COMPUTATIONAL EME COMPLIANCE ASSESSMENT OF THE 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 APX Series Model Number M37TXS9PW1AN (HUW1001A) Mobile Radio and vehicle-mounted antennas with the US Federal Communications Commission (FCC) guidelines for human exposure to radio frequency (RF) emissions. The radio operates in the following frequency bands:

Bands	Frequency Band (MHz)
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 mobile radio with respect to applicable *maximum permissible exposure* (MPE) limits. All test conditions (47 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 considerations, total 44 independent simulations had been performed addressing exposure of passenger and bystander to the VHF mobile radio 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 shows 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.

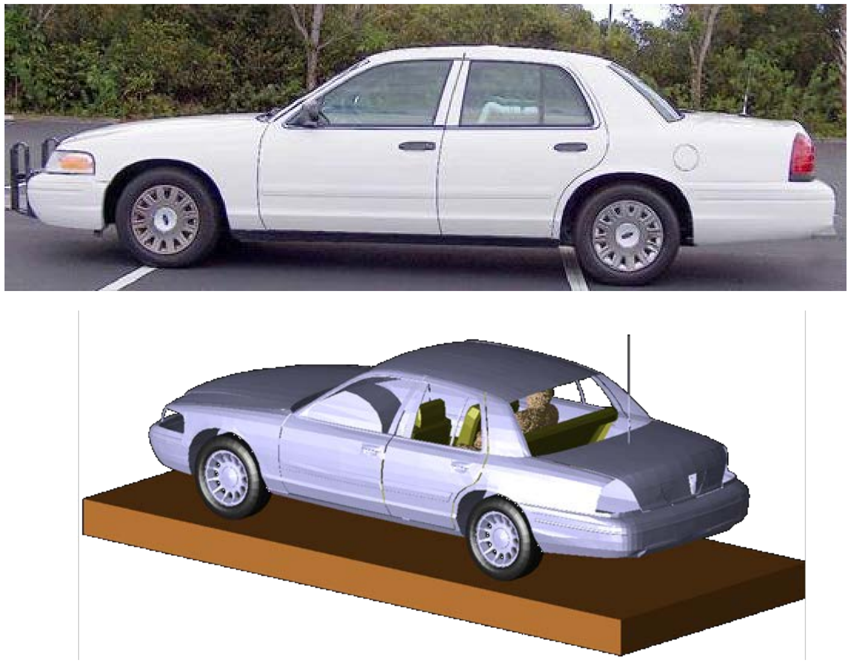


Figure 1: The photo picture of the car and the corresponding CAD model used in simulations

Figure 2 shows some of the XFDTD™ computational models used for passenger exposure to roof mounted antennas.

For bystander exposure, the antenna position is at the side of the roof with separation distance 90 cm from antenna. Figure 3 shows some for the XFDTD™ computational models used for bystander exposure configurations.

According to the IEC/IEEE 62704-2-2017 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.

