A Study of SAR on Child Passengers and Driver Due to Cellphone Connectivity within Vehicle

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Abstract **─** In this work, SAR values in passenger and driver head and body regions due to the presence of one or more cellphones were determined via simulation for the situation in which all vehicle passengers are children. Additionally, the adult driver has access to a hands free cellphone as part of increased in-vehicle connectivity. The FEKO tool, using the Method of Moments, was utilized for simulations.

Index Terms **─** Cellphone, in-vehicle connectivity, RF, SAR, specific absorption rate.

I. INTRODUCTION

Potential adverse impacts to health due to tissue heating [1] can result from radio frequency (RF) emissions. Such emissions are becoming more ubiquitous, due to the prevalence of cellphones, connected devices and increased expectations of connectivity within a vehicle. SAR is defined as:

$$SAR = (\sigma / \rho) |E|^2, \quad (1)$$

where σ is the tissue conductivity (S/m), ρ is the tissue mass density (Kg/m^3) and E is the (rms) electric field (v) in the tissue. Limits on the SAR values (in W/Kg) allowable have been set by various regulatory jurisdictions. In the United States, this limit is 1.6 W/kg. A standard SAR value of interest is the spatial peak SAR averaged over 1 gram of tissue.

It is known that SAR values for the same level of RF can be larger in a child's brain tissue (due to increased conductivity in the brain tissue) as contrasted with that of an adult [2, 3]. Gender differences also exist; this work utilizes a male child model at ten years old, in the fiftieth percentile of growth.

An initial study [4] on the level of SAR in a vehicle from cellphones involved a driver and adult passengers; a subset of whom utilized a cellphone at frequency 900 MHz. This study was extended [5] to higher frequencies. ***Our work considers*** an in-vehicle scenario in which *all passengers are children*, each with a cellphone, and the *adult driver has the option of using a 'hands-free' cellphone.*

The paper is organized as follows. Section II presents relevant models for use in the FEKO simulation environment with the Method of Moments (MOM) technique. Section III provides (spatial) peak SAR results (head and body) of vehicle occupants for different cases of passenger loading. Conclusions are given in Section IV.

II. MODEL DEVELOPMENT

A. Adult driver and child passenger models

The shape properties for the adult driver model are (1) a sphere for the head and (2) parallelepipeds for the torso, right and left lap and right and left legs. The adult model, shown in Fig. 1, utilizes dimensions from [4, 5]. Adult dimensions include: brain radius, 0.1 m and height from bottom of leg to center of head, 0.94 m. Neither brain nor body are modeled with any internal structure, following [4, 5].

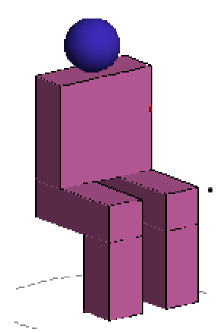

Fig. 1. Adult driver model.

Ibrani et al. [3] state that a child's head size phantom is eighty percent of an adult phantom, for children between seven and ten years old. Child body height is

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approximately seventy percent of an adult's height [2]. The ten year old male child model's dimensions are: brain radius, 0.08 m and height from bottom of the leg to center of brain, 0.668 m.

Permittivity (ε_r) and conductivity (σ) values differ between adult and child models and are frequency dependent. Our simulations use 900 MHz frequency. For adult brain tissue, $\varepsilon_r = 45.81$ and $\sigma = 0.77$ S/m. For adult muscle tissue, $\varepsilon_r = 55.96$ and $\sigma = 0.97$ S/m. In child brain tissue, $\varepsilon_r = 56.01$ and $\sigma = 1.00$ S/m. In child muscle tissue, $\varepsilon_r = 58.01$ and $\sigma = 0.99$ S/m.

B. Cellphone model

The cellphone model used is that of a ($\lambda/4$) monopole antenna radiating at frequency 900 MHz, also used in [4, 5]. The S1,1 parameter value, with resonant frequency at 900 MHz, is less than -25 dB. Antenna length is 108.3 mm. Antenna ground plane is 40 mm in length and 20 mm in width.

C. Vehicle model

Figure 2 shows the vehicle structure used in [4], modified for use in this work. Red lines show the modifications; these make the vehicle boxier. The windscreen is now flat above the metal front bottom. Side windows are rectangular; additional roof surface adjacent to side windows is now glass. This results in 0.92 m^2 more glass instead of metal in the front part of the roof. Note coordinate directions in Fig. 2. Vehicle components are aluminum and untreated glass. Permittivity and conductivity values are found in [4].

