Simulation of In-vehicle SAR Levels at 900 MHz for a Car with Various Transmitter Positions and Human Occupancy Configurations

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INTRODUCTION

The impact of source location and human occupancy configurations on in-vehicle SAR levels due to 400 MHz on-board transmitters has previously been investigated using numerical models [1–2]. These results suggest that the ICNIRP [3] whole-body average SAR limits for general public exposure would be reached at lower power levels than the localized SAR limits, and that the average field levels over the empty vehicle interior would be approaching twice the field reference levels at the power associated with the average SAR limit in the worst case. This paper reports on an extension of this work to 900 MHz sources.

MATERIALS AND METHODS

A 3D numerical model was used to compute the electromagnetic field distribution over the passenger compartment of a car for horizontal and vertical dipoles located inside the cabin and for an external monopole mounted at the rear of the roof. Human simulants of realistic shape but homogeneous dielectric properties were added to the empty vehicle model in order to compute SAR for a driver and up to three passengers, resulting in nine simulations for each antenna configuration. The vehicle model was based on the major metallic parts of the car, including the bodyshell, doors, seat frames, steering gear and rear window heater array. Broadband simulations were carried out using a TLM (transmission line matrix) full wave field solver [4], and spatial field and SAR distributions were obtained at 900 MHz.

Electric and magnetic field data was extracted at more than 19 million points over the passenger compartment, and SAR values (averaged over 10 g of contiguous tissue) were obtained at more than 430,000 points for each of the four human simulants. These data sets were used to obtain average field levels for the empty vehicle and to determine the whole body average and maximum SAR values for each of the human simulants. The results were also normalized to 1 W CW radiated power in order to allow direct comparison between source/occupancy configurations and for convenient scaling to other radiated power levels.

RESULTS

The whole-body average SAR limit was found to be reached at lower power levels than the localized SAR limits, for all source positions and occupancy configurations. The results presented in Table 1 indicate the empty vehicle average internal electric fields at radiated power levels corresponding to the whole-body average SAR limit relative to the free space reference level. In Table 1 DR, FP, RD and RP denote the driver, front passenger, passenger behind the driver, and rear passenger behind the front passenger, respectively. The worst case over all of the occupancy configurations for each of the three source positions is indicated in bold. Thus, the SAR limits would be reached at radiated power levels producing average empty vehicle fields of 1.93 times the field reference levels for the roof-mounted antenna: for the internal dipoles this factor is 2.002 for the vertical case, and 2.278 for the horizontal case.

Vehicle occupancy case	RMS electric field at 900 MHz averaged over empty vehicle interior relative to reference level for radiated power levels corresponding to whole-body average SAR limit of [3]											
	Internal vertical dipole				*Internal horizontal dipole*				*Roof-mounted monopole*			
	DR	***FP***	***RD***	***RP***	***DR***	***FP***	***RD***	***RP***	***DR***	***FP***	***RD***	***RP***
1 person	2.766				2.547				2.326			
2 people	2.966	3.090			2.899	2.985			2.689	2.845		
	2.960		**2.002**		3.416		2.481		2.752		**1.929**	
	3.726			2.038	3.267			2.332	2.878			2.074
3 people	4.296		2.438	2.108	4.595		2.882	2.281	3.463		2.096	2.193
	4.060	3.208		2.053	3.553	3.755		2.409	3.289	3.325		2.080
	3.030	4.129	2.093		3.860	4.024	2.573		3.049	3.462	2.005	
4 people	4.270	4.661	2.459	2.061	4.851	5.314	2.921	**2.278**	3.750	4.040	2.123	2.263

Table 1: Safety factors provided by free space electric reference level at 900 MHz for in-vehicle whole-body average SAR over all source locations and human occupancy configurations investigated

CONCLUSIONS

At 900 MHz, comparing the average field over the interior of the empty vehicle with the field reference levels of [3] appears to give a reasonable safety factor for exposure risk assessments. These results are very similar to those found in earlier 400 MHz investigations.

The power balance method [5] has been shown to provide good estimates for the average fields over the interior of a car for the band 1–2 GHz [6]. This approach is expected to be increasingly successful at higher frequencies and for larger systems, where 3D numerical simulations may be impracticable. These observations suggest that initial risk assessments for in-vehicle human exposure could be achieved using relatively simple analytical calculations requiring very little geometrical data (only the window areas and glazing construction).

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