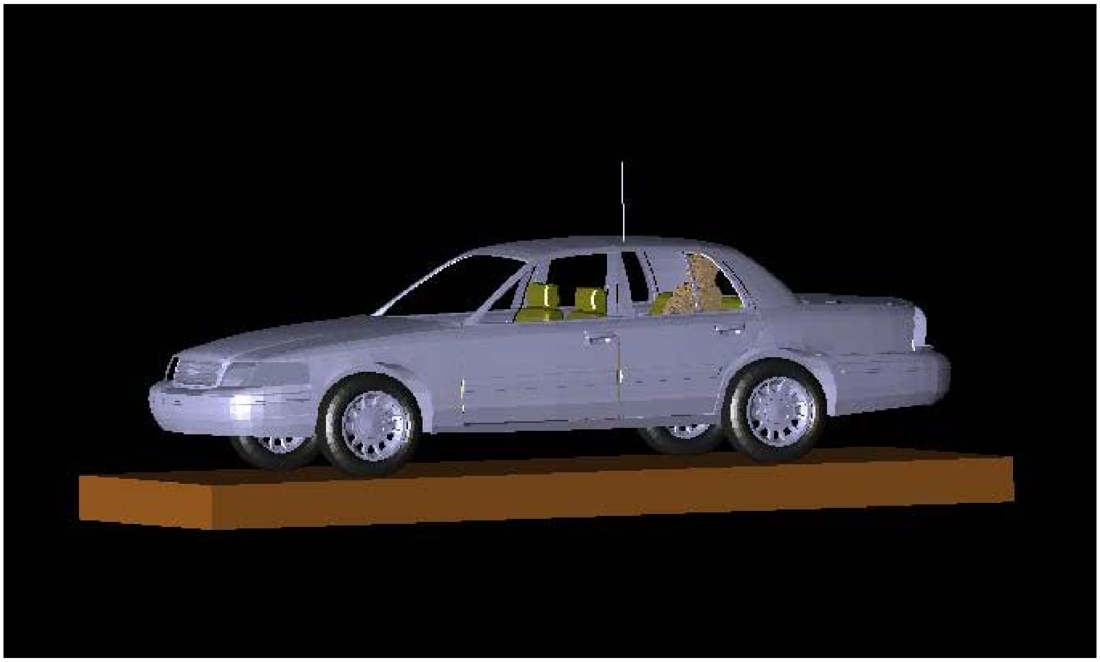


Figure 2: Passenger model exposed to a roof-mount antenna

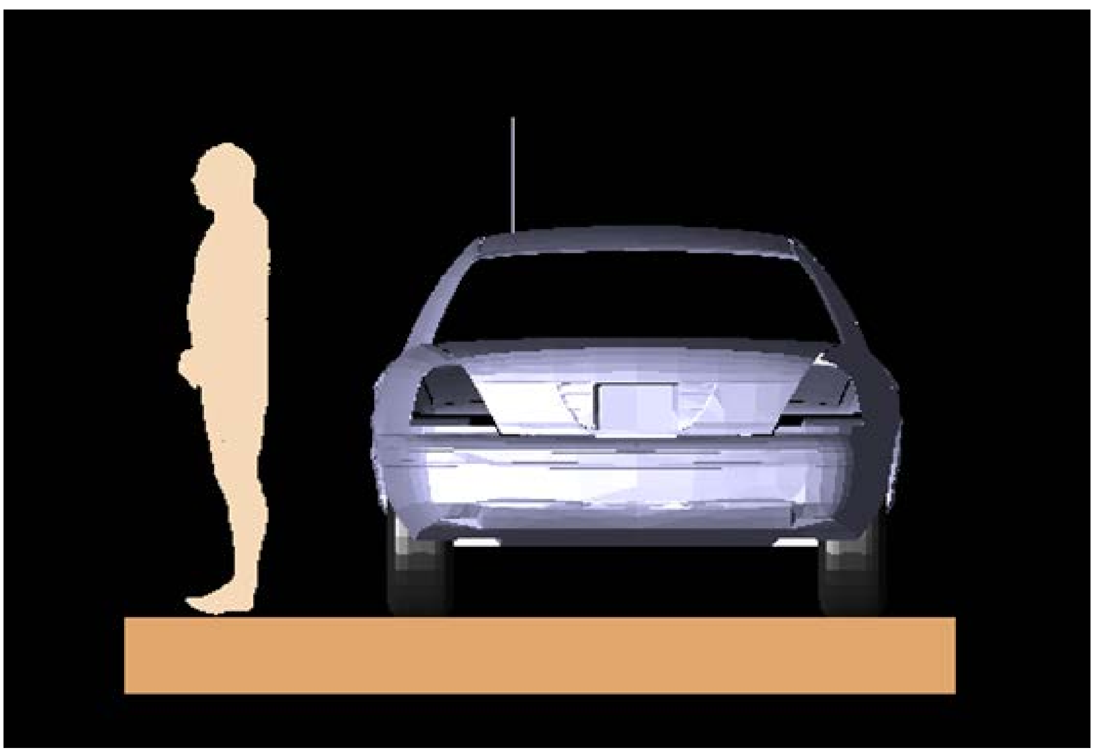


Figure 3: Bystander model exposed to a roof-mount antenna

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 mobile radio antenna is 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 (50% talk time) were employed, all computational results are normalized to 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.

Results of SAR computations for car passengers and bystanders

The test conditions requiring SAR computations are summarized in Table 1 (Bystanders) and Table 2 (Passengers) 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 roof. The antenna length in tables 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.

The bystander is located at the measurement distance from the transmit antenna as described in the MPE report and is assessed separately for front and back (rear) exposure.

All the transmit frequency, antenna length, and passenger/bystander location combinations 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 1: Results of the Computations and Adjusted SAR for Bystanders exposure

