Statistical Analysis of the Power Spatial Distribution induced in the head of a GSM Mobile Phone User

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Introduction

With the fast growth of mobile telecommunication systems, concerns have been expressed about the possible health effects of exposure to ElectroMagnetic Field (EMF). Nevertheless questions are still open, to address these concerns the World Heath Organization launched the International EMF Project to provide a co-ordinated international response to the concerns about possible health effects of exposure to EMF. An international epidemiological case-control feasibility study has been conducted and it had put forward the importance of the Radio Frequency (RF) exposure estimation. Therefore, reliable instruments to measure and characterize RF exposure are needed for epidemiological studies, and an accurate assessment of RF field exposure, known as dosimetry, must be carried out.

However, this is not an easy task because the exposure depends on the handset position relatively to the head, on the design and characteristics of the mobile (e.g. the location and technology of the antenna), and on the power emitted by the handset: a GSM (Global System Mobile) phone does not emit always at its maximum power. Because of the different techniques used by GSM, the power emitted depends on the power control and is affected by the discontinuous mode of transmission which depends on the environment and the network managing.

The objective of this paper is to define a methodology, which allows us to characterize the spatial distribution of the exposure. It is based on a statistical analysis of the values of a set of observables that characterize the spatial distribution of the exposure. These observables have also been used to build a metric that allows one to compare the behavior of off the shelf mobile phones handsets.

A Principal Component Analysis (PCA) have been used to link the observables to some features of a handset, such as its size, antenna technology or phone design. This methodology allows one to produce a map of the power deposition in the head for the future analysis of the correlation between possible biological effects and RF exposure.

The first objective has been to define a limited number of statistical observables (e.g location of the main exposed area, shape of this area..) which are able to describe the RF exposure. These parameters define a metric that allows to compare the RF exposure. The second step has been to estimate these parameters for various handsets.

Since the measurements are carried out in homogeneous liquid, an effort have been done to compare, using the metric defined in the first, the RF exposure in homogeneous to heterogeneous head and the RF exposure in head phantoms. The equivalence of measurements and the validity of the extrapolation from homogeneous to heterogeneous model has been demonstrated.

The last step has been using statistic to analyze the RF exposure induced by classes of handset

Using this new approach the RF exposure in an operating network should be characterized and considered in the epidemiological study.

Observables definition for RF exposure characterization

The data acquisition was performed using an experimental procedure based on SAR (Specific Absorption Rate, $\mathrm{SAR} = \frac{\sigma E^2}{\rho}$) measurements (Figure 1(a)). A phantom of the head, is placed in an anechoic chamber and filled with an homogeneous liquid the electrical characteristics of which are similar to those of biological tissues as defined in the CENELEC standard. A probe is placed in the liquid to measure the electric field, radiated by a mobile phone, at a number of locations inside the phantom. The SAR values are then computed ($\mathrm{SAR} = \frac{\sigma E^2}{\rho}$)(Figure 1(b)).

Thirty one off the shelf mobile phones with different antenna types (wired, helicoidal and patch antennas), relative position with respect to the phantom, shape and size have been used.

An image processing of the data was carried out first to extract the iso-level n dB power contours (n=0.5,1,1.5,…,4dB).Then, the contours are described by ellipses. The peak value of the SAR is not a relevant parameter for classification purposes of mobile phones. Same amplitude and location of the Peak SAR can be obtained with different phones. In order to conduct the comparisons, we have considered seven parameters, called the observables. They are defined in Table1 and their values calculated for each phone and for each of the n dB contour equivalent ellipse. We can see a large variability of contours distribution for different phones.

Transposition of the study to an heterogeneous head

The constraints linked to measurement do that the liquid in which the measurements can be done is only homogenous. Our objective is to predict the exposure of real phones in a human head. We consider now the possibility of predicting the SAR spatial distribution due to a real phone in a human head, from the comparison of measured values of the SAR induced by a generic phone in a homogeneous liquid, and the numerical values of the SAR in a heterogeneous liquid.

For that purpose, we have superimposed the SAR contours of the generic phone extracted from measurements on those extracted from the numerical simulation, for the sagittal and transversal slices (Figure 2).

This will permit us to deduce the power spatial distribution for different mobile phones in the human head.

