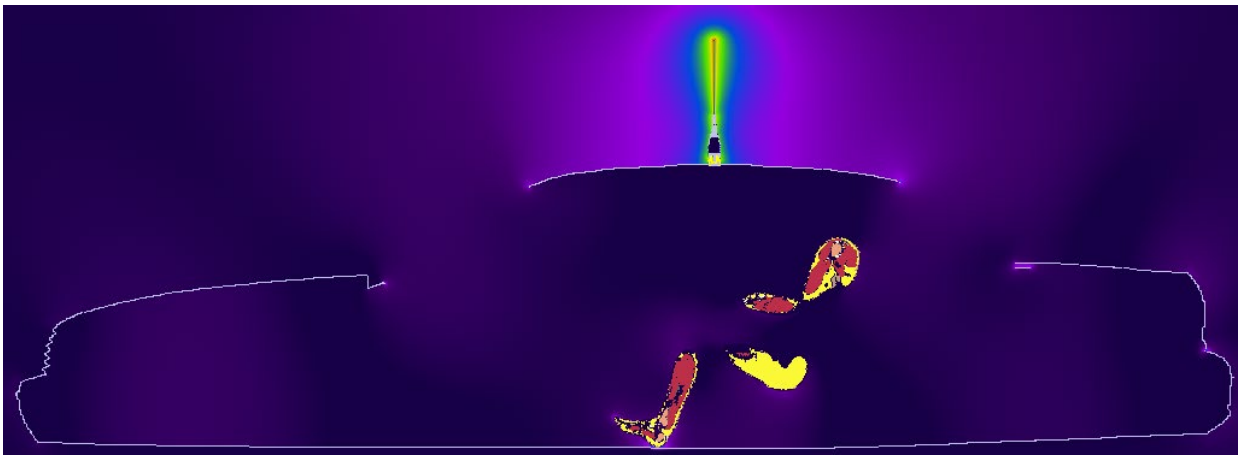
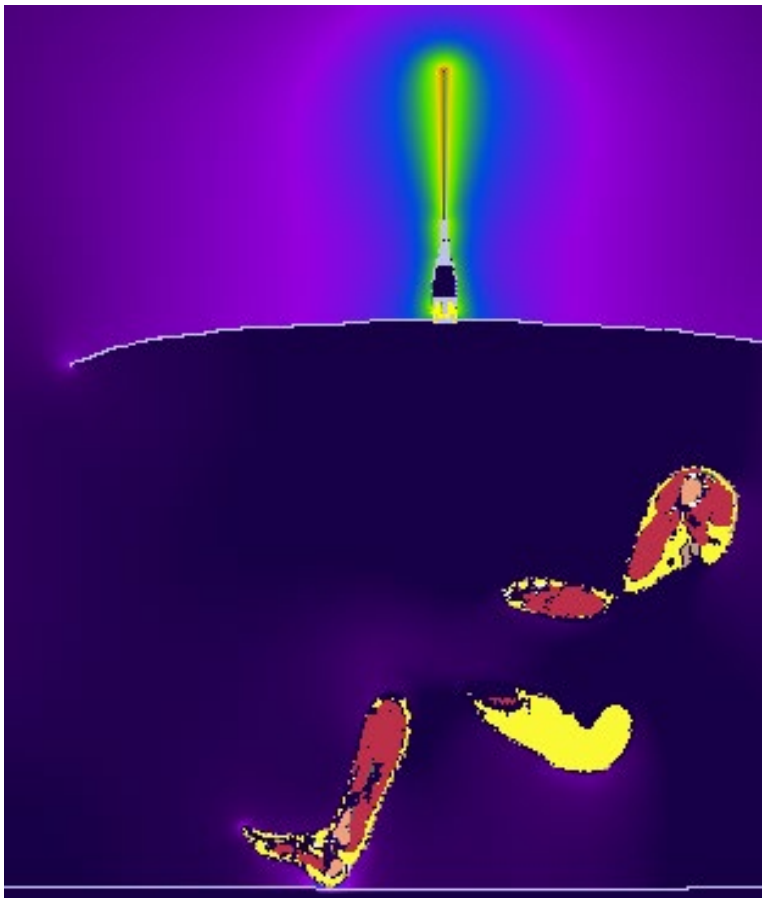