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)1	57.5	150.8000	0.33	Front	0.43	0.020	1.29	1.80	0.55	0.037
					Rear	0.38	0.020	1.29	1.80	0.49	0.036
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	105.5	173.0125	0.25	Front	0.28	0.010	1.32	1.80	0.36	0.018
					Rear	0.39	0.011	1.32	1.80	0.52	0.019
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	114.3	158.0125	0.20	Front	0.15	0.006	1.30	1.80	0.19	0.010
					Rear	0.18	0.006	1.30	1.80	0.24	0.011
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	128.6	150.8000	0.20	Front	0.14	0.005	1.29	1.80	0.18	0.009
					Rear	0.14	0.006	1.29	1.80	0.19	0.010
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	91.7	173.0125	0.30	Front	0.44	0.018	1.32	1.80	0.58	0.033
					Rear	0.71	0.019	1.32	1.80	0.94	0.034
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	98.3	165.0125	0.23	Front	0.28	0.013	1.31	1.80	0.37	0.023
					Rear	0.48	0.013	1.31	1.80	0.63	0.023
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	104.5	158.0125	0.22	Front	0.21	0.010	1.30	1.80	0.27	0.017
					Rear	0.33	0.010	1.30	1.80	0.43	0.018
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	115.8	150.8000	0.22	Front	0.21	0.009	1.29	1.80	0.28	0.017
					Rear	0.33	0.010	1.29	1.80	0.42	0.017
Roof	HAD4016A, 1/4 Wave (136-162MHz)	53.1	150.8000	0.37	Front	0.42	0.020	1.29	1.80	0.54	0.035
					Rear	0.38	0.019	1.29	1.80	0.49	0.035
Roof	HAD4017A, 1/4 Wave (146-174MHz)	48.0	158.0125	0.34	Front	0.36	0.017	1.30	1.80	0.47	0.030
					Rear	0.36	0.016	1.30	1.80	0.47	0.030
Roof	HAD4021A, 1/4 Wave (136-174MHz)	53.5	150.8000	0.34	Front	0.42	0.020	1.29	1.80	0.54	0.035
					Rear	0.38	0.019	1.29	1.80	0.49	0.035
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	50.8	150.8000	0.41	Front	0.42	0.020	1.29	1.80	0.55	0.036
					Rear	0.38	0.019	1.29	1.80	0.49	0.035
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	47.3	156.4000	0.36	Front	0.37	0.016	1.30	1.80	0.48	0.030
					Rear	0.37	0.016	1.30	1.80	0.48	0.029
Roof	HAD4009A, 1/4 Wave (162-174MHz)	44.8	173.0125	0.32	Front	0.50	0.028	1.32	1.80	0.65	**0.050**
					Rear (Figure 4 & 5)	0.78	0.027	1.32	1.80	**1.03**	0.048
			165.0125	0.31	Front	0.34	0.020	1.31	1.80	0.45	0.035
					Rear	0.50	0.020	1.31	1.80	0.66	0.035

Note:
* Antenna length trimmed to frequency.
Bold Blue – the highest SAR results computed for the respective frequency bands

Table 2: Results of the Computations and Adjusted SAR for Passenger exposure

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)1	57.5	158.0125	0.37	Back Center	0.26	0.005	1.27	2.07	0.33	0.011
					Back Side (Figure 6 & 7)	0.56	0.005	1.02	1.53	**0.57**	0.008
Roof	HAD4016A, 1/4 Wave (136-162MHz)	53.1	162.0000	0.34	Back Center	0.06	0.003	1.31	2.11	0.08	0.006
					Back Side	0.21	0.004	1.03	1.55	0.22	0.005
Roof	HAD4017A, 1/4 Wave (146-174MHz)	48.0	165.0125	0.42	Back Center	0.05	0.003	1.34	2.14	0.07	0.006
					Back Side	0.18	0.004	1.04	1.56	0.19	0.006
Roof	HAD4021A, 1/4 Wave (136-174MHz)	53.5	158.0125	0.33	Back Center	0.17	0.004	1.27	2.07	0.21	0.009
					Back Side	0.28	0.004	1.02	1.53	0.29	0.006
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	50.8	150.8000	0.37	Back Center	0.25	0.006	1.21	2.01	0.30	**0.013**
					Back Side	0.53	0.008	1.00	1.50	0.54	0.012
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	47.3	162.0000	0.36	Back Center	0.06	0.003	1.31	2.11	0.08	0.006
					Back Side	0.22	0.004	1.03	1.55	0.22	0.006
Roof	HAD4009A, 1/4 Wave (162-174MHz)	44.8	165.0125	0.35	Back Center	0.05	0.003	1.34	2.14	0.07	0.006
					Back Side	0.18	0.004	1.04	1.56	0.19	0.006

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

The SAR distribution in the bystander exposure condition that gave highest adjusted 1-g SAR is reported in Figure 4 (173.0125 MHz, bystander back (rear) at the side of the roof, HAD4009A antenna).

