Investigation of the radiated power and the SAR induced by a mobile phone held by a human body inside a car

Abdelhamid Hadjem[1], Man Faï Wong[1], Joe Wiart[1]

[1] France Télécom, Orange labs, R&D. RESA/SAFE. 38-40 rue Général Leclerc,
92794 Issy les Moulineaux, France

Abstract

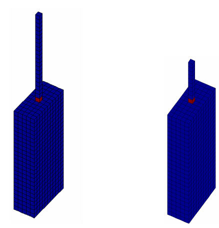
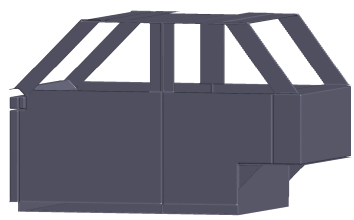
The aim of this study is to analyse the communication quality and the SAR (Specific Absorption Rate) induced in different human bodies in the presence of a car when using a mobile phone at two frequencies 900 MHz and 2100 MHz. In a first case study, the mobile is positioned at the head against the left or the right ear. In the second case study, the mobile is positioned near the hip, either in the trousers pocket or at the hip. The SAR and the power budget are determined using the finite-difference time-domain method.

1.Introduction

The wireless communications operators use more and more systems based on the transmission and reception of electromagnetic waves. Many questions are raised and related to the biological effects of these electromagnetic waves and in particular when using a radiofrequency source in a confined space as inside a car. As well, the loss due to a car is needed for the link budget. Today, the mobile phone is used by millions of users in different places. Therefore, it is of interest to analyse both the TRP (Total Radiated Power) and the SAR (Specific Absorption Rate) distribution in the human bodies. Previous studies have been carried out [1-3] dealing with different confined spaces as inside automotive environments. To protect the public from overexposure to electromagnetic fields, limits have been established by international organizations such as ICNIRP (International Commission on Non Ionizing Radiation Protection) [4] and IEEE [5]. This paper contributes to the analysis of the electromagnetic waves transmission and absorption in confined spaces. For this purpose, a comparison is performed concerning the SAR and the power budget between two case studies. The first one considers the mobile phone in voice position at the head of the human body seated inside a car. The second one considers the mobile phone placed either in the trousers pocket or at the hip of a human body seated inside a car. The results are computed with the well known finite-difference time-domain (FDTD) method [6].

2.Model and methodology

For the analysis, the body adult model named VH (Visible Human) [7] is used. The model is seated, follows the human morphology and is heterogeneous (Fig. 1). The resolution of this model is 4x4x4 mm^3 and is contained in a parallelepiped of 60.4x99.2x146 cm^3. The source model is composed of a perfect conductor body 20x44x100 mm^3. The length of the antenna is 84 mm for 900 MHz and 32 mm for 2100 MHz (Fig. 2). The truncated and simplified car model is contained in the parallelepiped of 132x240x152.4 cm^3 (Fig. 3).

	 *a. at 900MHz* *b. at 2100MHz*	
Fig. 1: VH Body seated	*Fig. 2: Different "monopole" mobile phone*	*Fig. 3: car's model*

For the two frequencies of 900 and 2100 MHz, the dielectric characteristics of human living tissue are chosen accordingly [8], the simulations are carried out for each studied frequency.
For each case of exposure, the absorbed power, due to the conductivity of human tissues, is calculated from the definition of the local SAR:

$$SAR = \frac{\sigma E^2}{\rho} \qquad (1)$$

where E is the rms amplitude of the electrical field in the body tissue (Volts per meter), σ is the tissue conductivity (Siemens per meter), and ρ is the tissue density (kilograms per meter). The "SAR10 g" is the maximum of the 10-g averaged SAR, which is obtained by averaging the SAR around each point in the volume adding the nearest points until an averaging mass of 10g is reached, the resulting volume has the shape of a portion of sphere.
The "SAR Whole Body (wb)" is calculated by averaging the local SAR over the whole body

A. First case study

In this first study, the mobile is positioned against the ear. In a first situation, only one seated phantom is inside a car. In the second situation, four seated phantoms are inside the car (Fig. 4. a). The source is positioned always on the same phantom (Fig. 4. b & c) and is positioned on the left ear and then on the right ear.

a. 4 VH inside the car *b. 1 VH and one source* *c. 4 VH and one source*

Fig. 4: Different configurations.

B. Second case study

The second case study, we use four phantoms and each phantom have two sources, the first in positioned at the hip level and the second one, is positioned in the trousers pocket (Fig. 5). The two seated phantoms in the front have their sources face to face, and the two seated phantoms in the rear have their sources facing the car metal body. The aim here is to calculate the worst case of TRP and SAR, when the source is in front of the car body, the distance between the source and the metal is ten centimetre.

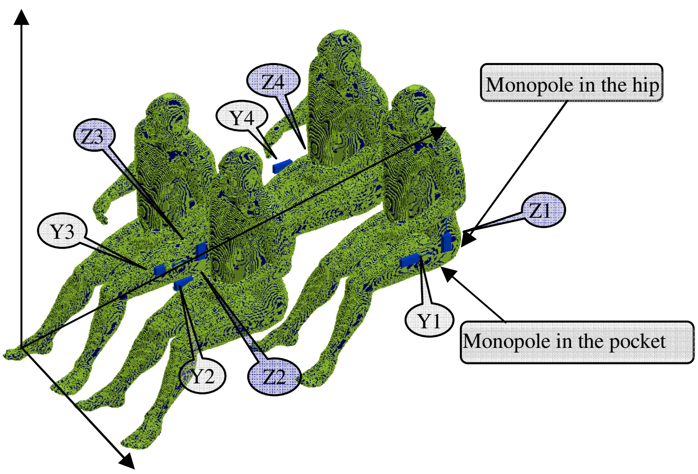


Fig. 5. Different positions of the source on the four phantoms

3.Numerical results and comparison

A. Results of the first case study

For the two frequencies, it is found that the presence of the car influence strongly the radiated power (Tables I & II) and it depends also on the position of the mobile (right ear: inside the car, left ear: in front of the glass), this radiated power variation can reach 40%. On the other hand, only 10% variation on the SAR over 10g is obtained at 900MHz and at 2100MHz the variation is as low as 2%. For SAR whole body (wb) the maximum variation is always 10% for both frequencies. The presence of the car can influence on the TRP value, this variation is between -0.4dB and -2.3dB.

