

THE CRAWFORD CELL IN BIOELECTROMAGNETIC STUDIES

Pawel Bienkowski, Hubert Trzaska
Technical Univ. of Wroclaw, Poland
hubert.trzaska@pwr.wroc.pl

1. Introduction

The Crawford cell, primarily applied as an EMF standard, became one of the most popular tools, called TEM cell, in EMC in general, and in bioelectromagnetics in particular. Its most important advantages include: simple and inexpensive construction, simple relation between excitation and field intensity inside it, possibility to generate quite high EMF using quite low power and many others [1].

Unfortunately, an experience shows that there are many factors limiting the above enthusiasm that are not taken into account while the cell is in use [2]. Among others they are: very limited volume of quite uniform field, the uniformity is affected by an OUT, there are mutual couplings between an OUT and the cell walls and between the objects, problems with excitation measurements of loaded cell, presence and role of reflections, etc.

Observations of presented methodologies in bioelectromagnetics studies show that in many cases the studies are performed in conditions leading to large measuring errors. In order to call attention of the researchers upon the errors, the authors decided to briefly summarize role of several factors limiting accuracy of the experiments.

2. Limiting factors

2.1 Length of the cell

At the first approximation it may be concluded that a cell may be of arbitrary length and such solution applications may be seen in the literature. Let's consider allowed reflection factor at the output of the cell (Γ_2) versus its electrical length (l_c/λ) for the case while an input voltage of the cell is measured and field uniformity in the cell at the level of 2.5% and 5% is required. Results of estimations are presented in Fig.1.

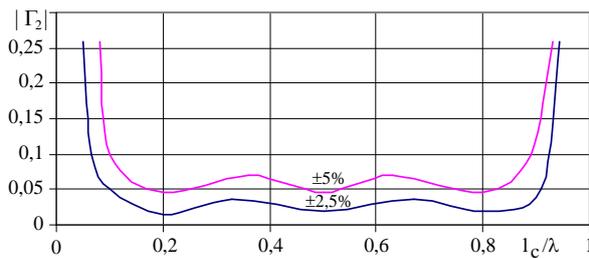


Fig.1 Allowed Γ_2 versus l_c/λ

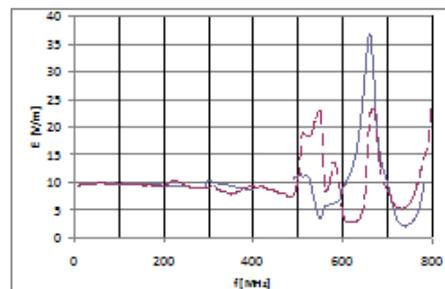


Fig.2 Measured field uniformity

Fig.1 allows concluding that a cell may be of any length and Γ_2 may be arbitrary for short cells ($l_c/\lambda < 0.05$). It is a result of very simplified approach to the estimations. In practice the field uniformity even within an empty cell is a function of its electric length and the case is illustrated in Fig.2, presenting results of the field uniformity measurements within a 30 cm long cell (the length includes two matching transformers at the both ends of the cell). Estimations and measurements were performed for an empty cell. The problem with excitation measurements and the field uniformity dramatically increases if the cell is loaded by an OUT. The experiment accuracy requires a measuring set (including a cell, wiring, couplers, etc.) as small as possible (in electric sense). For the field uniformity checking within a cell, empty and loaded, a small dipole probe is suggested. It will allow to see as frequency

limitations of the set as differences in the OUTs exposure in different parts of the cell. The probe should be as small as possible.

2.2 Mutual couplings

Apart from the field distribution in a cell and mismatching it an OUT, immersed between plates of the cell, is affected as by coupling with its mirror reflections in the walls of the cell and by coupling with other objects simultaneously exposed in the cell. It means that electric parameters of the objects in the cell are different as compared to that in the free space. It is followed by different absorption of EM energy. In order to illustrate the phenomenon a simple estimation was performed. Between two metallic plates are immersed three mice (Fig.3) such a way that mouse 2 is in the center and two others are in the center between it and a wall of the cell. For estimations the mice were replaced by 5 cm cubes of parameters typical for living matter. Results of absorbed power estimations (for $E = \text{const} = 1 \text{ V/m}$) are shown in Fig. 4. The estimations lead to a conclusion that the phenomenon may be neglected for objects fivefold smaller than the distance between plates.

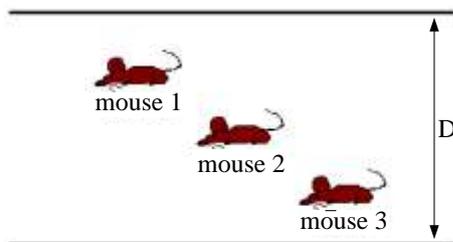


Fig.3 Three mice in a cell

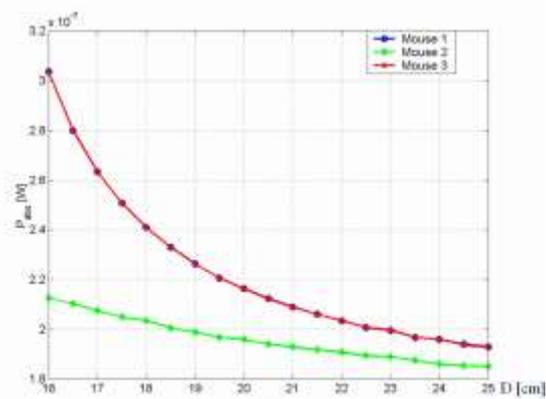


Fig.4 Power absorption versus D

3. Conclusions

Only two examples are above presented. Even it is enough to deduce that absorption measurements sometimes may be loaded by an error exceeding one order of magnitude. It is not fantasy of the authors. It is a typical scenario, presented in the literature. OUTs, exposed in dramatically different conditions, then are assumed and analyzed as exposed in identical conditions. What is an accuracy of such an experiment and what is worth of its results does not need any comment.

Any accuracy adjustment, in accordance with limiting influence and role of presented here factors (and other ones), would need a limitation of number and size (in relation to an exposure system) of exposed objects. It is evident that the approach will increase complexity of experiments and necessary spendings; however, it is a cost of the accuracy improvement.

The main problem here is not in the error. The problem is in mutual understanding between biomedical and technical part of experimenting teams and limited role of the latter. A physicist or an engineer, experienced in electromagnetics, must be responsible, in the team, for correct designing and exploitation of an exposure system that would assure the technical correctness of the system and minimization of measuring errors.

More details on the subject may be found in the literature [3]. In the final paper the newest results of studies and experiments will be shown.

References:

1. M.L.Crawford – Generation of standard EM fields using TEM transmission cells. IEEE Trans. Vol. EMC-16, No4/1974, pp. 189-195.
2. T.Babij, H.Trzaska - Accuracy limitations of the Crawford cell
Proc.1976 Conf.on Precision Electromagnetic Measurements, p.52, Boulder, CO.
3. E.Grudzinski, H.Trzaska – EMF standards and exposure systems. Scitech2013.