Thus, we can see a large variability of SAR spatial distribution in the head (Figure 3).This variability will be confirmed and justified by the statistical analysis and in particular by the Principal Component Analysis.

Statistical analysis

The observables defined and described previously were calculated for each of the thirty one mobile phones and each threshold. The variables and their values are then stored in a table which is of very great dimension. From which it appears thus difficult to extract a relevant information.

Then, a principal component analysis was carried out where the phones are called “Individuals” (N) and the observables “Variables” (P). Its aims are to synthesize the data by reducing the number of variables, and to determine closeness relations between individuals and variables.

In our analysis, we will seek a representation of the N individuals in a subspace of dimension K. In other words, it consists in defining K new variables, linear combinations of the initials. These new variables are called “Principal Component”, and the related coordinate axis the “Principal Axis”.

Among the results provided by the PCA, a measure of the degree of correlation between the variables.

A convenient geometrical representation of the variables and individuals in the first factorial plane (Figure 4) shows possible clusters of phones or outsiders.

Determining exposure levels

Starting from the previous study, it is of interest to establish levels of exposure in the head and to associate the exposure from each phone to each organ of the human head.

For this purpose, we have proceeded to a cartography of human head in order to quantify the exposure of each cube from a dosimetric point of view.

The constraints of construction of the cartography was that it must be simple and obvious to be operated quickly by the doctors and applicable to different head sizes. It must discriminate the areas of the head without associating them a very precise level of exposure. This discrimination of the areas of the head should permit the association of the localization of a tumor with the exposure of classes of phones and the main RF exposed areas.

The cartography has been chosen starting from referential anatomical planes: VCA, VCP, CACP, corpus callous tangential axis and anterior and posterior corpus callous edges. It was built on the three slices of the human head: sagittal, coronal and axial and the grid chosen was 1cmx1cmx1cm.

Phones classification

Starting from the PCA, we noticed that the clusters of mobile phones formed in the correlation circle represent classes of phones. We can count five classes .

The statistical tools approach allowed the construction of classes of phones with respect to the power distribution in the human head (Figure 5).

For each class of telephones defined previously, we calculated an average exposure of the power of all the telephone composing it, a median and a standard deviation.

Conclusion

In theory, it is possible to get the RF exposure induced by handset by measurement or numerical calculation. But some handsets are too complex to model, on the other hand commercial phones have to be measured in homogeneous phantom in order to verify their compliance to the international guidelines. The idea has been to use these measurements to estimate the RF exposure. We have conducted an analysis of the spatial distribution of the absorbed power which is strongly related to the characteristics of the phones. The use of statistical tools allow the construction of classes of phones with respect to their power distribution in the head. A methodology has been defined to analyze the correlation between tumors location and main exposed area of human head by knowing the SAR spatial distribution of real phones and the main exposed areas of the classes of mobile phones defined.

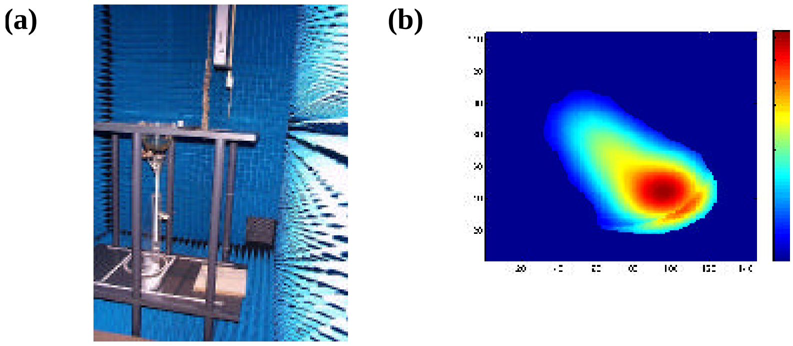


Figure 1 : (a) Dispositif de mesure(b) Map des valeurs de SAR dans le plan horizontal

Observables	Description
Large axis of the ellipse	
Teta	Tilt angle of the large axis in the XY plane (Figure4)
Surrounding ellipses eccentricity	e=c/a with $c^2=a^2-b^2$ focal distance
Peak SAR amplitude	
Depth	Distance between the peak SAR and the farthest point on the n dB contour in the YZ plane (Figure 4)
Contours deformation(Cont_Def)	Distance between the peak SAR and the most distant point of the given n dB contour
Included power (E_stand)	In each n dB contour, normalized to the relative peak SAR

