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Field Emission of Portable Radio Transceivers and Its Deposition in Dielectric and Magnetic Head Tissues during Communication

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ABSTRACT

A radio transceiver used in front of the face, at full power emission of 5 W, was used for measurement and computation of the human head exposure to radiowaves emitted during its use. The incident power density and the absorbed power were assessed and compared against the human safety limits in the exposure standards, considering the brain as pure dielectric or as a magnetic dielectric respectively.

Key words: portable transceiver, electromagnetic exposure, power loss density, human brain, magnetite

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INTRODUCTION

Numerous electromagnetic field (EMF) emitting devices are used in front of the face presently, for communication reasons, the most well-known being mobile phones and portable transceivers. Mobile terminals are much better represented in literature, as being investigated from the point of view of the user's exposure to radiation. Portable transceivers, both low-power ones, like walkie-talkies, and medium-power ones, like professional or semi-professional ones, are less checked for their safety of use [1-3].

With the growing evidence that human brain contains significant quantities of magnetite nanoparticles (at tens of nanometres diameter), the contribution of EMF to overall power deposition in the head, when transmitted communication signals are propagating away from the terminal device, becomes even more interesting to be quantified in the head [4-5]. It is the objective of the present work to assess, both experimentally and by simulation, the exposure level due to the use of a dual-band (very high frequency, VHF, and ultra-high-frequency, UHF) portable transceiver in front of the face. Practically, the incident field level was measured and, using it as an input information, we computed, by means of a professional software, the power dissipated and the dose of radiation deposited in a human head model. Since the head model generally used in dosimetric studies is purely dielectric, here we also approached the magnetic-dielectric brain situation. In this case, magnetite (Fe_3O_4) millimetre particles were spread in the brain tissue. The reason was to observe if the magnetic (H)-field contribution significantly changes the total electromagnetic absorbed power and the stored energy in the head tissue, with consequences on the safety levels of use of the device.

MATERIALS AND PROCEDURE

The experiment was made using a portable transceiver model ID-51E Plus from iCOM (Japan), which allows communications in the bands 144-146 MHz (VHF) and 430-440 MHz (UHF). The device can emit on a set of five input power levels (Pin), the highest one being of 5 W. In all the cases treated here we made use of this Pin value.

A human head mannequin (empty shell) was used to locate the two field probes in front of the forehead for the measurements, as shown in Fig. 1. The electric (E)-field probe was a tri-axial one, model EM Sense 10 from ETS-Lindgren, while the H-field probe was model PBS-H2 from Aaronia, and for the measurements this one was connected to a swept spectrum analyser model FSH3 from Rohde & Schwarz. Both field probes are sensitive at both frequency bands. They are used to locally measure the EMF level incident to the forehead at 16 cm from the transceiver during its emission for voice communication. Both probes measured all three spatial components of the vector fields, Ex, Ey, Ez, Hx, Hy, Hz. All the components need to be known in the same point in space, since the power density (PD) can be computed afterwards by relation (1). The exposure situation is in the near-field conditions in both sub-bands so that E and H need separate determination.

$$\vec{S}=\vec{E} \times \vec{H} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ Ex & Ey & Ez \\ Hx & Hy & Hz \end{vmatrix} \tag{1}$$

In relation (1) S represents the Poynting vector, whose module is equal to PD. By using relation (1) we can calculate the incident PD, locally. This value will be then used as an input level for the simulations of the absorbed power. A series of artefacts may affect the measurements, as always when near-field conditions are met (deforming of the field by the probe's presence, capturing part of the field by the connecting cables, etc.). For the E-field probe, while it is using optical fibres exclusively, no such perturbations and collections are happening, but for the H-field probe, some errors may have not been excluded during the measurements.

Knowing the average value of the PD in a vertical plane parallel to the face of a person (incident PD value), as measured by the probes, we then aimed at the quantification of the power deposition in the head. This part of the work consisted in modelling-simulations made in CST Studio Suite [6], a commercial software destined to EMF dosimetry. Practically, the head model of Gustav, belonging to the Bio-Models library, 2.08 x 2.08 x 2 mm spatial resolution, containing 11 tissue types, was imported and used; from this, a number of 134028 voxels belong to the brain tissue while its mass is of 1211.905 g. This is the pure dielectric brain model. In a second approach, in the pure dielectric brain, a number of 100 small spheres of magnetite with radius of 1 mm were inserted. This second one will be called magnetic-dielectric brain model.

