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MICROWAVE THERMAL EFECT EVALUATED ON A GENERIC MODEL OF THYROID GLAND

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Abstract: *The rapid diffusion of wireless communication systems has caused an increased concern for the potential detrimental effects on human health deriving from exposure to electromagnetic field. It penetrates the body and acts on all the organs, altering the cell membrane potential and the distribution of ions and dipoles. The thyroid gland is one of the most exposed vital organs and may be a target for electromagnetic radiation. This paper presents the computed temperature and specific absorption rate inside to a generic model of a human thyroid using signals radiated by an antenna operating in the 2450 MHz band and the power density levels up to 10 W/cm^2. Calculations were carried out using the Finite Difference Time Domain method for the solving of two coupled differential equations, Maxwell and Pennes. The results show that the temperature can rise up to very dangerous levels, i.e., 46 ^{0}C, in a very short time. The estimated temperature distribution in the human thyroid due to exposure from microwave signals can be used to design the dangerous aria for personal working around high power emitted antenna and for medical applications.*

Keywords: *microwave thermal efect, thyroid, bioheat, specific absorbtion rate, microwave antenna*

1. INTRODUCTION

In the last 20 years, the modern industrial society has known an exacerbation of environmental pollution by substances that have a high level of danger, by non-ionising radiations, mainly in the microwave spectrum, and by a large amount of data leading to an informational intoxication [1].

By 1990, radio frequency band was occupied mainly by several radio and TV transmitters, located in remote areas and in places somewhat higher. After the introduction of wireless communications, electromagnetic contamination in cities has increased greatly. The investigated experiments of the effects of electromagnetic radiation on living organisms are complex because of the large number of existing variables which has to be controlled. Non-thermal effects are difficult to be determined because they are nonlinear [2].

In this generic framework of the electromagnetic smog, that becomes less and less friendly, it is necessary to perform theoretical and experimental studies on the possible field levels that are currently applied to certain body parts.

People have the ability to physiologically regulate their inner environment to ensure stability in response to fluctuations in the outside environment and the weather as a result of homeostasis process. They maintain a near-constant body temperature, about 37 ^{0}C, by thermoregulation. The limits of medical emergency are 32^{0}C and 41^{0}C. Death usually occurs when the temperature values are less than 24 ^{0}C or higher than 44 ^{0}C. Usually, these values are possible when the subject is under a dangerous environment. Hyperthermia occurs when the body produces or absorbs more heat than it can dissipate. This is usually due to excessive exposure to heat. Hyperthermia can also be produced artificially by medical devices and it may be used as a therapeutic method to bring about an artificial rise in temperature in certain types of cancer tissues, such as skin cancer.

Electromagnetic fields penetrate the body and act on all the organs, altering the cell membrane potential and the distribution of ions and dipoles. These alterations may influence the biochemical processes in the cell. It has been shown that microwaves produce a temperature and energy distribution in living tissues [3]. Temperature is an important factor in the regulation of the release of endocrine hormones. For example, cold temperature increases the activity of thyroid hormones; acute psychological stress increases TSH secretion from the pituitary, and increases the release of T3 and T4 from the thyroid.

The thyroid gland is one of the most exposed vital organs and may be a target for electromagnetic radiation; it is apt to be a region of high SAR at microwaves. The thyroid hormones (T2, T3, and T4) provide energy and fuel to the body and also regulate the body's temperature by controlling the body's metabolism. The thyroid hormones affect brain function, heart health, and they improve the function of the immune system. It has been established that even a small change in circulating thyroid hormone levels is sufficient to alter the brain functions [3, 4].

However, there are only few published papers reporting the effect of microwave radiation on thyroid [5]. The aim of the present study was to assess the temperature rise of thyroid gland situated in an intense microwave field radiation emitted by an antenna located on a maritime ship.

2. METHODS AND MODELS

The wave equation models the electromagnetic field propagation, i.e., for electric component:

$$\nabla \times \left(\nabla \times E_r\right) - k^2 E_r = 0 \qquad (1)$$

where k is the wave number defined by: $k = k' - jk'' = \omega\sqrt{\mu\varepsilon}$. The wave number of free space k_0 is defined as $k_0 = \omega\sqrt{\varepsilon_0\mu_0} = \frac{\omega}{c_0}$, where c_0 is the speed of light in vacuum. From theoretical point of view, a generic model of thyroid was designed and situated in far field aria of a transmitted antenna. The electromagnetic field radiated from antenna is propagating as a plane wave having the two components, electric and magnetic field intensities [5]:

$$\overline{E}_r = E_r \exp(-\gamma r)\overline{r} \qquad (2)$$

$$\overline{H}_z = \frac{E_r}{377} \exp(-\gamma r)\overline{z} \qquad (3)$$

When a plane wave propagating in a homogenous medium encounters an interface with a different medium, a portion of wave s reflected from the interface while the remainder of the wave is transmitted. The reflected and transmitted waves can be determined by enforcing the electromagnetic field boundary conditions at media interface.

The feed point is modeled using a port boundary condition with the level of the power density between 0.1 and 100 W/cm^2. As a result of microwave radiation, the thyroid temperature will be grown up with some degrees. The bioheat equation describes the stationary heat transfer problem, Pennes equation [4], as:

$$\nabla \bullet (-k\nabla T) = \rho_b C_b \omega_b (T_b - T) + Q_{met} + Q_{ext} \quad (4)$$

where k is the liver's thermal conductivity, ρ_b represents the blood density, C_b is the blood's specific heat capacity, and ω_b denotes the blood perfusion rate. Further, Q_{met} is the heat source from metabolism, and Q_{ext} is an external heat sourc. This model neglects the heat source from metabolism. The external heat source is equal to the resistive heat generated by the electromagnetic field:

$$Q_{ext} = \frac{1}{2}\mathrm{Re}\left[(\sigma - j\omega\varepsilon)\overline{E} \bullet \overline{E}\right] \quad (5)$$

This example models the heat-transfer problem only in the neck domain.

