E-Field Distribution and Dosimetry of an Anatomical Human Body model, Inside Elevator cabin:

Comparison between five different structures of elevator cabins

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***Abstract*—We study the distribution of electromagnetic field when a mobile phone is used inside an elevator cabin. To this end numerically accurate models of mobile phone and human are utilized. Two different positions in the elevator are examined and the mobile phone is placed at three different talk positions, vertical, tilt and cheek. Also five different cabin types are employed. As found, position of the user or placement of phone give drastically different maximum electromagnetic field values.**

***Index Terms*—Finite-difference time-domain (FDTD), Realistic Human Body, Specific Absorption Rate (SAR), Power Absorption, Elevator Cabin**

I. INTRODUCTION

Numerous efforts have been carried out to determine hazards from the use of mobile phones. Attention of the scientists has been put, among others on determining the power absorption when a phone user is in closed environment, like a car or elevator cabin.

C. K. Tang et.al [1], studied the effects of using mobile phone inside both fully and partially enclosed metallic elevators. They have found that the whole-body Specific Absorption Rate (SAR) increases more drastically as compared to local SAR, in other word whole body exposure assessment might be equally significant with the peak SAR assessment in the head [1]. Further, the level of exposure greatly depends on the design of mobile phone [2]. For different positions of mobile phone user, in full metallic enclosure, the induced E-field inside the head from a mobile phone user would variate considerably as compared to each other. Also the peak averaged over 10g of tissue SAR_{10g} depends on the position of the passenger and the antenna against the elevator walls [4].

Modeling only human head, some additional papers have studied the effects from metallic walls and full metallic enclosures of small size (much smaller than the size of a proper elevator cabin). They have shown that SAR values are increased in the full enclosures as compared to the free space [5,6]. Also when antenna is tilted 45 degrees from its initial position the SAR_{10g} is increased [7]. The structure of the enclosure and the material it is made of plays a role in determining SAR as well [8].

In this paper, we investigate the effects of five different structures of elevator cabins on the electromagnetic radiation that is generated by a mobile phone device used by a human. The anatomical human model is placed in two different positions inside the elevator and the cell phone is placed in three different talk positions: parallel, tilt & cheek position (IEEE 1528 std and CENELEC EN 62209) [9,10]. Two different frequencies, 1000MHz and 1650MHz, are implemented.

The numerical dosimetry simulations were carried out with the computational platform SEMCAD-X [11].

II. SPECIFIC ABSORPTION RATE (SAR) & LIMITS

Restrictions on exposure to time-varying electromagnetic fields are based directly on established health effects. The physical quantity used to determine these constraints is Specific Absorption Rate (SAR), which represents the level of absorption of electromagnetic power by biological tissue per unit mass of tissue.

The specific absorption rate (SAR) at any point inside the tissue can be calculated as:

$$SAR = \frac{\sigma |E|^2}{\rho} [W/kg]$$

where: σ *(Si/m):* the electrical conductivity, ρ *(kg/m^3):* the mass density of tissue and *E:* the effective value of the electric field. The whole body SAR can be calculated as:

$$SAR_{WB} = \frac{P_{abs}}{m} \; [W/kg]$$

where: P_{abs} *(W):* the absorbed power and m (kg): the whole mass of the absorber.

Standards for safety levels, with respect to human exposure to radiofrequency electromagnetic fields, determine that maximum allowed peak spatial average SAR over 1g of tissue is 1.6W/kg, for 10g of tissue is 2.0W/kg and for Whole-Body is 0.08W/kg.[12,13]. The above values are calculated for 6 minutes of exposure.

III. MODELS AND METHODS

The human model that was used in our research, is a numerically accurate anatomical human model of a 34-year old male, based on MRI (Magnetic Resonance Imaging), (Duke) from the Virtual Family (VF) [14].

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The mobile phone employed consists of 5 different materials, casing, screen, metal, antenna substrate and air (Fig. 1), developed by the French ANR project Kidpocket [15].