In both brain models the total power loss density and the stored electric- and magnetic-energy density were computed. The doses were compared against protective standards in use [7-8].

The dielectric properties of the head tissues in the frequency bands of interest are extracted from [9] while the dielectric and magnetic properties of magnetite were extrapolated from [10]. Relative electric permittivity, real and complex ones (ε_r', ε_r''), and relative complex magnetic permeability (μ_r', μ_r'') at the main interesting frequencies in the two bands are the following: a) at 145.5 MHz, ε_r'= 12.6, ε_r'' = 0.85 μ_r' = 4.2, μ_r'' = 0.3; b) at 432 MHz, ε_r'= 12.3, ε_r'' = 0.7 μ_r' = 3.5, μ_r'' = 0.4.

Fig. 1 The E-field probe (left) and the H-field probe (right) positioned for measurements in a plane parallel to the face

In the EMF stimulation a monopole helix antenna was modelled, to provide approximately the same average value of E- and H-field strengths in air, in a vertical plane which in the real measurements the field probes were positioned (Fig. 2). The antenna had 30 turns, was fed by a waveguide port, had a length of 22.5 cm and it was placed at 18.8cm from the plane were the incident field level was described (very near to the forehead). The position of this vertical plane is observed in Fig. 2 – right. One turn of the helix antenna had a diameter of 1 cm, the conductive wire of the antenna had a diameter of 1 mm and it was made of a perfect electric conductor.

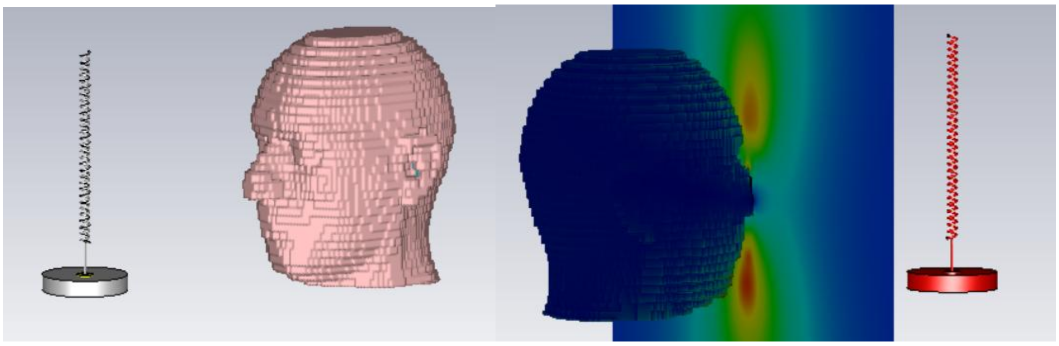

Fig. 2 Human head model (Gustav) with the emitting antenna placed in front of the face (left); Position of the vertical plane where the E- and H-fields in air were computed, so as to be approximately the same as the ones provided by the real antenna of the transceiver

RESULTS AND DISCUSSION

Fig. 3 shows the average values of the measured E-field strength, H-field strength and respectively the calculated PD, in the vertical plane of incidence in air, at 16 cm from the transceiver.To compare against the reference limits given in the protective guidelines of the population [7], [8], in case of the public and for local exposure,we indicate the limit values in the (144-146) MHz range: E_{limit}= 62 V/m, H_{limit}=0,163 A/m and PD_{limit}=10 W/m^2. Fig. 3 (left) shows that the measured E-field levels exceed thelimit, but they are still lower than the safe limit for professional exposure, which in this band is of 139 V/m. H-field levels (Fig. 3 – centre) and PD values (Fig. 3 – right) are all below the safety limit of the population in the VHF range. The emissions of the transceiver in the UHF range show the same exceedance of the incident E-field level (Fig. 3 – left), because in the frequency range (430-440) MHz the safe limits for local exposure of the public are: E_{limit}= 64.65 V/m, H_{limit}=0,168 A/m and PD_{limit}=10.88 W/m^2. The safety limit for occupational exposure is however obeyed, and this is of 144.93 V/m.So, in both bands of operation, E-field component is higher than the safe limit for population but lower than the safe limit of professional exposure.