3. RESULTS AND DISCUSSION

A simplified model for the the thyroid consists from two ellipsoids, corresponding to two lobes, and by one horizontal ellipsoid for isthmus. The neck aria with thyroid is modeled by a cylinder placed in a block, fig. 1. In order to reduce memory volume, the coupled equations, (1) and (5), the simulation was done on a half of block, fig. 2.

A TEM wave with 2.45 GHz frequency was applied to a face of block, fig. 1. As a result of the finite conductivity for neck and thyroid regions, their local temperatures will be modified [5].

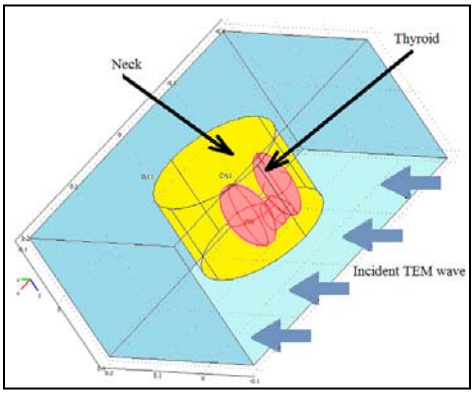

Fig. 1 Generic model of thyroid and the used structure for testing

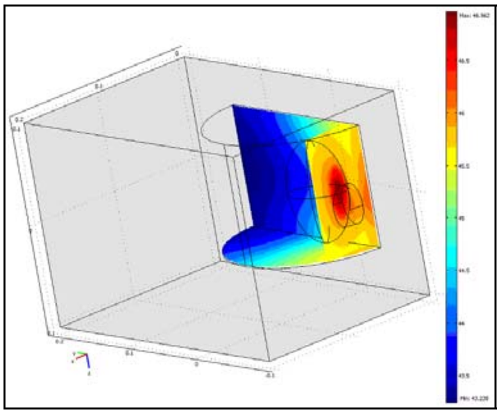

Fig. 2 The temperature variation inside the thyroid generic model

The temperature variation inside of neck region is illustrated on fig. 2 for 100 W/cm^2 power density applied at the input. It can be seen that the thyroid will have a higher temperature than neck area. The maximum value depends on the input power density level. The initial thyroid temperature was 37.0^{0}C. If the power density is less than 100mW/cm^2, the temperate does not exceed 37.1^{0}C. When the power density is increased, then the temperature will be increased, as well. The thyroid temperature variation is shown in the fig. 3 when microwave power density grows up from 0.1 to 100 W/cm^2. For each power density applied at the input, two temperatures are shown, representing minimum and maximum temperatures inside the thyroid model.

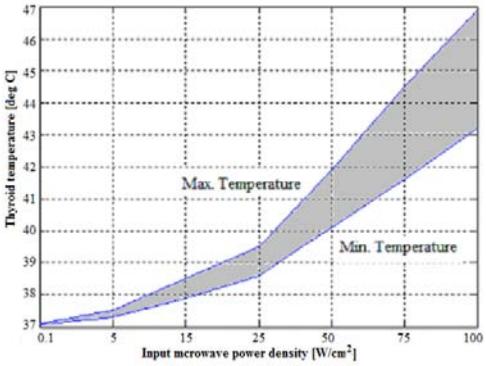

Fig. 3 Thyroid temperature versus microwave power density input level

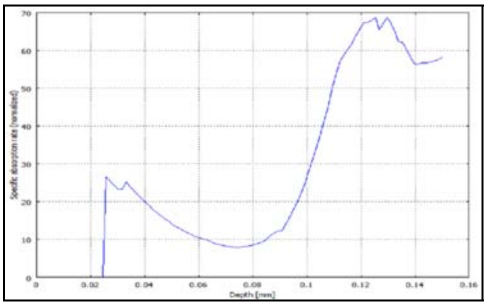

Fig. 4 SAR versus depth in thyroid, for 1 g of tissue

One of the most interested parameter for operator protection is specific absorbtion rate, SAR. On the fig. 4 it is shown the SAR values for 100 W/cm^2 microwave power density at the input device. Although a temperature elevation in the human is a dominant factor due to microwave exposure, the relationship between incident electromagnetic fields absorbed by human being and temperature elevation was not well experimental quantified because the dosimetric techniques were not well established.

4. CONCLUSIONS

Public or occupational exposure limits at microwave field vary with frequency in a complex way. Countries set their own national standards for exposure to average level of electromagnetic fields. There are several international guidelines recommending limits on exposure. The new ship antenna system operates on short pulses but with high power, and operators work in their vicinity. New researches are necessary for the high power and short pulse conditions.

Thyroid is very sensitive tissue to electromagnetic radiation and operators working near transmitting antennas are at high risk. Usual powers of tens of watts can cause on certain directions an increase power density and thyroid temperature will rise by several degrees.

Detailed knowledge of how microwave radiation interacts with biological material is required to account for the various deleterious effects of microwaves which have been. Elevated temperature (1-2 ^{0}C) resulting from energy absorption is known to be a dominant factor inducing adverse health effects such as heat exhaustion or heat stroke.

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