Configurations	Source at 900MHz	Z (Ohm)	Abs. Power (%)	Rad. Power (%)	SAR10g (W/kg)	SAR wb (mW/kg)
1	**4 VH_Left_Car**	62+25i	84	16	0.79	6.56
1 bis	**4 VH_Left_CarLess**	65+20i	73	27	0.74	6.23
2	**4 VH_Right_Car**	67+33i	77	23	0.84	6.33
2 bis	**4 VH_Right_CarLess**	70+27i	68	32	0.76	5.94
3	**1 VH_Left_Car**	64+21i	77	23	0.78	6.86
3 bis	**1 VH_Left_CarLess**	64+19i	70	30	0.74	6.21
4	**1 VH_Right_Car**	67+32i	72	28	0.83	6.43
4 bis	**1 VH_Right_CarLess**	70+27i	67	33	0.76	5.94

Table I. Peak SAR and SAR (wb) for each configuration at 900MHz

Configurations	Source at 2100MHz	Z (Ohm)	Abs. Power (%)	Rad. Power (%)	SAR10g (W/kg)	SAR wb (mW/kg)
1	**4 VH_Left_Car**	54+35i	76	24	1.75	5.34
1 bis	**4 VH_Left_CarLess**	54+34i	64	36	1.73	5.05
2	**4 VH_Right_Car**	60+30i	65	35	0.96	5.32
2 bis	**4 VH_Right_CarLess**	61+30i	59	41	0.97	5.08
3	**1 VH_Left_Car**	53+34i	66	34	1.79	5.58
3 bis	**1 VH_Left_CarLess**	54+35i	60	40	1.73	5.04
4	**1 VH_Right_Car**	61+30i	62	38	0.96	5.43
4 bis	**1 VH_Right_CarLess**	61+30i	58	42	0.97	5.08

Table II. Peak SAR and SAR (wb) for each configuration at 2100MHz

Legend:

4 VH_Left Car : Four VH inside the car and the source is positioned on the left ear
4 VH_Left CarLess: Four VH in free space (without presence the car) and the source is positioned in the left of the ear

B. Results of the second case Study

For the two frequencies, it is found that the presence of the car, when the mobile is positioned at the hip of the phantom influence more strongly the radiated power (Table III & IV) and it depends also on the position of the mobile (in front of the metallic car body: position Z1 or Y1 and in the middle of the car: Z2 or Y2), this variation can reach 88%, the worst case is observed when the mobile phone is positioned between the phantom and the metallic car body.

Source (900MHz)	Z (Ohm)	Abs. Power (%)	Rad. Power (%)	SAR10g (W/kg)	SAR wb (mW/kg)
Z1	122-71i	96.5	3.5	0.51	2.2
Z1_carLess	112-35i	68.5	31.5	0.39	1.6
Z2	106-41i	94	6	0.40	1.7
Z2_CarLess	107-41i	87.5	12.5	0.39	1.65
Y1	107+9.7i	95	5	1	2.1
Y1_Carless	92+21i	78	22	0.84	1.76
Y2	89+18i	94	6	0.87	1.8
Y2_CarLess	90+19i	92	8	0.86	1.8

Table III. Power budget at 900MHz

The variation of the whole body SAR can reach 27% at 900 MHz and 50% at 2100 MHz. For SAR over 10g, the variation is 23% for 900MHz and at 2100MHz the variation is less important only 18%. When the source is positioned between the phantoms, the presence of the car does not influence the SAR over 10g and the whole body SAR.

It is found that the presence the car, in this study can strongly influence the TRP value, this variation is between -3dB and -9dB.

Source (2100MHz)	Z (Ohm)	Abs. Power (%)	Rad. Power (%)	SAR10g (W/kg)	SAR wb (mW/kg)
Z1	87+29i	89.7	10.3	0.81	1.9
Z1_CarLess	85+19i	42	58	0.66	0.96
Z2	87+21i	86.5	13.5	0.69	1.1
Z2_CarLess	88+20i	73	27	0.70	1.1
Y1	67+34i	93	7	1.78	1.8
Y1_CarLess	69+30i	68	32	1.63	1.5
Y2	69+32i	89	11	1.69	1.6
Y2_CarLess	69+32i	81	19	1.68	1.5

Table IV. Power budget at 2100MHz

4. Conclusion

A comparison of the TRP and SAR using monopole mobile phone in the presence or not of the car has been given for two frequencies 900MHz and 2100MHz. Both the average SAR (over mass of 10 g and whole body) in the phantom and the power budget are determined in two case studies using the FDTD method.
It is found that the presence the car, in the first case study (voice case) can strongly influence the TRP value, this variation is between -0.4dB and -2.3dB. In the second case study (mobile is positioned at the hip of the human body), the TRP variation is between -3dB and -9dB. For SAR over 10g at 900MHz, it is found that the 10% variation in the first case study and 30% variation in the second case study, for 2100MHz the variation is only 2% in the voice case and 10% in the second case study.

5. REFERENCES

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