Interaction of electromagnetic fields and biological tissues

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Abstract. This paper deals with the electromagnetic field interact in biological tissues. It is actually one of the important challenges for the electromagnetic field for the recent years. The experimental techniques are use in Broad-band Dielectric Measurement (BDM) with LCR meters. The authors used Bones and scales of Fish taken from Narmada River (Rajghat Dist. Barwani) as biological tissues. Experimental work carried out done in inter-university consortium (IUC) Indore. The major difficulties that appear are related to the material properties, to the effect of the electromagnetic problem and to the thermal model of the biological tissues.

1. Introduction
A large number of equipment used everyday are electric or electronic ones, and thus generate electromagnetic fields. People are more and more concerned with the consequences of the exposure to the electromagnetic fields. The electromagnetic phenomenon into the cells to the electromagnetic properties values of the tissues. The daily exposure to an electromagnetic environment raises the question of the effects of electromagnetic fields on human health. The accurate assessment of the currents induced in the human body by an electromagnetic field is a major issue, not only for its relevance in medical research, but also for its implications on the definition of industrial standards [1]. Two types of applications may be highlighted. On one hand, electromagnetic fields can be considered as harmful to the health. Using the results of epidemiological studies and by application of the ALARA (As Low As Reasonably Achievable) principle, the from these restrictions using measurement techniques performed on very simple models. Unfortunately governments have imposed some limitations to the authorized radiated fields by the power systems. It has been proposed a set of maximum values of current density or specific absorption rate (SAR), according to the frequency. These values are called the basic restrictions, and reference levels for the fields are derived these reference levels are only external values. They cannot take into account the way the field develops inside the body and they do not take into account the environment of the exposed person. It is now necessary to increase the knowledge of the distribution of the fields inside the body in order to give a more acceptable limit to these radiated fields. On the other hand, electromagnetic fields are used for medical diagnosis (medical scanning MRI) or for medical treatment. As example, hyperthermia is used in oncology treatment to treat localized cancerous tumor [2]. The evaluation of temperature in the Bone and Scale is obtained by fish body tissues to a radiofrequency (RF) electromagnetic field. The
focalization of the heat inside the Bone and Scale is obtained by using several RF sources having specific phases and amplitude. The objective of this paper is to show the present difficulties related to the interaction of induced electromagnetic quantities in biological tissues [3]. The first part deals with the biological material properties. Second part deals with the effect of the electromagnetic problem.

2. Materials and method
The biological tissues with low water content (Dry) have been measured by performance dielectric probe kit. This performance dielectric probe kit is based on broad band measurement (BDM). To quickly and accurately estimate plant biological tissues in situ may provide producers with essential information for making this production. The power source for this method is impedance analyzer and LCR meters with high frequency resolution. The complete system is based on impedance analyzer. This measures the materials response to RF and microwave energy. The samples (Bones and Scales) were performed by different biological tissues in low water content (Dry). The two different fish species (catla-catla and common carp) of biological tissues (Bones and Scales) were taken from Narmada river Rajghat distt. Barwani (M.P.). First Bones and Scales body tissues remove from fish body. The remove biological tissues dried within 7 days in sunlight heat and preservations. The dried body tissues sample low water content (Dry). The samples prepare proper shape and size at different frequency ranges. The experimental works carried out done in inter university consortium UGC-DAE Indore (M.P.).

The Specific Absorption Rate (SAR) distribution has to be determined since it gives a measure of the energy absorption which can be manifested as heat, and since it gives a measure of the internal fields which could affect the biological system without heating (non-thermal interactions). The SAR (W/kg) is defined by

$$\text{SAR} = \frac{\sigma E^2}{P_m}$$

where $\sigma$ is the conductivity (S/m), $E$ is the root-mean-square magnitude of the electric field (V/m) at the considered point, and $P_m$ is the mass density (kg/m$^3$) of the tissue at that point.

3. Results and discussion
Compared to the material usually used in classical electromagnetic systems, the biological tissues are made of a large number of materials, each of them having specific properties. These properties have been extensively studied in the last fifty years from 10 Hz to almost 10 GHz [4]. In a parametric model able to represent them is presented together with the values of the model parameters for different tissues. Since biological tissues mainly consist of water, they behave neither as a conductor nor a dielectric, but as a dielectric with losses. It is also shown that electromagnetic properties values are highly depending on the frequency. Compared to classical dielectric materials, the dielectric permittivity is high: for example, at 1 KHz, the relative permittivity of the bone is 56. It generally decreases with the frequency. The electric conductivity is low but not zero. As example, the conductivity of the bone varies from 0.3211 to 0.9982 in the 1KHz-1GHz frequency band. The wetter a tissue is, the lossier it is; the drier it is, the less lossy it is. On the other hand, the permeability of biological tissues [5] is that of free space.