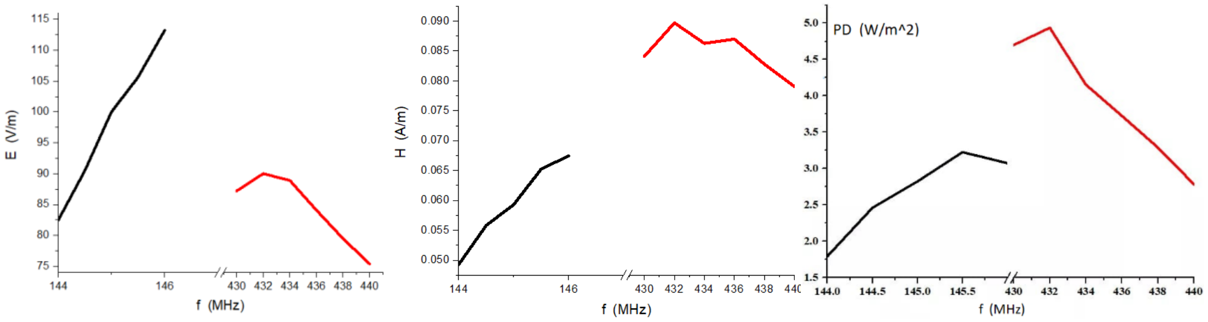

Fig. 3 Frequency variation of E-field, H-field and power density levels at 16 cm from the portable transceiver

To emphasize the impact of such exposures on the head, and using the Gustav head model, we were interested to observe the differences between the pure dielectric brain and in the magnetic-dielectric brain. We chose just one frequency per band, to make the computations: 145.5 MHz for the VHF range and 432 MHz for the UHF range – as they presented the maximums in the real exposure situations. The total volume occupied by the magnetite millimeter spheres in the brain was 0.419 cm^3 while the brain had a volume of 2144.661 cm^3. To mimic similar exposure levels in air, we first set the simulated powers in the helix antenna model, so as to get the approximate values of the E- and H-field strengths. In Fig. 4, the distribution of these fields are shown in the vertical plane indicated in Fig. 2 – right. Fig. 4 reveals that the presence of magnetite micro particles in the brain does not influence much the incident field levels in air, so that almost the same distributions are obtained. Fig. 4 – left present E-field levels at the two frequencies, while Fig. 4 – right present H-field levels in air, at incidence. If compare the couple of sub-figures (corresponding to the pure dielectric versus magnetic-dielectric brain model), we see no big differences in the external exposure. As seen in Fig. 4, similar values of the exposure were set in the simulation. For a better characterization of the incident field components distribution shown in Fig. 4, in Table 1 we present an overview of the values of the E- field and H-field strengths in air.