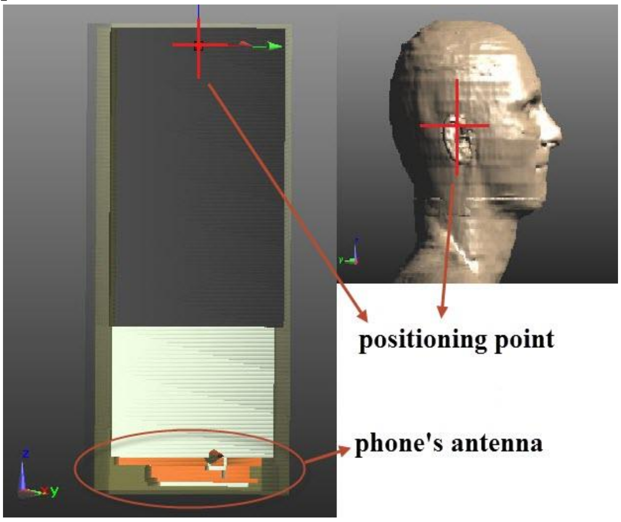

Figure 1. Numerical Mobile Phone model (105 x 28.5 x 10mm) and positioning points on phone and human model (not in real scale).

Phone antenna is at the bottom of it, and operates at 1000MHz and 1650MHz. The S_{11} at free space, is shown at Fig. 2 (a,b). The positioning point is chosen symmetrically for the horizontal axis of the phone and 5mm below the top edge of the phone (see Fig. 1). The reference power is 1W for both 1000MHz and 1650MHz.

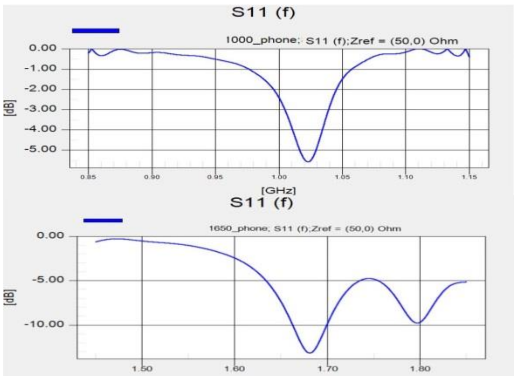

Figure 2. S_{11} of mobile phone in free space operating at, (a) 1000MHz, (b) 1650MHz. Zref=50 Ohm.

According to the directive for lifts from Greek Regulations for Buildings [16], for buildings higher than 9 meters, must be equipped with elevators that are able to serve people with disabilities and having a capacity for 8 people with a max-load of 600kg. The minimum size of such a lift is 1.50x1.70 m, and the corresponding dimension of the cabin platform is 1.10x1.40 m. We made an elevator cabin of dimensions 1.10x1.40x2.10m^3 and 10mm thick walls. Five different cases of lifts were examined:

1. full metal: a totally metallic enclosure,
2. dielectric floor: full metallic enclosure with a dielectric floor over the bottom of the cabin, with dielectric properties of ε_r=2.5, σ=0S/m, ρ=1000kg/m³
3. glass door: metallic enclosure with one wall made of glass at the same dimensions, representing a glass door, with dielectric properties ε=4.82F/m , μ=1H/m, σ=0.0043S/m, ρ=1000kg/m³
4. full glass: full glass enclosure with dielectric properties ε_r=4.82, σ=0.0043S/m, ρ=1000kg/m³
5. roof opening: metallic enclosure with an opening 250mm x 308mm, at center of the top wall, at 5% of the total dimensions of cabins roof (following the direction for existence of ventilation at elevators [17].

For these five cases, the human model-Duke, was placed at the center of elevator cabin (named center), at 433mm away from the left wall, from phone's side or 2.4λ at 1000MHz and 0.9λ away at 1650MHz Fig. 3 (a).