'Figure 1’, ‘Figure 2’, ‘Figure 3’, ‘Figure 4’, shows the variation of electromagnetic properties for three representative tissues in the range 1kHz-1GHz: bone (low water content) and scale (low water content). These non-usual values of the electromagnetic properties change the way that Maxwell’s equations are dealt with. According to the frequency-domain Ampere’s law, the ratio between conduction current and displacement current densities is given by the ratio $\omega \varepsilon / \sigma$. ‘Figure 5’, shows the variation of this ratio for the three previous tissues in the range 1kHz -10MHz (bone and scale) [6]. ‘Figure 6’, shows a zoom in the range 1 kHz-10MHz. Clearly, displacement currents cannot be neglected at low frequencies. Dosimetric studies are performed to quantify the interactions of electromagnetic fields with biological tissues. Whether they are numerical or experimental, determining the electromagnetic properties values of biological tissues is a critical step when calculating the SAR. There is not a real consensus on these values: straight comparison of the present data shows significant differences among permittivity values for the same tissue type. Variability
in reported values for a single organ may result from different reasons, such as the heterogeneous nature of the biological tissues [7], the freshness of the sample, the tissue preparation procedure, or metabolic changes in samples that occur after death. This poses the question of the effect of these values on calculated SAR values in biological systems. In, it is clear that the dependence of SAR on permittivity changes is important [8].

We have obtained slightly different results in the effect of the Bones and Scale tissues (which are actually not well known) on SAR distribution in local hyperthermia is analyzed. It is shown that neither the permittivity nor the conductivity has a great effect on the mean electric field inside the bones and scale (Table 1). On the other hand, since the SAR is directly proportional to the conductivity, the SAR value in the Bones and Scale is affected by the conductivity value. The temperature will consequently be modified: a SAR value of 20.62 & 10.4 W/kg induces an elevation temperature of 30°C, while a SAR value of 48 &111.75 W/kg increases the temperature in the bones and scale by 100°C.

![Figure 1. Bone catla-catla](image1.png)

![Figure 2. Bone common carp](image2.png)

![Figure 3. Scale catla-catla](image3.png)

![Figure 4. Scale common carp](image4.png)

**Figure 1 - 4. Variation with the frequency of the electromagnetic properties values of two representative fish body tissues.**

A biological tissue is represented as a heterogeneous and lossy dielectric, whose macroscopic dielectric properties are described by complex permittivity. Interfacial processes, such as Maxwell-Wagner effects, dipolar relaxation effects or counter ion relaxation effects, play an important role in the dielectric properties of tissues. This poses the problem of modeling assemblies of biological cells exposed to electric fields. When exposed to electric fields, a potential difference is induced across the cell membrane. This trans membrane potential (TMP) may be of sufficient magnitude to be biologically significant.
Table 1. The effect of different body tissues on the SAR calculate values

| Body tissues | ELF [Hz] | 30 °C | 50 °C | 100 °C | 150 °C |
|--------------|---------|-------|-------|--------|--------|
| Bone εr     | 147     | 254   | 666   | 799    |
| Bone σ      | 1.65 x 10^10 | 5.69 x 10^10 | 8.94 x 10^9 | 1.50 x 10^7 |
| Bone SAR    | 20.62   | 71.12 | 111.75 | 18.75  |
| Scale εr    | 196     | 37.5  | 9.2   | 6.36   |
| Scale σ     | 4.16 x 10^9 | 7.95 x 10^9 | 1.93 x 10^9 | 2.46 x 10^9 |
| Scale SAR   | 10.4    | 19.80 | 48.75 | 61.2   |

Figure 5. Variation with the frequency of the ratio ω ε/σ of two fish body tissues: Bones and scales

Figure 6. Variation with the frequency of the ratio ω ε/σ of two fish body tissues: Bones and scales-zoom on 1Hz - 10MHz band

4. Conclusions

An increasing use of the electromagnetic fields in medical applications can be forecast. Modelling the electromagnetic field distribution in these devices will allow designing optimized systems. On the other hand, a large number of equipment used everyday are electric or electronic ones, and thus generate electromagnetic fields. People are more and more concerned with the consequences of the exposure to the electromagnetic fields. The electromagnetic phenomena into the cells to the electromagnetic properties values of the tissues, to get accurate results on the whole frequency range, validate the electromagnetic-thermal coupling. But in any case, the control of the interaction between electromagnetic fields and biological tissues is one of the challenges for the recent years for which the Compumag community may play an important part.

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