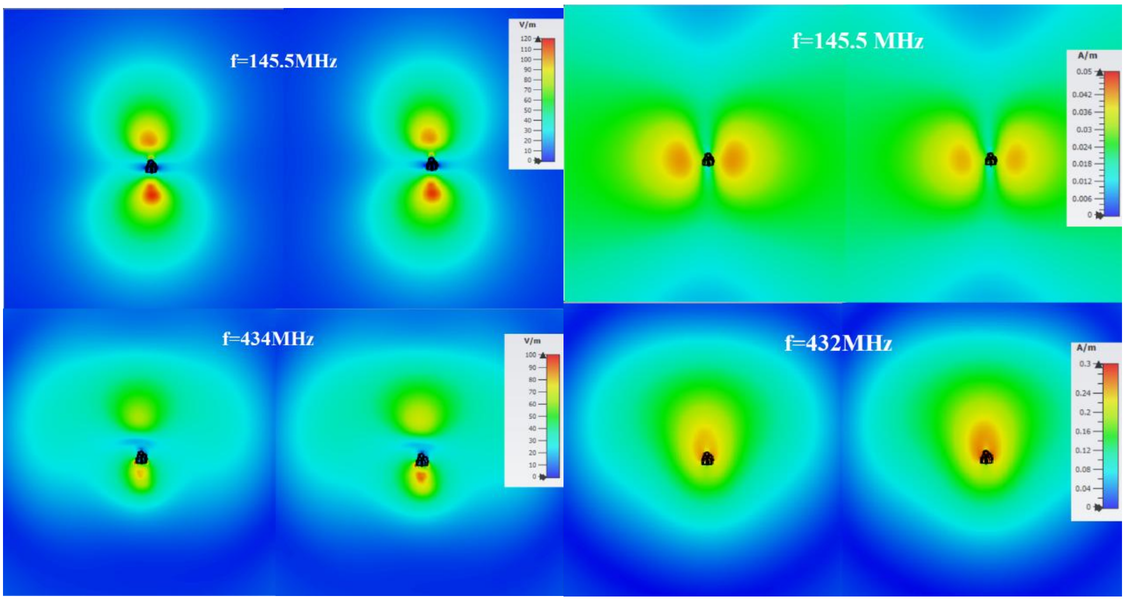

Fig. 4 Incident E-field levels (left) and H-field levels (right) in air, in the plane of incidence situated in front of the face; pairs of figures show minute differences when the head model doesn't contain or contains magnetite microspheres

Table 1- Overall values of the incident E- and H-field levels in the vertical incidence plane (in air) in the simulations

Brain case		E-Max (V/m)	E-Min (V/m)	E-Average (V/m)	H-Max (V/m)	H-Min (V/m)	H-Average (V/m)
145.5MHz	Pure dielectric	116.25	2.98	23.31	0.160	0.0149	0.0463
	Magnetic-dielectric	114.63	2.79	23.03	0.154	0.0146	0.0454
432MHz	Pure dielectric	108.14	8.99	23.91	0.39	0.026	0.0682
	Magnetic-dielectric	103.63	9.09	25.53	0.409	0.0259	0.0903

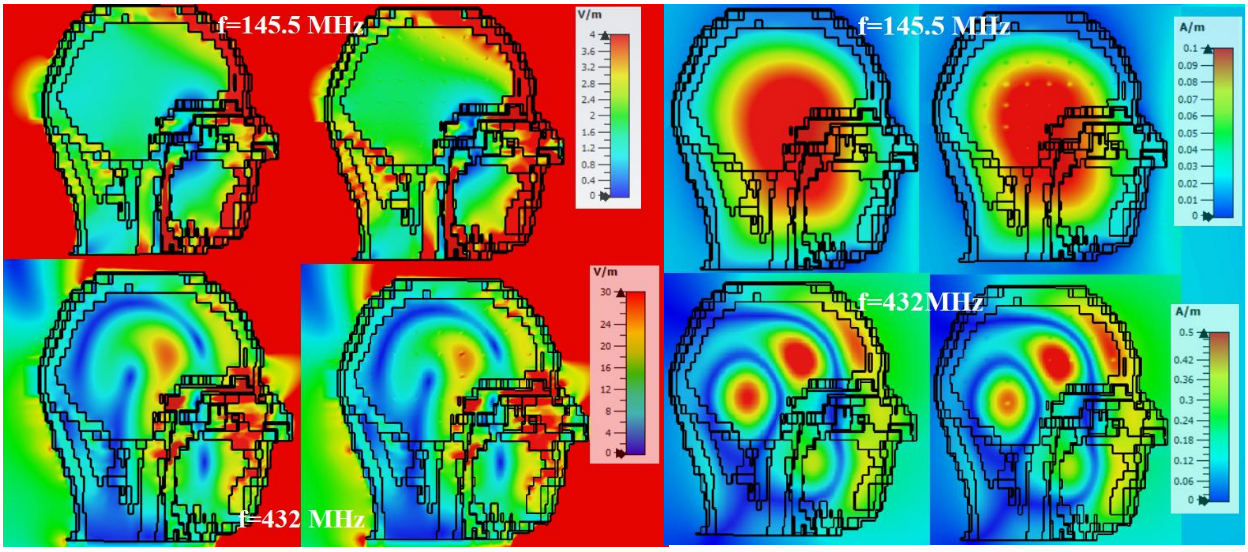

Fig. 5 Internal E- and H-field levels distribution in a central section plane in the head model at the two frequencies. Left subfigures show the pure dielectric brain, right sub-figures show the magnetic-dielectric brain

Fig. 5 depicts in couples of subfigures, the E- and H-field levels distributions in the vertical section plane cutting the head in its center, in the case of dielectric brain and in the case when the magnetic micro particles are present. In some subfigures their position is emphasized by observing completely different values of the local field strengths. Mainly the H-filed component shows the presence of magnetite spheres. Generally, at 432 MHz, both field components show higher maxima than at 145.5 MHz. The presence of magnetite may increase or decrease the local field.