The second position for Duke was at the front left side of the lift Fig. 3 (b). Here the human model is located at 170mm away from the wall, from phone's side or 1.4λ at 1000MHz and 0.5λ away at 1650MHz.

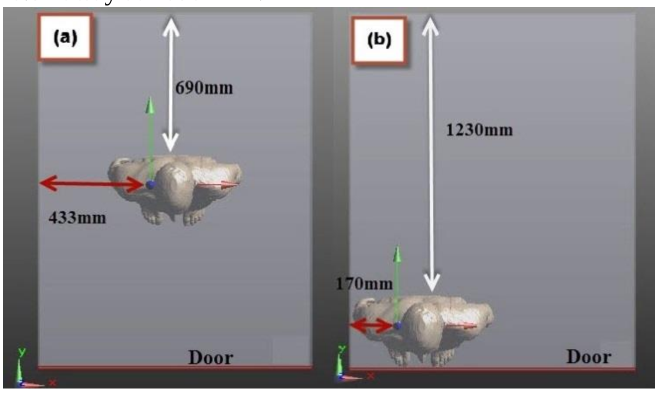

Figure 3. Positions of the human model inside the elevator cabin, (a) center, (b) front left (top view).

The cell phone is placed in three different talk positions: parallel, tilt & cheek position (IEEE 1528 std and CENELEC EN 62209) [9,10] (see Fig. 4).

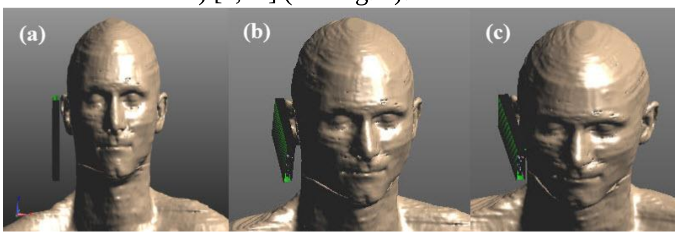

Figure 4. Positions of mobile phone in relation with Duke, (a) "vertical" position (b) "tilt" position and (c) "cheek" position.

IV. RESULTS & DISCUSSION

The SAR 1-g and the SAR 10-g results, are graphically represented below for 1000MHz and 1650MHz (Fig. 5- 6). For comparison, Duke at free space is also presented.

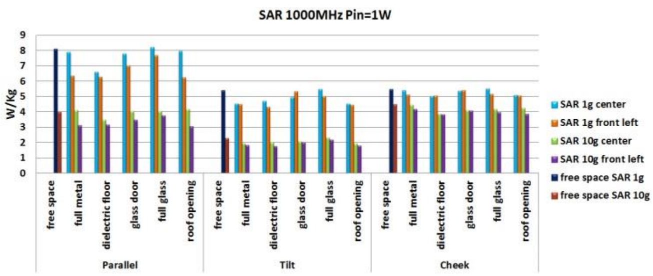

Figure 5. Graphic representation of SAR1-g & SAR 10-g for the two positions of Duke inside the elevator cabin and for three mobile phone's positions at operating frequency of 1000MHz and Pin = 1W.

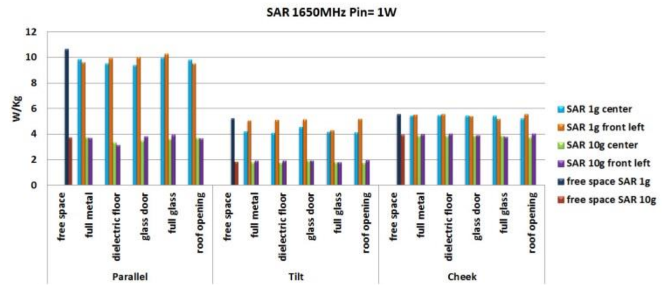

Figure 6. Graphic representation of SAR1-g & SAR 10-g for the two positions of Duke inside the elevator cabin and for three mobile phone's positions at operating frequency of 1650MHz and P_{in}=1W.

