Power Frequency Electromagnetic Environment for Studying Bio-effects

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Abstract — In order to study the possible effects of power frequency electromagnetic irradiation of transmission lines on white mice, a power frequency electromagnetic environment was constructed in laboratory. Charge simulation method and Biot-Savart law have respectively been adopted to compute the three-dimensional electric and magnetic fields (EMF) in exposed environment. Both methods are programmed using the MATLAB software. Simulation and measurement indicate that the intensity of electric field can reach up to 10kil-volt per meter (kV/m) at ground level, and the magnetic flux density can amount to 100microtesla (μT). The paper concluded that the electromagnetic environment can be utilized to study on white mice simultaneous exposure.

I. INTRODUCTION

In 2002, International Agency for Research on Cancer (IARC) published a monograph classifying ELF magnetic field as "possibly carcinogenic to humans" [1].Unfortunately, there is still uncertainty about the relationship between childhood leukaemia and long-term exposure to extremely low frequency electromagnetic fields. If there were a known biophysical mechanism of interaction, it would be possible to identify the critical parameters of exposure. Due to the fields produced by power transmission lines can be characterized by many different physical parameters. In general, these parameters include transients, harmonic content, peak values and time above thresholds, as well as average levels [2]. It is not known which of these parameters is relevant for the induction of health effects. Moreover, it is very difficult to eliminate other potential risk factors, such as temperature, humidity and other deleterious gases. So some researches have begun to pay more attention to laboratory animal studies.

Animal studies are used when it is unethical or impractical to perform studies on humans and have the advantage that experimental conditions can be rigorously controlled for chronic exposure. In order to consider field characteristics sufficiently and eliminate other potential risk factors, a physical modeling is provided for the development of corresponding programs.

II. PHYSICAL MODELING

A three-phase single-circuit is consisted of a lots of line spans. The characteristics of electromagnetic fields induced by each line span are similar if the variable terrain is ignored. So a modeling simulated one line span of flat configuration would satisfy the condition.

The modeling mainly contains a step-down transformer, a step-up transformer, an insulating board, three-phase voltage lines, three-phase current lines, and a group of loads. The field environment under the board can be used to mice studies. Layout of modeling is simplified in Fig. 1.

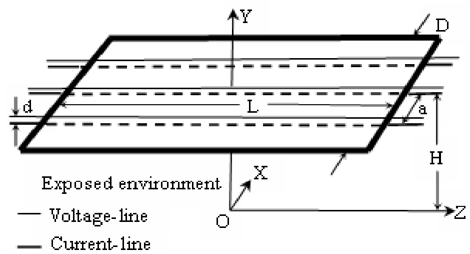


Fig. 1. Physical modeling

III. ELECTRIC AND MAGNETIC FIELD CALCULATION

The designated area of concern is the ground level directly under the insulating board. All calculations are based on the coordinate system shown in Fig. 1.

A. *Electric Field Calculation*

The solution methodology for electric field is based on three-dimensional charge simulation method [3][4]. The general relationship used to calculate the densities of linear charges on a multi conductor system is presented in matrix form in (1).

$$[\tau] = [P]^{-1}[\mathbf{U}] \quad (1)$$

Where [**τ**] is a column vector of the linear charge density on each conductor, [**U**] is a column vector of the potentials of the conductors, $[P]^{-1}$ is the inverted matrix of the Maxwell potential coefficients of the conductors. A set of image conductors is used with linear charges opposite to those of the transmission line. The actual conductors and their images are characterized by real and imaginary voltages and diameters. The self and mutual Maxwell potential coefficients are calculated for the conductor system on the basis of line geometry and conductor diameter using the following equations.