Fig. 6 shows in a similar manner the electric energy density (left side group of four subfigures) distribution in the section plane, and respectively the magnetic energy density distribution (right side group of four figures). Significant differences are observed between the stored energy densities at the two frequencies and between dielectric versus magnetic-dielectric brain. Position and value of the maxima are different, and the presence of magnetite microspheres may change significantly the local values. At 432 MHz the stored energy densities are generally larger than at 145.5 MHz.

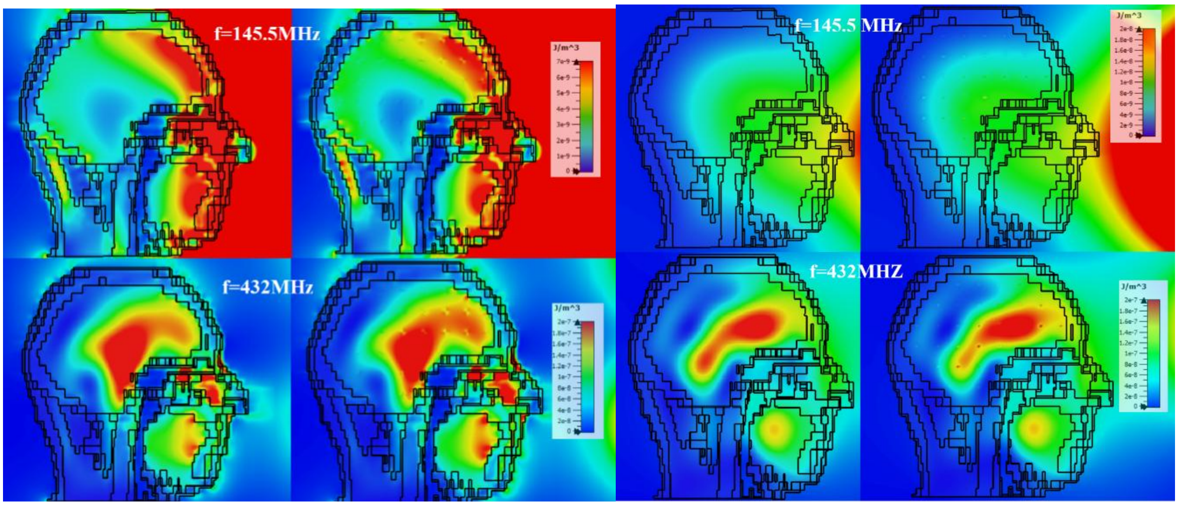

Fig. 6 Electric energy density (left half) and magnetic energy density (right half) distribution in the section plane in a non-magnetic versus magnetic brain model at the two frequencies.

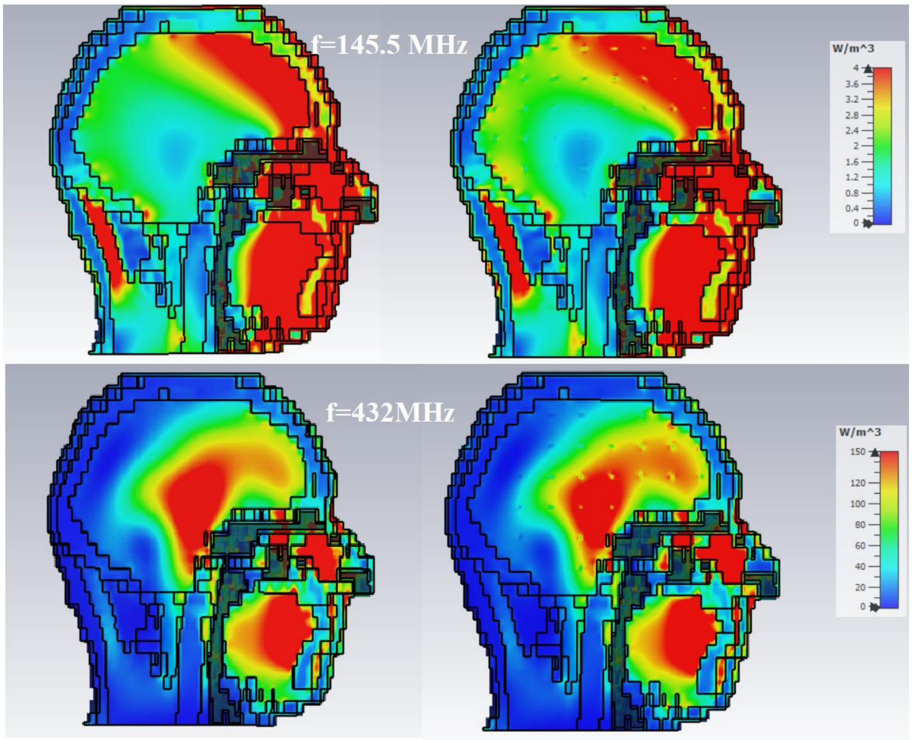

Fig. 7 Power loss density in the pure dielectric (left case) versus magnetic-dielectric (right case) brain model, at the two frequencies