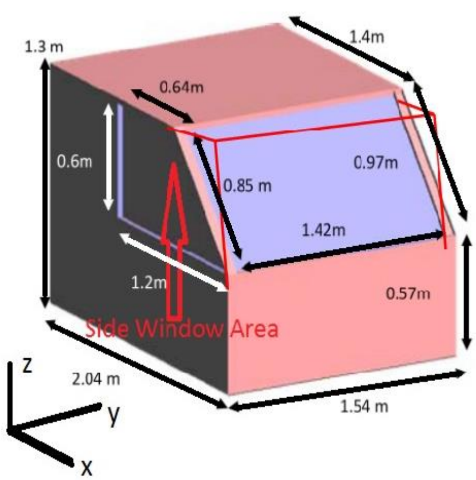

Fig. 2. Vehicle model.

D. Driver, passengers, and cellphones in vehicle

The left hand side of Fig. 3 shows the passenger layout (as in [4]). Here, each child passenger has a cellphone, indicated by a red dot. The rear seat child passengers have their torsos' back edge at x=0.167 m; the front seat child passenger's and adult driver's are at x=0.883 m. The right hand side of Fig. 3 shows the driver. The hands-free cellphone, indicated by the red dot, is located at approximately the same height as the middle of the driver's head; it is 0.72 m in front of the driver's torso's front and is at the windscreen's lateral midpoint. The front windscreen is x=0.03m beyond the cellphone placement. Windows and front windscreen are untreated glass (shown in brown).

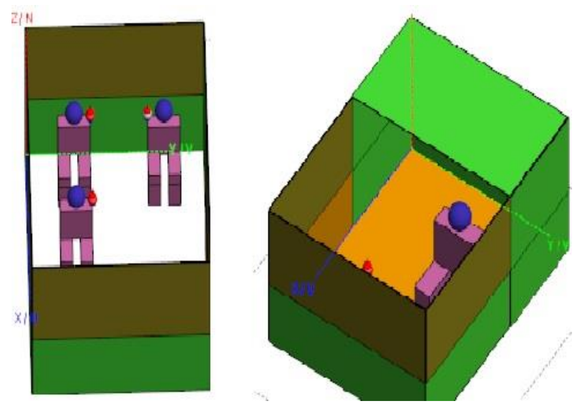

Fig. 3. Layout of child passengers (each with cellphone) and driver (with hands-free cellphone) in the vehicle.

III. SIMULATION RESULTS: SPATIAL PEAK SAR VALUES

Peak spatial SAR results for eleven different simulations developed in FEKO [6] are given in Table 1. Total power in each simulation run is 1.6 W. Note that Case 1 has one cellphone using 1.6 W power; thus, all SAR is due to radiation from one high powered cellphone.

Table 1: SAR simulation results

S	D	RF	RB	LB	HS	WHS	BS	WBS
1		X			0.845	RF	1.728	RF
2				X	0.914	LB	1.170	LB
3	X				0.014	DR	0.105	DR
4	X			X	0.596	LB	0.165	LB
5	X		X	X	0.32	LB, RB	0.573	LB
6	X		X		0.607	RB	0.843	RB
7	X	X		X	0.337	RF	0.563	LB
8	X	X			1.012	RF	1.272	RF
9	X	X		X	0.470	RF	0.755	RF
10	X	X	X		0.377	RB	0.622	RB
11	X			X	0.900	LB	1.148	LB

Keys to table abbreviations are: S=Simulation case number, D = Driver, (RF, RB, LB) = respectively, the Right Front Seat Child, Right Back Seat Child, and Left Back Seat Child, HS = Maximum Head SAR, BS = Maximum Body SAR, WHS = Person having the Maximum Head SAR, WBS = Person having Maximum Body SAR. SAR values are given in units of W/Kg.

Note the hands-free cellphone is not used in cases 1, 2, 9 and 11.

In cases Sim9 and Sim11, the hands-free cellphone is *not* used; induced SAR in the driver is due to passenger cellphones only. Note that the driver's head SAR is roughly an order of magnitude less than the driver's body SAR. In Sim3 (hands-free cellphone utilized), body SAR is 0.105 W/kg and head SAR is 0.014 W/Kg. Maximum body SAR of passengers is found in the upper torso region, close to the cellphone location. Peak body SAR is usually greater than the peak head SAR, consistent with a passenger's cellphone location being not immediately adjacent to the ear.

VI. CONCLUSION

This work, part of a larger effort investigating SAR values in child and adult occupants when multiple RF devices are in use, provides SAR results for multiple child and driver head and body regions. The hands-free cellphone option offers increased in-vehicle connectivity as well as increased RF. Physical reflection also contributes to SAR; as metal surface area is decreased in the boxier vehicle by approximately 1 m^2 relative to that of [4], reflections are reduced.

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[6] FEKO, Altair Hyperworks FEKO, Suite 7.0, Troy, MI.

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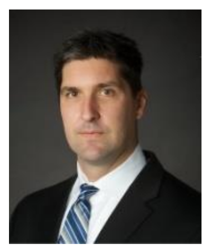

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