Self:

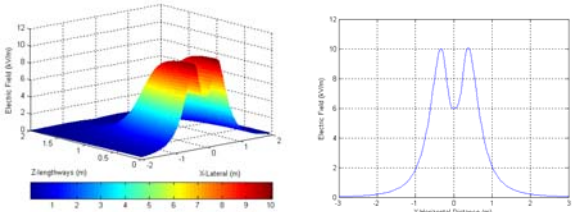
$$l_{ii} = \frac{1}{2\pi\varepsilon_r\varepsilon_0}\left(\ln\left(\frac{2L}{ND}\right) - \frac{L}{N(y_i)}\right) \quad (2)$$

Mutual:

$$l_{ij} = \frac{L}{4\pi\varepsilon_r\varepsilon_0 N}\left(\frac{1}{S} - \frac{1}{M}\right)$$
$$S = \sqrt{\left(x_j - x_i\right)^2 + \left(y_j - y_i\right)^2 + \left(z_j - z_i\right)^2} \qquad (3)$$
$$M = \sqrt{\left(x_j - x_i\right)^2 + \left(y_j + y_i\right)^2 + \left(z_j - z_i\right)^2}$$

Where ε_r and ε_0 are relative and absolute permittivity of the free space, L is the length of conductors, N is the number of nodes, D is geometric diameter of conductors, x_i, y_i, z_i and x_j, y_j, z_j are coordinates of two adjacent nodes with respect to a reference. The inverted potential coefficient matrix $[l]^{-1}$ is multiplied by the column matrix of line-ground conductor voltages to yield the charges per unit length of the conductor, as shown in (l).

The data is gathered in the three dimensions (3D) volume in the exposed environment. Since the modeling is symmetric for XOY-plane, the 3D calculated values are given for half span for the specified right and left lateral distance.



(a) 3D Profile (b) 2D Profile
Fig. 2. Electric field distribution

B. Magnetic Field Calculation

The magnetic flux density produced by a short element of current is given by the Biot-Savart law (4):

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl \times R^0}{R^2} \qquad (4)$$

Where d**B** is the element of the magnetic flux density vector, μ_0 is a permeability constant used for both air and ground. **Idl** is the vector of the current element, R is the vertical distance between vector **Idl** and point of interest. R^0 is the unit vector in the vector cross-product direction of vector **Idl** and the vector R^0.

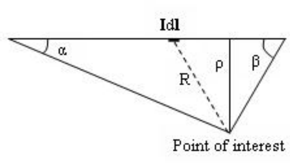


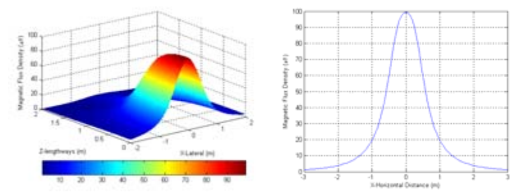
Fig. 3. Calculation of magnetic field

$$B = \frac{\mu_0 I}{4\pi\rho}\left(\sin\alpha - \sin\beta\right) \qquad (5)$$

A flowing current in any conductor, no matter how complicated shape of the conductor, can be broken down into a series of infinitesimally segments, joined end-to-end. So the following equation of integral form can be used for calculating the magnetic flux density of a conductor which is finite length (5). Fig. 3 shows the relationship of each parameter.

Where ρ is the vertical distance between the conductor and point of interest, α is the angle between **Idl** and **R** when **Idl** at the left end of the conductor, β is the angle between **Idl** and **R** when **Idl** at the right end of the conductor.

Fig. 4 displays the magnetic field distribution from XOY-plane to left base line of the insulating board only half of the span study area because of the symmetry.



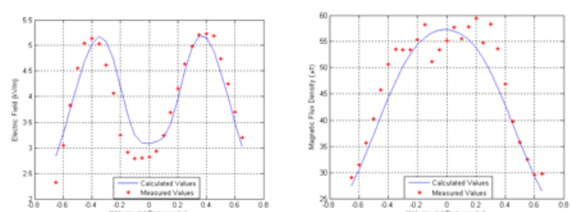
(a) 3D Profile (b) 2D Profile
Fig. 4. Magnetic field distribution

IV. COMPARISON OF MEASUREMENT AND SIMULATION

The device for producing electromagnetic environment was constructed, as showed in Fig. 5.

(a) Console (b) Electromagnetic environment
Fig. 5. Photos of power frequency electromagnetic device

We had measured the intensity of electric field and the magnetic flux density of simulation points with electromagnetic radiation analyzer (PMM8053B and EHP50C) at XOY-plane when designating a certain values of voltage and current, as shown in Fig. 6.



(a) Electric Field (b) Magnetic Flux Density
Fig. 6. Calculated values and measured values of electromagnetic fields

V. REFERENCES

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