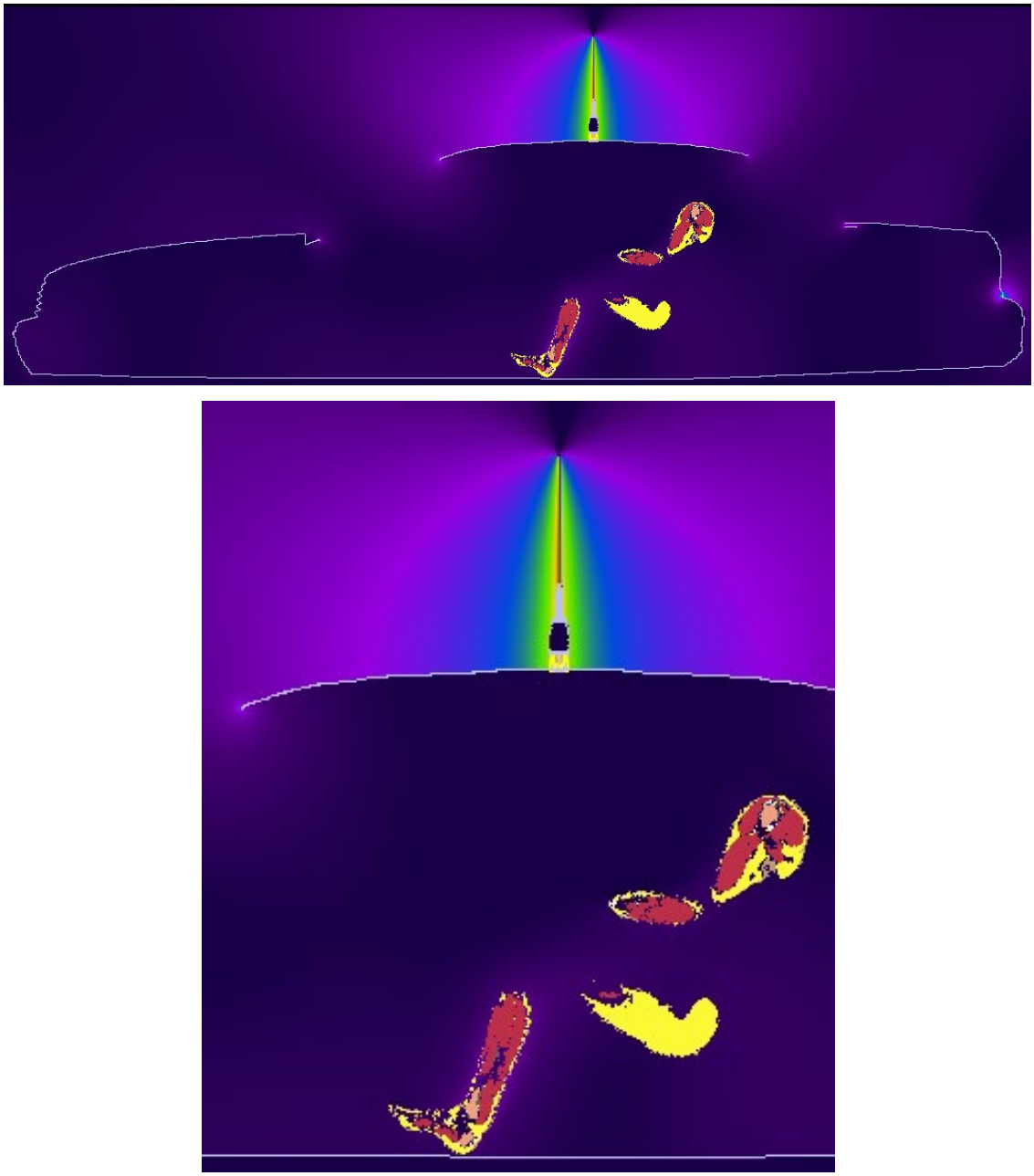
Figure 5. SAR distribution at 158.0125 MHz in the passenger model located on the side of the back seat, produced by the roof-mount AN000131A01 antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

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 AN000131A01 antenna at 158.0125 MHz (passenger on the side of the back seat).

