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An Evaluation for Coupling of Human to Magnetic Fields in Human Ellipsoidal Models with Frequency up to 100kHz

Şükrü Özen[1], Selçuk Çömlekçi[1], and Osman Çerezci[2]

[1]Suleyman Demirel University Department of Electronics and Communication Engineering Isparta/Turkey

[2]Sakarya University Department of Electrical and Electronics Engineering Adapazarı/Turkey

ozen@mmf.sdu.edu.tr

Abstract: **Recently, so many studies were carried out about interaction between magnetic field on the band of 0-100kHz and human biology. Many of them are adressed to the canser risk of children. In this paper, certain band fields to the ellipsoid human models were investigated. As ellipsoid human models, average man, average woman, average endomorphic (fat) man, 10-year-old-child, 5-year-old-child, and 1-year-old-child models were selected. Investigations were made for different situations and orientations. Field strenghts induced by the external 10 mG (1µT) field were estimated for different variations. In the situation of external field was in front of the body, the maximum value was faund. When the external field was positioned parallel to major axis, the minimum value was obtained. For example, for 10-year-old child model, at 10 kHz, when the magnetic field was parallel to lenght axis induced electrical field, (E_{rms}) was 1.923 mV/m. When the magnetic field was parallel to the intermediate axis of body, its value was 2.176 mV/m and it was parallel to the minor axis of body, optained value was 3.93 mV/m.**

Key words: Electromagnetic field dosimetry, ellipsoidal models, exposure calculation.

I. INTRODUCTION

A number of epidemiological studies have reported positive associations between childhood cancer, leukemia, and the configuration of nearby residential electric power lines, often referred to as the wire code[1,2]. Several reports on this subject have appeared since Wertheimer and Leeper (1979) an association between childhood cancer mortality and proximity of homes to power distribution lines with what the researcher classified as high current configuration. To date there have been more than a dosen studies on childhood cancer and exposure to power frequency magnetic fields in the home produced by nearby power lines[1,3,4,5,6,7]. The fact that results for leukemia based on proximity of homes to power lines are relatively consistent led the U.S. National Academy of Sciences Committee to conclude that children living near power lines appear to be at increased risk of leukemia[8].

Over the years there also has been substantial interest in whether there is an association between magnetic field exposure and childhood brain cancer, the second most frequent type of cancer found in children. The recent studies completed after the NAS Committee's review fail to provide support for an association between brain cancer and children's exposure to magnetic fields, whether the source was power lines or electric blankets or whether magnetic fields were estimated by calculations or by wire codes[5,9,10]. The most intensively investigated environmental factor has been the time weighted average magnetic fields associated with electric currents on power lines and grounding systems. A large U.S. Case control Studies to test wheather childhood acute lymphoblstic leukemia is associated with exposure to 60-Hz magnetic field was published by Linet et. al.,[11].

According to [12], the power lines was the most important source of exposure when the magnetic field due to line was greater than about 0.2 micro T. The result of the study indicated that children who lived close to a power line had a higher magnetic field exposure than other children.

This study analyzes whole body exposure of homogeneous adults and children models-shaped elipsoids to uniform sinusoidal electric and magnetic fields with frequency up to 100kHz.

This frequency range are practical upper limits for dosimetric concern because of the time constants (>10µs) inherent to biological signaling within cell membranes[2].

Although this studies of whole body exposure to uniform electric and magnetic fields yields clear results, there may be limits to its applicability, because at least some sources of transient electric and magnetic fields are localized and will produce only partial-body exposures.

II. COUPLING MECHANISMS BETWEEN FIELDS AND THE BODY

The interaction of time-varying electric fields with the human body results in the flow of electric charge (electric current, the polarization of bound charge (formation of

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Abstract

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electric dipoles), and the reorientation of electric dipoles already present in tissue. The relative magnitudes of these different effects depend on the electrical properties of the body that is, electrical conductivity and permittivity. Electrical conductivity and permittivity vary with the type of body tissue and also depend on the frequency of the applied field. External electric fields to the body induce a surface charge on the body; this results in induced currents in the body, the distribution of which depends on exposure conditions, on the size and shape of the body, and on the body's position in the field.

The physical interaction of time-varying magnetic fields with the human body results in induced electric fields and circulating electric currents. The magnitudes of the induced field and the current density are proportional to the radius of the loop, the electrical conductivity of the tissue, and the rate of change and magnitude of the magnetic flux density. For a given magnitude and frequency of magnetic field, the strongest electric fields are induced where the loop dimensions are the greatest. The exact path and magnitude of the resulting current induced in any part of the body will depend on the electrical conductivity of the tissue.