The SAR_{1g} at parallel phone position is higher for center and front left Duke's position inside the elevator as compared to the rest of configurations for both operating frequencies 1000MHz and 1650MHz. The SAR_{10g} tilt phone, center position, has the lowest values.

Figs. 7 and 8 are showing the whole-body SAR for the human model inside the elevator for all configurations considered.

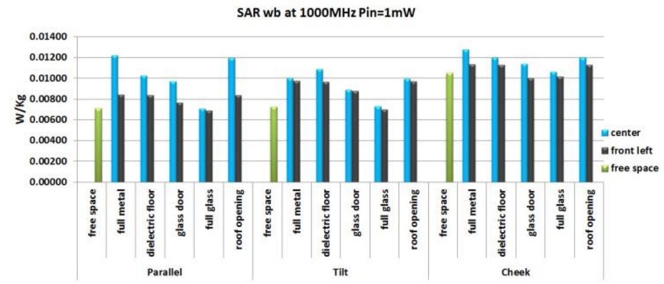

Figure 7. Graphic representation of whole-body SAR for the two positions of Duke inside the elevator cabin and for three mobile phone's positions at operating frequency of 1000MHz and Pin=1W.

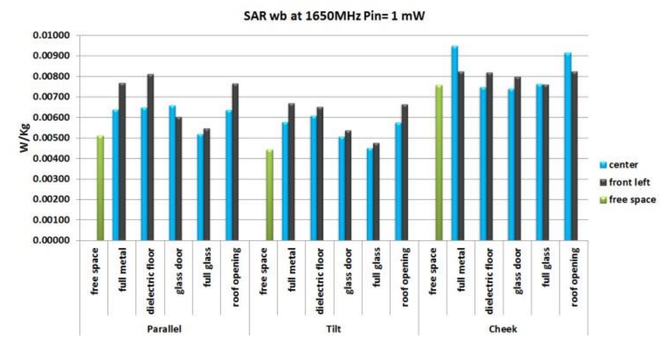

Figure 8. Graphic representation of whole-body SAR for the two positions of Duke inside the elevator cabin and for three mobile phone's positions at operating frequency of 1000MHz and P_{in}=1W.

All results from whole body SAR are far below limit, if we consider that the whole body SAR limit is 0.08W/kg and our highest value is 0.0032W/kg at 1000MHz and 0.00119W/kg at 1650MHz, both at cheek position of phone.

The power that has been absorbed by Duke can be seen at the table I & II below.

TABLE I. POWER ABSORBED BY DUKE AT THE TWO OPERATING FREQUENCIES OF PHONE 1000MHz FOR Pin=1W FOR ALL POSITIONS OF THE MODELS.

1000MHz						
	Duke center			**Duke front left**		
	Parallel	**Tilt**	**Cheek**	**Parallel**	**Tilt**	**Cheek**
free space	0.51	0.53	0.76	0.51	0.53	0.76
full metal	0.89	0.74	0.93	0.61	0.71	0.83
dielectric floor	0.88	0.85	0.88	0.61	0.7	0.82
glass door	0.71	0.65	0.83	0.56	0.64	0.78
full glass	0.52	0.53	0.77	0.5	0.51	0.74
roof opening	0.86	0.72	0.87	0.61	0.71	0.82

TABLE II. POWER ABSORBED BY DUKE AT THE TWO OPERATING FREQUENCIES OF PHONE 1650MHz FOR Pin=1W FOR ALL POSITIONS OF THE MODELS.