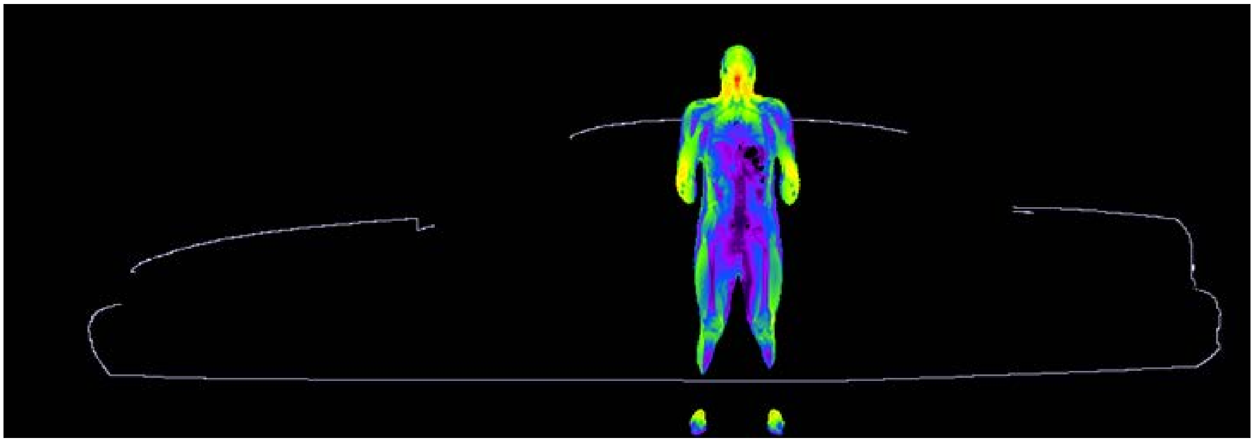
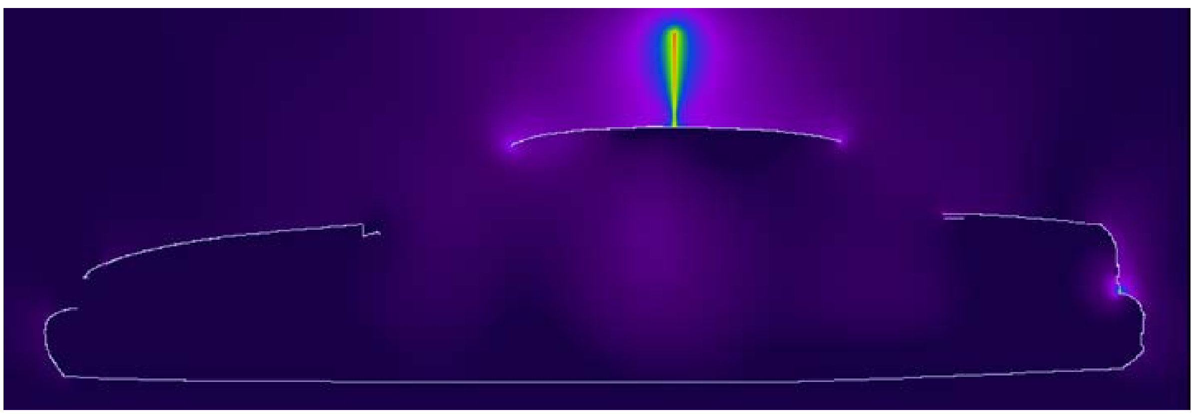
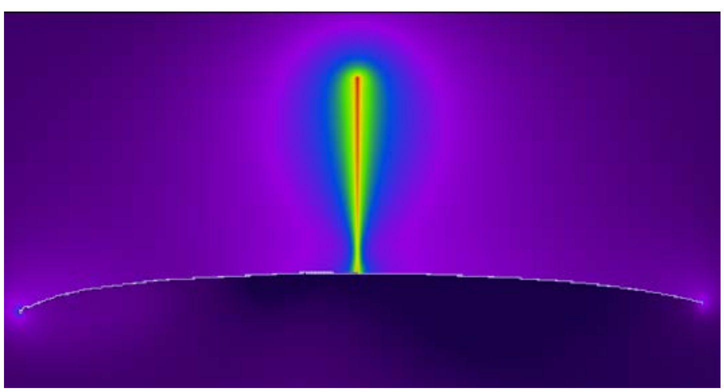


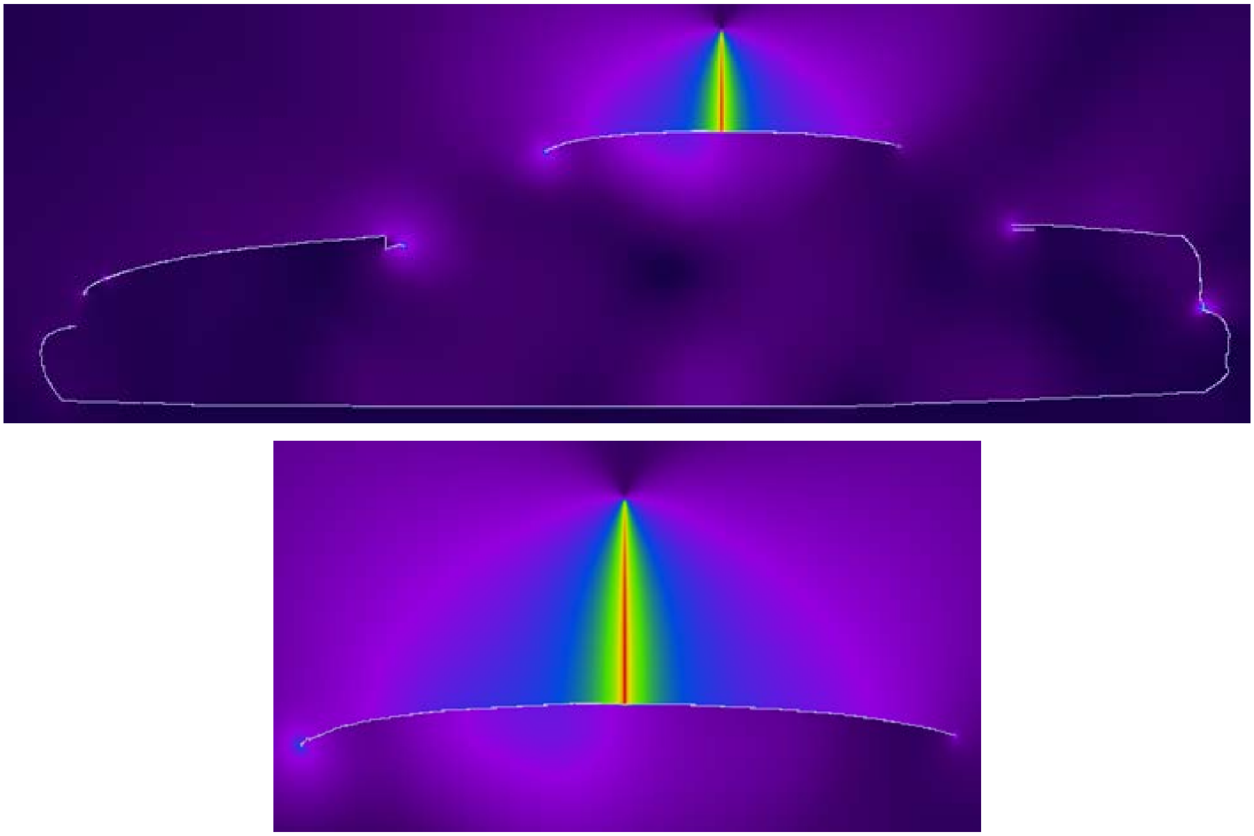
Figure 4. SAR distribution at 173.0125 MHz in the bystander back (rear) located at the side of the roof, produced by roof-mounted antenna HAD4009A antenna. The contour plot for SAR distribution in the figure is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