III. ELLIPSIODAL MODELS OF ADULTS AND CHILDREN

The surface of an ellipsoid is defined by the equation (1),

$$(x/a)^2+(x/b)^2+(x/c)^2=1 \qquad (1)$$

Where x,y, and z are rectangular coordinates, and the size and shape of the ellipsoid are determined by the three parameters a, b, and c. (In this study, c≤b≤a).

A basic ellipoid is shown in Figure.1 Where 2a defines the lenght of the mojor (i.e., longest) axis of the body, 2b defines the lenght of the intermediate axis, and 2c defines the lenght of minor axis. When using an ellipsoid model to a person, 2a defines the person's height, 2b defines the person's width (measured from hip to hip), and 2c defines the person's depth (measured approximately from the surface of the abdomen to buttocks). Table.1 list the ellipsoid models and parameters of adults and children

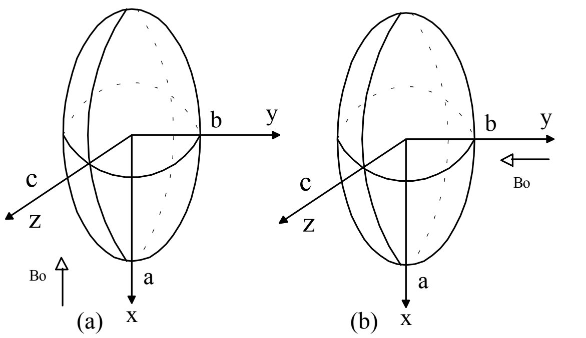

Figure.1 Ellipsoid models representation; a) Magnetic field is aligned with the major axis of the body, b) Magnetic field is aligned with the intermediate axis of the body

TABLE.I
ELLIPSOID PARAMETERS
FOR SELECTED HUMAN MODELS[13]

Selected Models	a	b	c
Average Man	0.875	0.195	0.098
Average Women(	0.805	0.2	0.091
Average Endomorphic (fat)man	0.88	0.225	0.17
10-Year-Old- Child	0.69	0.143	0.078
5-Year-Old- Child	0.56	0.12	0.069
1-Year-Old- Child	0.37	0.095	0.068

IV. MATHEMATICAL RELATIONS FOR COUPLING OF UNIFORM MAGNETIC FIELD TO ELLIPSOID

Consider a magnetic field, B_0, aligned parellel to the x axis. It can be shown that the induced electric field is in the y-z plane and is everywhere tangent to the ellipse $(y/b)^2+(z/c)^2=\eta^2$, where $1 \geq \eta \geq 0$ [14,15]. The strenght of the induced field E is [14]

$$E = \frac{\omega B_0}{b^2+c^2}\sqrt{b^4z^2+c^4y^2} \qquad (2)$$

The values of E_{max} and E_{rms} induced inside the ellipsoid are; [2]

1) B_0 is aligned with a (x) axis:

$$E_{\max} = B_0\omega\frac{b^2c}{b^2+c^2},$$

$$E_{rms} = \frac{\omega B_0}{\sqrt{5}}\frac{bc}{\sqrt{b^2+c^2}} \qquad (3)$$

2) B_0 is aligned with b (y) axis:

$$E_{\max} = B_0\omega\frac{a^2c}{a^2+c^2},$$

$$E_{rms} = \frac{\omega B_0}{\sqrt{5}}\frac{ac}{\sqrt{a^2+c^2}} \qquad (4)$$

3) B_0 is aligned with c (z) axis:

$$E_{\max} = B_0\omega\frac{a^2b}{a^2+b^2},$$

$$E_{rms} = \frac{\omega B_0}{\sqrt{5}}\frac{ab}{\sqrt{a^2+b^2}} \qquad (5)$$

V. INDUCED FIELDS INSIDE THE SELECTED HUMAN ELLIPSOIDAL MODELS

Table.II present calculated induced electric fields when the ellipsoidal models are with exposed 10 mG magneric fields. Data are given for each of the three orientations of external field relative to the axes of ellipsoidal models.

TABLE.II
VOLUME-RMS (E_{rms}) ELECTRIC FIELD STRENGHTS INDUCED
IN ELLIPSODAL MODELS OF HUMAN BY EXTERNAL 10 mG MAGNETIC FIELD