Table 1 : Summary of the observables describing the absorbed power

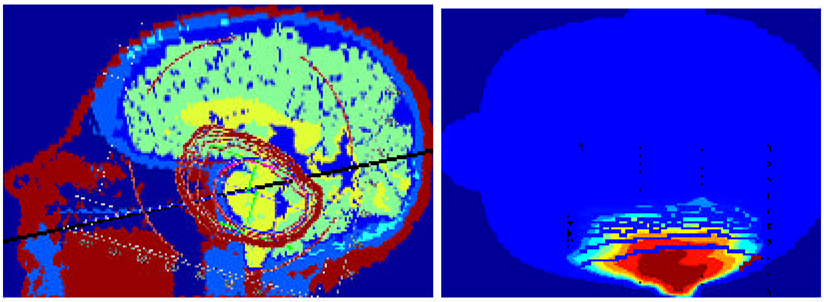


Figure 2 : Superimposition of measured SAR distribution of generic phone on an heterogeneous head

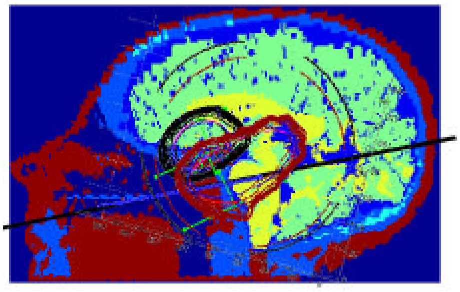


Figure 3: Different exposure areas according to each phone type

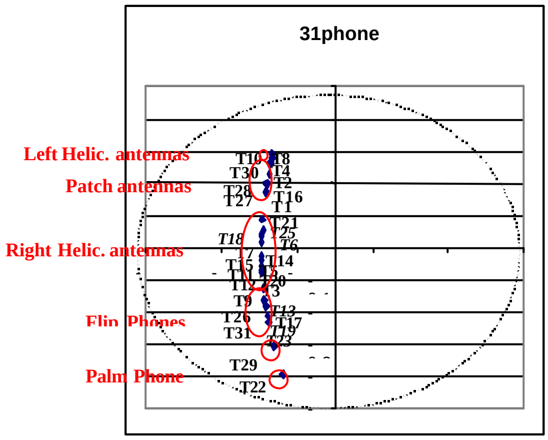
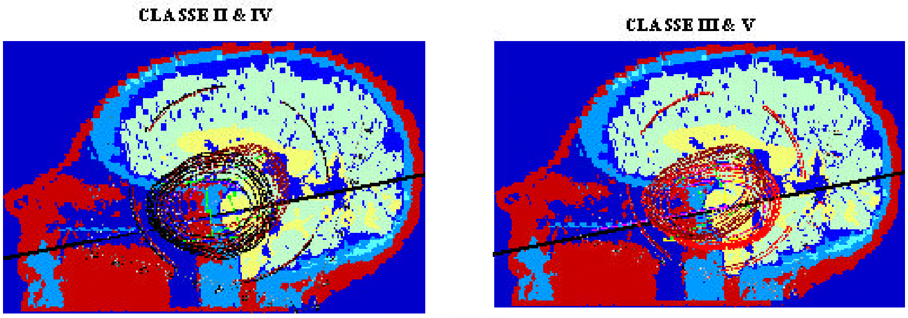


Figure 4: Classes of phones representation in the first factorial plane



CLASSE II & IV

CLASSE III & V

Classe I & V

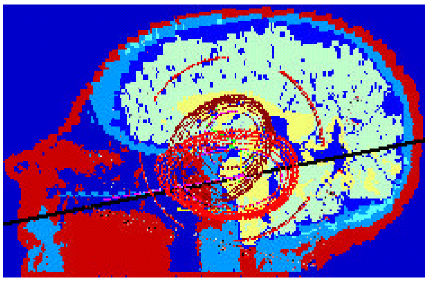


Figure 5: Power spatial distribution of phones classes