The two 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 bystander exposure condition with HAD4009A antenna at 173.0125 MHz (bystander back at the side of the roof).

The SAR distribution in the passenger exposure condition that gave highest adjusted 1-g SAR is reported in Figure 6. (158.0125 MHz, passenger on the side of the back seat, AN000131A1 antenna).

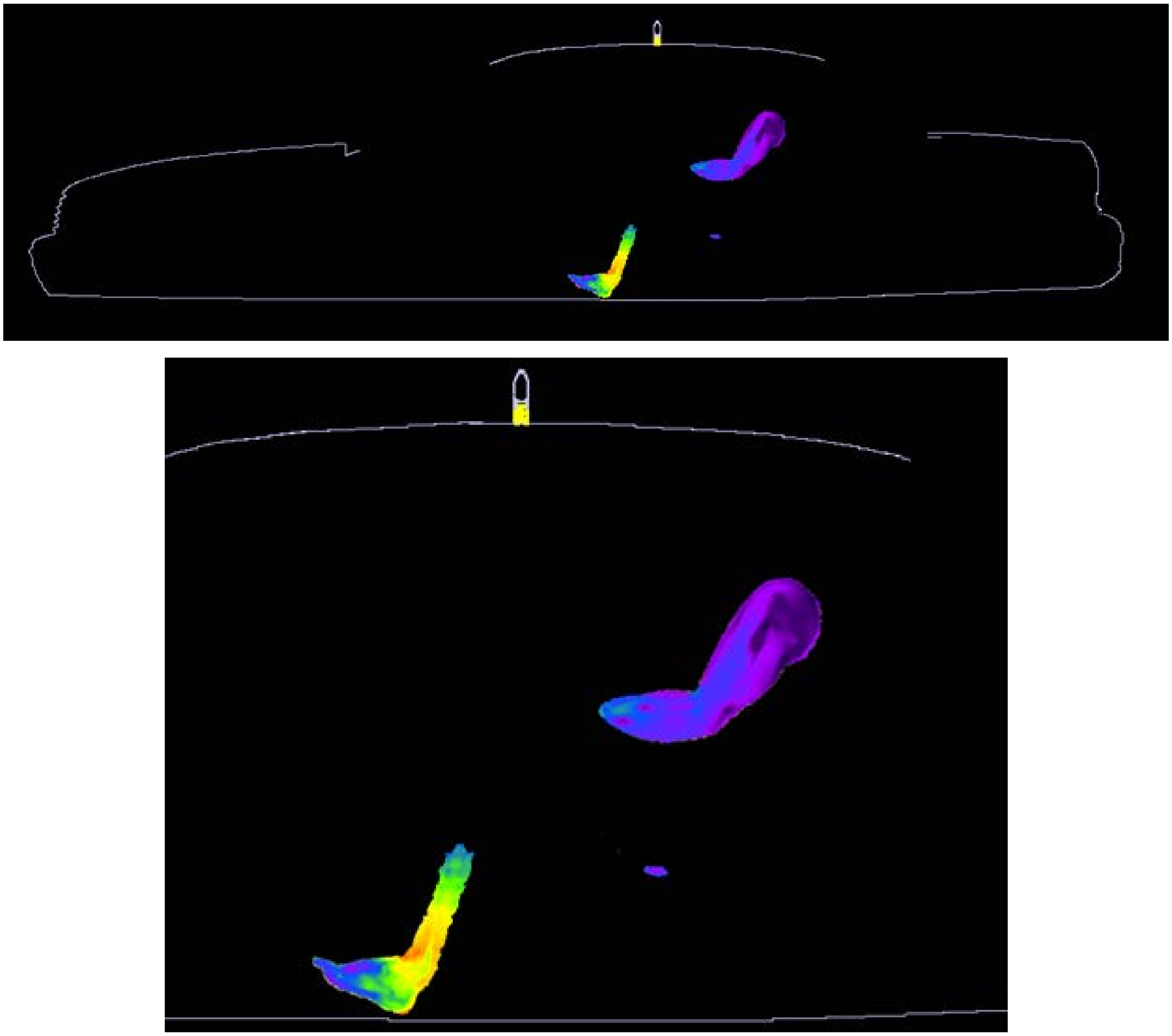
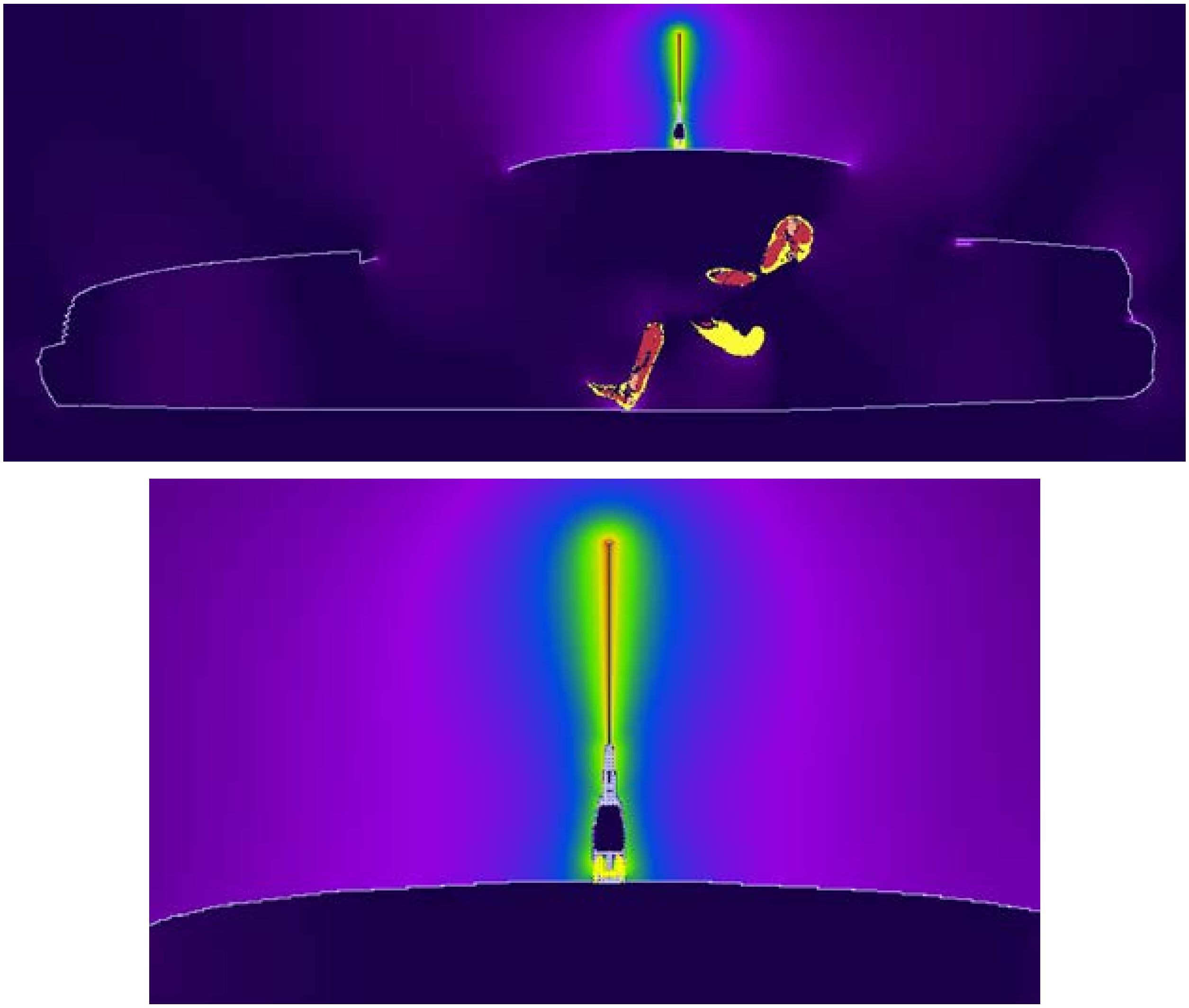
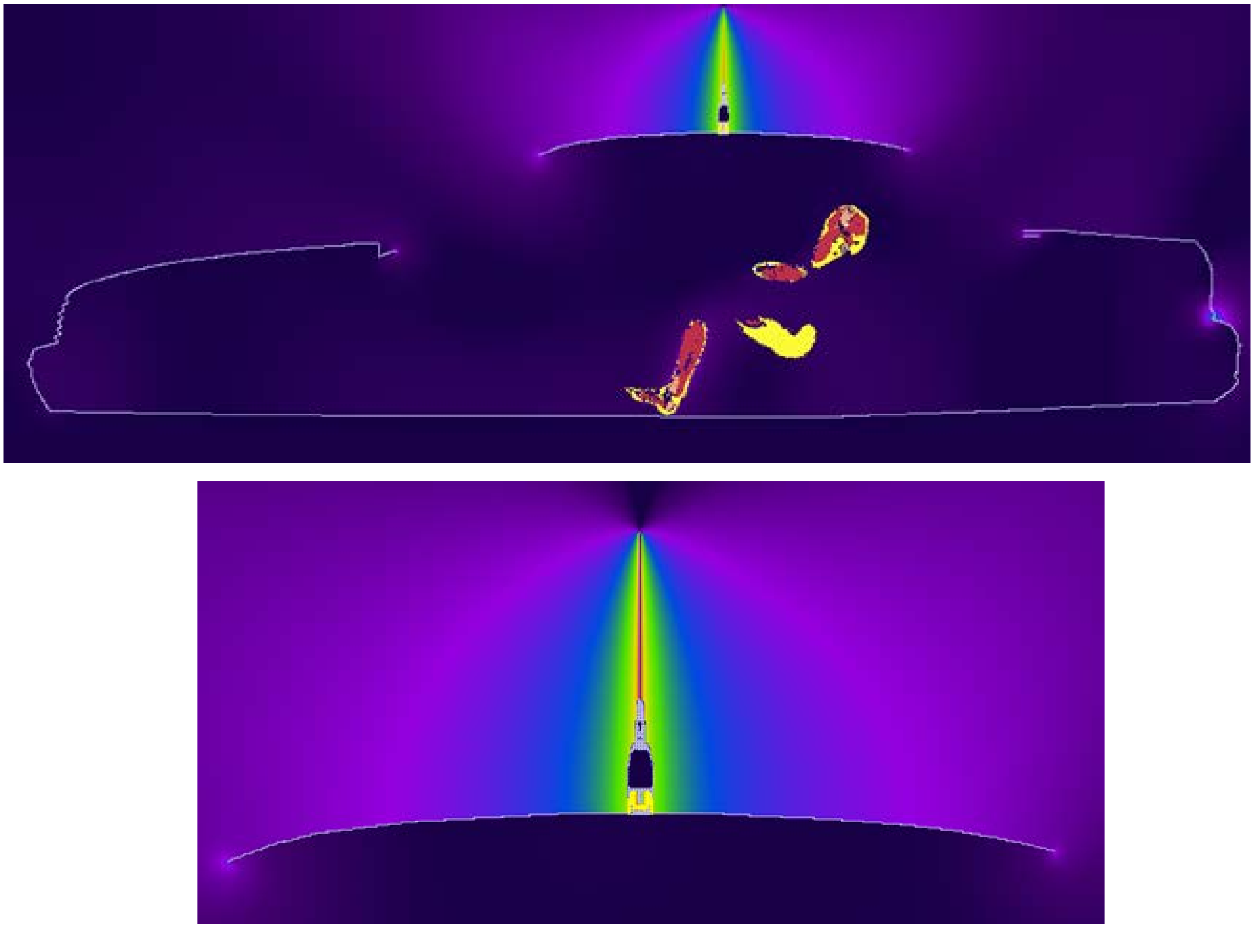