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 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 3: SAR Simulation Reduction Considerations for Passenger

DVRS 800		APX 8500 HP Mobile		Combine MPE (%)	Exposure Location	DVRS 800 Adjusted SAR Results (W/kg)		APX 8500 HP Mobile Adjusted SAR Results (W/kg)		Combine Adjusted SAR Results (W/kg)		SAR Simulation Reduction
Antenna Kit#	Freq (MHz)	Antenna Kit#	Freq (MHz)			1g	WB	1g	WB	1g	WB	
HAF4016A	815.0000	AN000131A01	158.0125	199.81	Back Center	0.09	0.007	0.34	0.010	0.43	0.017	
					Back Side	0.14	0.005	0.57	0.012	**0.71**	0.017	
	806.0000		158.0125	199.11								
	824.0000		158.0125	197.41								
	851.0000		158.0125	196.61								
	860.0000		158.0125	195.51								
	869.0000		158.0125	192.71								
	815.0000		165.0125	189.31								
	806.0000		165.0125	188.61								
	824.0000		165.0125	186.91								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		165.0125	186.11								
	860.0000		165.0125	185.01								
	869.0000		165.0125	182.21								
	815.0000		150.8000	156.81								
	806.0000		150.8000	156.11								
	824.0000		150.8000	154.41								
	851.0000		150.8000	153.61								
	860.0000		150.8000	152.51								
	869.0000		150.8000	149.71								

HAF4016A	815.0000	HAD4021A	158.0125	179.01	Back Center	0.09	0.007	0.22	0.008	0.31	0.015	
					Back Side	0.14	0.005	0.29	0.010	0.43	0.015	
	806.0000		158.0125	178.31								
	824.0000		158.0125	176.61								
	851.0000		158.0125	175.81								
	860.0000		158.0125	174.71								
	815.0000		150.8000	172.21								
	869.0000		158.0125	171.91								
	806.0000		150.8000	171.51								
	824.0000		150.8000	169.81								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		150.8000	169.01								
	860.0000		150.8000	167.91								
	869.0000		150.8000	165.11								
	815.0000		165.0125	152.81								
	806.0000		165.0125	152.11								
	824.0000		165.0125	150.41								
	851.0000		165.0125	149.61								
	860.0000		165.0125	148.51								
	869.0000		165.0125	145.71								