Selected Models	Induced Electric Field (mV/m)											
	B_0 is aligned with a axis (Bo//a)				B_0 is aligned with b axis (Bo//b)				B_0 is aligned with c axis (Bo//c)			
Exposure Frequency F, (kHz)	0.1	1	10	100	0.1	1	10	100	0.1	1	10	100
Average Man	0.0246	0.246	2.46	24.6	0.0273	0.273	2.735	27.35	0.0534	0.534	5.345	53.45
Av. Women	0.0232	0.232	2.326	23.263	0.0254	0.254	2.54	25.4	0.0545	0.545	5.451	54.51
Av. Endomorphic (fat)man	0.0381	0.381	3.809	38.094	0.0469	0.468	4.687	46.88	0.0612	0.612	6.122	61.22
10-Year-Old-Child	0.019	0.192	1.923	19.232	0.0218	0.217	2.176	21.77	0.0393	0.393	3.932	39.33
5-Year-Old-Child	0.0168	0.168	1.68	16.8	0.019	0.192	1.923	19.23	0.033	0.33	3.3	33
1-Year-Old-Child	0.0155	0.155	1.55	15.5	0.0188	0.187	1.878	18.78	0.0258	0.258	2.584	25.84

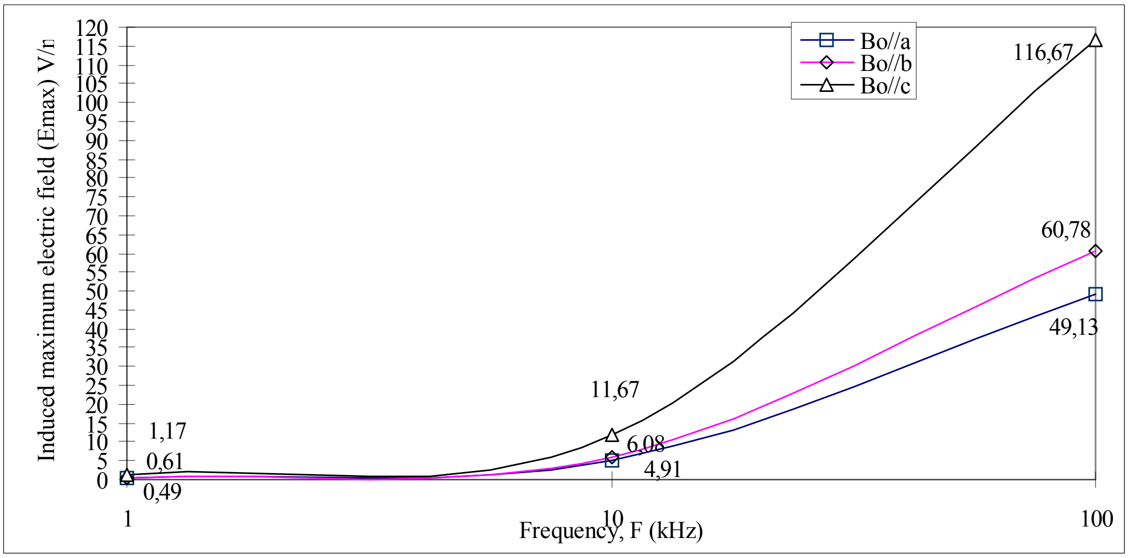

Figure.2 Comparison of exposure to field orientation for average man

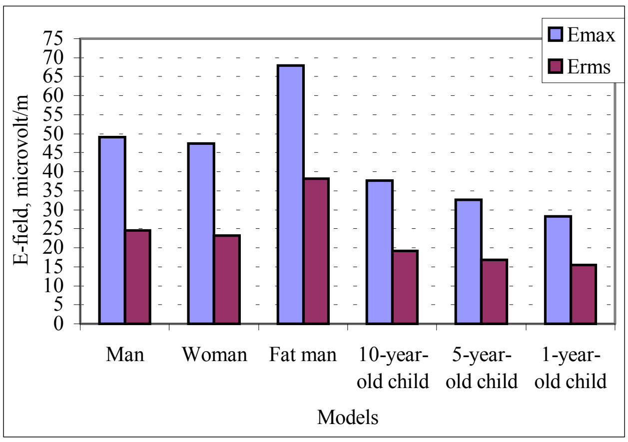

Figure. 3 Induced electric field for selected ellipsoidal human models, f=0.1kHz (External magnetic field aligned with the long axis of the body)

Some value of exposure can be found from Figure.2 It's easy to compare the exposures for field orientations. At exposure frequency, induced electric field varies with releated to field orientation and models. In Figure.3, for fat man, E_{max} is shown the greates value. But it varies from model to model. The size and shape of the body is the major parameter.

VI. CONCLUTIONS

In this paper, for ellipsoidal body models, in the situation of 10 mG (1μT) exposure, induced electric fields have been analyzed. Results vary with the orientation of field or the size of body. When the external magnetic field is applied as paralle to the long axis of body (B_o//a, i.e., aligned with the long axis of the body), induced field to the body is less then other field-body configurations (B_o//b and B_o//c). The greatest induced field strenght is aligned with lenght of the minor axis of body. As a result, induced field strenght may vary with shape and size of the body, exposure frequency, and the orientation of the body relative to the field.

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