Figure 6. SAR distribution at 158.0125 MHz in the passenger model located on the side of the back seat, produced by the roof-mount AN000131A01 antenna. The contour plot is relative to the plane where the peak 1-g average SAR for this exposure condition occurs.

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

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 and Table 4 below list all the configurations that did not conform with 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 Bystander

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	FCC Limit (mW/cm^2)	% To FCC Spec Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Roof	AN000131A01, 1/4 wave (136-870MHz)	150.8000	0.33	0.20	167.1	Front	0.55	0.037	
						Rear	0.49	0.036	
		158.0125	0.33	0.20	166.9	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		173.0125	0.32	0.20	158.2	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		165.0125	0.26	0.20	129.3	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	173.0125	0.25	0.20	127.1	Front	0.36	0.018	
						Rear	0.52	0.019	
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	158.0125	0.20	0.20	100.4	Front	0.19	0.010	
						Rear	0.24	0.011	
Roof	*RAD4010ARB, 1/2 Wave (136-174MHz)	150.8000	0.20	0.20	100.0	Front	0.18	0.009	
						Rear	0.19	0.010	
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	173.0125	0.30	0.20	148.8	Front	0.58	0.033	
						Rear	0.94	0.034	
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	165.0125	0.23	0.20	114.2	Front	0.37	0.023	
						Rear	0.63	0.023	
Roof	*HAD4022A, 5/8 Wave (132-174MHz)	158.0125	0.22	0.20	110.9	Front	0.27	0.017	
						Rear	0.43	0.018	
Roof	*HAD4022A, 5/8 Wave (132-	150.8000	0.22	0.20	107.6	Front	0.28	0.017	
						Rear	0.42	0.017	

Note:
* Antenna length trimmed to frequency.