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

Table 3 continued: SAR Simulation Reduction Considerations for Passenger

DVRS 800		APX 8500 HP Mobile		Combine MPE (%)	Exposure Location	DVRS 800 Adjusted SAR Results (W/kg)		APX 8500 HP Mobile Adjusted SAR Results (W/kg)		Combine Adjusted SAR Results (W/kg)		SAR Simulation Reduction
Antenna Kit#	Freq (MHz)	Antenna Kit#	Freq (MHz)			1g	WB	1g	WB	1g	WB	
	815.0000		165.0125	226.21	Back Center	0.09	0.007	0.07	0.005	0.16	0.012	
					Back Side	0.14	0.005	0.19	0.010	0.33	0.015	
	806.0000		165.0125	225.51								
	824.0000		165.0125	223.81								
	851.0000		165.0125	223.01								
	860.0000		165.0125	221.91								
	869.0000		165.0125	219.11								
	815.0000		158.0125	193.11								
	806.0000		158.0125	192.41								
HAF4016A	824.0000	HAD4017A	158.0125	190.71								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		158.0125	189.91								
	860.0000		158.0125	188.81								
	869.0000		158.0125	186.01								
	815.0000		150.8000	122.01								
	806.0000		150.8000	121.31								
	824.0000		150.8000	119.61								
	851.0000		150.8000	118.81								
	860.0000		150.8000	117.71								
	869.0000		150.8000	114.91								
	815.0000		162.0000	185.11	Back Center	0.09	0.007	0.08	0.006	0.17	0.013	
					Back Side	0.14	0.005	0.22	0.009	0.36	0.014	
	806.0000		162.0000	184.41								
	824.0000		162.0000	182.71								
	851.0000		162.0000	181.91								
	860.0000		162.0000	180.81								
	869.0000		162.0000	178.01								
	815.0000		156.4000	174.91								
	806.0000		156.4000	174.21								
HAF4016A	824.0000	HAD4016A	156.4000	172.51								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		156.4000	171.71								
	860.0000		156.4000	170.61								
	869.0000		156.4000	167.81								
	815.0000		150.8000	164.91								
	806.0000		150.8000	164.21								
	824.0000		150.8000	162.51								
	851.0000		150.8000	161.71								
	860.0000		150.8000	160.61								
	869.0000		150.8000	157.81								
	815.0000		150.8000	199.01	Back Center	0.09	0.007	0.32	0.012	0.41	0.019	
					Back Side	0.14	0.005	0.54	0.020	0.68	0.025	
	806.0000		150.8000	198.31								
HAF4016A	824.0000	HAD4007A	150.8000	196.61								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		150.8000	195.81								
	860.0000		150.8000	194.71								
	869.0000		150.8000	191.91								
	815.0000		162.0000	196.11	Back Center	0.09	0.007	0.08	0.006	0.17	0.013	
					Back Side	0.14	0.005	0.22	0.009	0.36	0.014	
	806.0000		162.0000	195.41								
	824.0000		162.0000	193.71								
	851.0000		162.0000	192.91								
	860.0000		162.0000	191.81								
	869.0000		162.0000	189.01								
	815.0000		156.4000	188.91								
	806.0000		156.4000	188.21								
HAF4016A	824.0000	HAD4008A	156.4000	186.51								The highest MPE configuration has SAR below 50% of the limit.
	851.0000		156.4000	185.71								
	860.0000		156.4000	184.61								
	869.0000		156.4000	181.81								
	815.0000		150.8000	139.21								
	806.0000		150.8000	138.51								
	824.0000		150.8000	136.81								
	851.0000		150.8000	136.01								
	860.0000		150.8000	134.91								
	869.0000		150.8000	132.11								
	815.0000		165.0125	187.21	Back Center	0.09	0.007	0.07	0.005	0.16	0.012	
					Back Side	0.14	0.005	0.19	0.010	0.33	0.015	
	806.0000		165.0125	186.51								
	824.0000		165.0125	184.81								
	851.0000		165.0125	184.01								
	860.0000		165.0125	182.91								
HAF4016A	869.0000	HAD4009A	165.0125	180.11								The highest MPE configuration has SAR below 50% of the limit.
	815.0000		162.0000	157.91								
	806.0000		162.0000	157.21								
	824.0000		162.0000	155.51								
	851.0000		162.0000	154.71								
	860.0000		162.0000	153.61								
	869.0000		162.0000	150.81								

Results of SAR computations for combined exposure

From all simulated results the worst case peak SAR values were identified for both DVR 800 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 4 and Table 5 present the worst case composite peak SAR value.

Table 4: Worst case peak 1-g average SAR for passenger exposure conditions and composite 1-g average SAR from simultaneous exposure.

	Passenger location	DVR 800 [W/kg]	VHF mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.09	0.34	0.43
	Back Side	0.14	0.57	0.71

Table 5: Worst case peak whole body average SAR for passenger exposure conditions and composite whole body average SAR from simultaneous exposure.

	Passenger location	DVR 800 [W/kg]	VHF mobile radio [W/kg]	Total [W/kg]
FCC US	Back Center	0.007	0.012	0.019
	Back Side	0.005	0.020	0.025

From Table 4 and Table 5 the maximum combined peak 1-g SAR is 0.71 W/kg, less than the 1.6 W/kg limit, while the maximum combined whole-body average SAR is 0.025 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 these mobile radio products, the present analysis shows that the computed SAR values are compliant with the US FCC exposure limits for the general public.

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