1650MHz						
	Duke center			**Duke front left**		
	Parallel	**Tilt**	**Cheek**	**Parallel**	**Tilt**	**Cheek**
free space	0.37	0.32	0.55	0.37	0.32	0.55
full metal	0.46	0.42	0.69	0.56	0.49	0.6
dielectric floor	0.47	0.52	0.55	0.59	0.47	0.6
glass door	0.48	0.37	0.54	0.44	0.39	0.59
full glass	0.38	0.33	0.55	0.4	0.34	0.55
roof opening	0.46	0.42	0.67	0.56	0.48	0.6

The absorbed power from the human model has the maximum values at cheek phone position, for both operating frequencies of 1000MHz and 1650MHz and both positions inside the cabin. At cheek position and full metal enclosure we have the maximum value of absorbed power.

The E-field distributions for all cases considered are given in Figs. 9, 10.

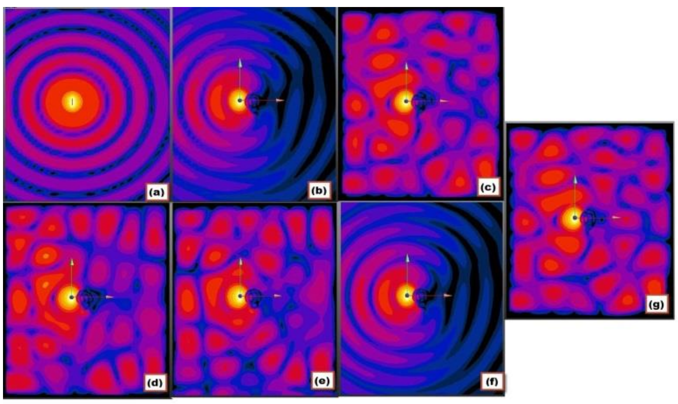

Figure 9. Graphic representation of the E-field distribution at 1000MHz at z layer for (a) the cell phone in free space, (b) Duke with cell phone in free space, (c) Duke inside the full metal enclosure, (d) the enclosure with dielectric floor, (e) the cabin with glass door, (f) full glass elevator and (g) the cabin with roof opening, at the center position of Duke and parallel for mobile phone.

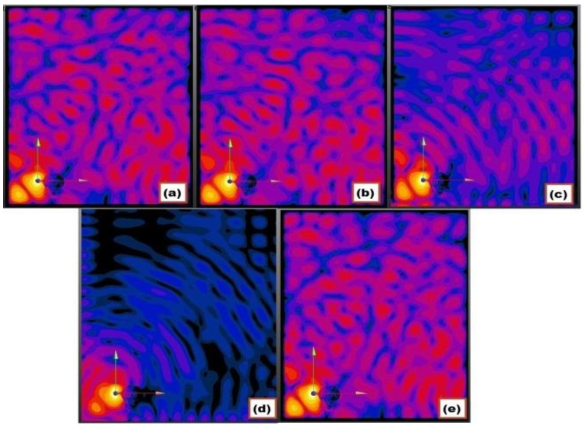

Figure 10. Graphic representation of the E-field distribution at 1650MHz at z layer for (a) Duke inside the full metal enclosure, (b) the enclosure with dielectric floor, (c) the cabin with glass door, (d) full glass elevator and (e) the cabin with roof opening, at the front left position of Duke and parallel for mobile phone.

From the E – field distributions we can see that the free space operation including the human model, has similar field distribution with the full glass model elevator when human is at center of it. Also the elevator with the glass door when Duke is at the center of cabin has similar field distribution with those of full enclosure and dielectric floor. However when Duke is at front left position full glass and glass door configuration give similar EM Field distribution. Full glass elevator seems also not to affect radiation, greatly, as expected. In all the other cases several hot spot areas can be noticed. This also explains why full glass SAR values are similar to those of free space.

V. Conclusion

From the obtained results we can see that the cheek position of mobile phone has the highest values for whole body SAR and SAR_{10g}, while the parallel position has the highest values for SAR_{1g}. The two positions of Duke inside the elevator didn't give many differences for both SAR's and absorbed power. Furthermore, the investigation of more passengers in the elevator cabin, under different occupancy conditions for the studied cases, should be explored.

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