Table 3 (Continued): SAR Simulation Reduction Considerations for Bystander

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	FCC Limit (mW/cm^2)	% To FCC Spec Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Roof	HAD4016A, 1/4 Wave (136-162MHz)	150.8000	0.37	0.20	187.4	Front	0.54	0.035	
						Rear	0.49	0.035	
		162.000	0.32	0.20	158.9	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		156.4000	0.31	0.20	156.0	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
Roof	HAD4017A, 1/4 Wave (146-174MHz)	158.0125	0.34	0.20	168.8	Front	0.47	0.030	
						Rear	0.47	0.030	
		173.0125	0.31	0.20	156.5	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		165.0125	0.29	0.20	143.2	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		150.8000	0.25	0.20	122.6	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
Roof	HAD4021A, 1/4 Wave (136-174MHz)	150.8000	0.34	0.20	168.0	Front	0.54	0.035	
						Rear	0.49	0.035	
		158.0125	0.29	0.20	147.3	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		165.0125	0.24	0.20	117.8	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		173.0125	0.22	0.20	109.8	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	150.8000	0.41	0.20	202.8	Front	0.55	0.036	
						Rear	0.49	0.035	
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	156.4000	0.36	0.20	180.0	Front	0.48	0.030	
						Rear	0.48	0.029	
		162.0000	0.34	0.20	168.5	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
		150.8000	0.29	0.20	144.5	Front	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Rear	NA	NA	
Roof	HAD4009A, 1/4 Wave (162-174MHz)	173.0125	0.32	0.20	159.1	Front	0.65	0.050	
						Rear	1.03	0.048	
		165.0125	0.31	0.20	152.9	Front	0.45	0.035	
						Rear	0.66	0.035	
		162.0000	0.28	0.20	140.2	Front	NA	NA	The 2nd highest MPE configuration has SAR below 75% of the limit
						Rear	NA	NA	

Table 4: SAR Simulation Reduction Considerations for Passenger

Mount Location	Antenna Kit#	Freq (MHz)	P.D. (mW/cm^2)	FCC Limit (mW/cm^2)	% To FCC Spec Limit	Exposure Location	Adjusted SAR Results (W/kg)		SAR Simulation Reduction
							1 g	WB	
Roof	AN000131A01, 1/4 wave (136-870MHz)	158.0125	0.37	0.20	185.7	Back Center	0.33	0.011	
						Back Side	0.57	0.008	
		165.0125	0.35	0.20	175.2	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
		150.800	0.29	0.20	142.7	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
Roof	HAD4016A, 1/4 Wave (136-162MHz)	162.0000	0.34	0.20	171.0	Back Center	0.08	0.006	
						Back Side	0.22	0.005	
		156.4000	0.32	0.20	160.8	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
		150.8000	0.30	0.20	150.8	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
Roof	HAD4017A, 1/4 Wave (146-174MHz)	165.0125	0.42	0.20	212.1	Back Center	0.07	0.006	
						Back Side	0.19	0.006	
		158.0125	0.36	0.20	179.0	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
		150.8000	0.22	0.20	107.9	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
Roof	HAD4021A, 1/4 Wave (136-174MHz)	158.0125	0.33	0.20	164.9	Back Center	0.21	0.009	
						Back Side	0.29	0.006	
		150.8000	0.32	0.20	158.1	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
		165.0125	0.28	0.20	138.7	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
Roof	HAD4007A, 1/4 Wave (144-150.8MHz)	150.8000	0.37	0.20	184.9	Back Center	0.30	0.013	
						Back Side	0.54	0.012	
Roof	HAD4008A, 1/4 Wave (150.8-162MHz)	162.0000	0.36	0.20	182.0	Back Center	0.08	0.006	
						Back Side	0.22	0.006	
		156.4000	0.35	0.20	174.8	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
		150.8000	0.25	0.20	125.1	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	
Roof	HAD4009A, 1/4 Wave (162-174MHz)	165.0125	0.35	0.20	173.1	Back Center	0.07	0.006	
						Back Side	0.19	0.006	
		162.0000	0.29	0.20	143.8	Back Center	NA	NA	The highest MPE configuration has SAR below 50% of the limit.
						Back Side	NA	NA	

Results of SAR Computations

The overall simulated results the worst case peak SAR values were identified and SAR value in corresponding locations of the human body model. The maximum peak 1-g SAR is 1.03 W/kg, less than the 1.6 W/kg limit. The maximum whole-body average SAR for is 0.050 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 1379 SAR of persons exposed to vehicle mounted antennas W. Simon”, ICEAA September 2-7, 2012, Cape 1380 Town.