To address the problem of tissue heating, the power loss density was computed. It took into account both parts of the dissipation: the electric and the magnetic losses. Usually, in the protection standards the specific absorption rate (SAR) of energy deposition is specified with its limit values. As SAR is expressed in W/kg while the power loss density is in W/m3, it can be easily transformed in SAR, if the mass density is known. However, in all computational software SAR calculation is based solely on the internal E-field strength values, since the tissues are generally considered purely dielectric. In our case, with considering the presence of magnetite micro particles, we were forced to use the total power loss density instead of SAR. Fig. 7 presents the power loss density distribution in the section plane at both frequencies and in both brain structure cases. It is observed that the influence of magnetite is significant and that the losses are much higher at the higher frequency. To address an overall image on the losseswhich will conduct to heating of the tissuesand on the stored energies in the head, in Table 2 we present the average and the max values of these parameters at both frequencies. Significantly higher values were gained at 432 MHz, even if incident average values of the field strengths (Table 1) are not very much different at the two frequencies. Generally, power loss density is also higher in situation no. 2 – corresponding to the sum of dielectric part of the brain and magnetite (magnetic brain mode) than in pure dielectric brain, at both frequencies. This implies that the presence of magnetite particles in the brain may increase the electromagnetic field absorption.

Table 2- Overall values of the deposited power loss density and of the stored energy densities (electric and magnetic parts) in the pure dielectric brain (situation no.1) and iin the magnetic-dielectric brain (situation no.2)

f = 144.5 MHz					
Brain type		**Power loss density (W/m^3)**		**Average energy density (J/m^3)**	
		Max	**Average**	**Electric**	**Magnetic**
1	Pure dielectric	30.78	2.04	2.77E-09	5.23E-09
2	Dielectric part	36.62	2.15	2.93E-09	5.34E-09
	Magnetite	4.30	1.71	2.88E-09	5.83E-09
f = 432 MHz					
1	Pure dielectric	466.2	46.68	6.36E-08	6.65E-08
2	Dielectric part	569.05	46.08	6.28E-08	6.64E-08
	Magnetite	141.93	38.83	6.55E-09	8.85E-09

CONCLUSION

The research treats the problem of human exposure to VHF and UHF frequencies generated by portable transceivers used for communication in front of the face. A specific type of such a transceiver was used as a source of radiation. Experimental exposure was assessed in the case when the transceiver's antenna received the highest input power, of 5W. During emission of voice signal, the transceiver was considered to be situated at 16 cm in front of the headof a mannequin. Both operating bands were considered: 144-146 MHz and 430-440 MHz in the expo-dosimetric analyses.

Due to recent discovery of significant quantities of magnetite in the human brain, in the numeric dosimetry part of the research we considered two cases of exposure: the pure dielectric brain and the magnetic-dielectric brain, to observe if the ferrimagnetic material's presence modifies significantly the absorbed electromagnetic power. The head model where the brain was located was an anthropomorphic one, composed of 11 tissue types. The simulated antenna was a helix monopole and, even not identic with the real one, it emitted field levels very similar with the real emitted ones, in the area of interest.

The exposure conditions were experimentally defined by measurements, and by simulations the doses were computed. In the measurements (near-field conditions) both the electric and the magnetic field components were determined. At the end it was revealed that: a) the electric field component exceeded the safety limits for local exposure (head)in case of population safety values, but not of occupational safety; b) for similar exposure conditions, the UHF band produces much higher absorption of energy and higher power dissipation in the head model; c) the presence of magnetite in the brain model intensifies both the stored energy and the power losses.

Present work provides a starting point in the assessment of the impact that some of the most intensive emitting commercial communication devices have on the user, from the point of view of bioelectromagnetic compatibility.

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