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Absorbed power distribution in heart lung system due to microwave irradiation at 750 MHz

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Summary

In order to help evaluate the diagnostic potential of low energy microwave energy regarding the pathological changes associated with emphysema, electrical field distribution and hence the power deposition in organs are needed.

In the present investigation the power deposited in the heart-lung system irradiated by microwaves at 750 MHz are computed using the tensor integral theorem. The modification as introduced due to the induction of emphysema are also simultaneously computed. It is found that the magnitude of the power deposition shows selective variation in the portion of the heart lung system having pathological state thus providing a possibility for selective heating of the biological tissues.

Introduction

In recent years the low intensity penetrating microwave energy is increasingly being speculated for medical diagnosis by non-invasive methods. Since microwaves at 1.0 GHz or lower will readily penetrate thebody, and because microwave energy is absorbed more in tissue with low water content, it follows that both reflection and transmission measurements from the lung are sensitive to changes in lung water. To quantitate this as in emphysema, the power distribution pattern in the organs are needed. This forms the basis for defining changes in the electromagnetic properties of the lung tissue that accompany these diseases. We have adopted the method developed by Livesay and Chen (1974) to compute the electromagnetic field in the heart lung system under normal and pathological (emphysema) state.

Outline of the Theoretical Method

A finite biological body of arbitrary shape, with permittivity $\epsilon(\vec{r})$, conductivity $\sigma(\vec{r})$ and permeability μ is illuminated in free space by an incident electromagnetic wave with an electric field $\vec{E}^i(\vec{r})$, the total induced electric field $\vec{E}(\vec{r})$ inside the body can be determined from the tensor integral equation:

$$\left[1+\frac{\tau(\vec{r})}{3j\omega_0}\right]\vec{E}(\vec{r}) - P.V.\int_V \tau(\vec{r})\cdot G(\vec{r},\vec{r}')\cdot dV' = \vec{E}^i(\vec{r}). \qquad (1)$$

$G(\vec{r},\vec{r}')$ is the free space Green function, and V is the volume of the body,

where $\tau(\vec{r}) = \sigma(\vec{r}) + j\omega(\epsilon(\vec{r}) - \epsilon_0)$, ϵ_0 is the free space permittivity, the P.V. symbol means the principal value of the integral. Equation (1) is solved by the moment method, where the total volume of the biological body is partitioned into N Cells. This can be transformed into 3N simultaneous equations for E_x, E_y and E_z at the centres of N cells by the point matching methods. These simultaneous equations can be written into matrix form as:

$$[\vec{G}_i]\,[\vec{E}] = -[\vec{E}]^i \qquad (2)$$

The $[\vec{G}_i]$ matrix is a 3N x 3N matrix, while $[\vec{E}]$ and $[\vec{E}^i]$ are 3N column matrices, expressing the total electric field at the centre of N cells.

A heart-lung model of the body system is supposed to be equivalent to as shown in Fig.1. One half equivalent of this is shown in Fig.2 for which the matrix equations are solved. The solutions for the other half can be obtained by symmetry.

In Fig.2, the σ and ρ values corresponding to the cells (1-5) are assumed to be belonging to the chest wall, that of 6 and 7 heart muscle. Due to emphysema the conductivity of the shaded portion is altered. The σ and ρ value for normal and affected tissues are computed using the expressions due to pederson et al., (1976). The computations are carried out at 750 MHz.

Numerical Computations

The total thickness of the chest wall has been taken to be 6 cm corresponding to the realistic situation, existing in the humans. Length and breadth of the system is taken to be 18 cm x 18 cm.

The geometry of the heart-lung system is taken as shown in Fig.2. The size of each cell is accordingly chosen as 3x3x3 cm^3 and hence the power deposited ($\sigma E^2/2$) in each layer cell is as calculated using equation (2) and are shown in Fig.3 and 4.

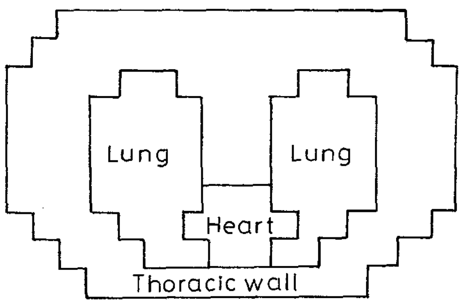

Fig.1. Heart,Lung model

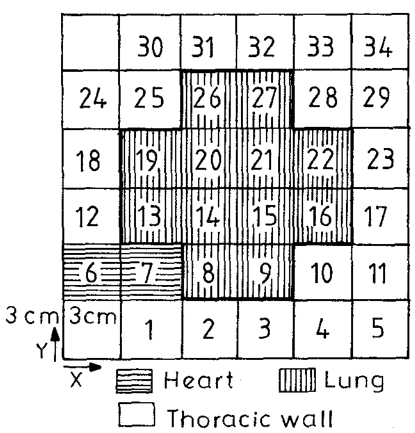

Fig.2. Division of Heart,Lung system in a realistic situation.

Results and Discussions

Computed power distribution is presented in Fig.3. and 4. A similar curve can be extended on the left of (12, 0) point of the x-axis. Owing to the symmetry of the biological body the computed values of the power deposition are shown for half portion only. The power deposition pattern in the

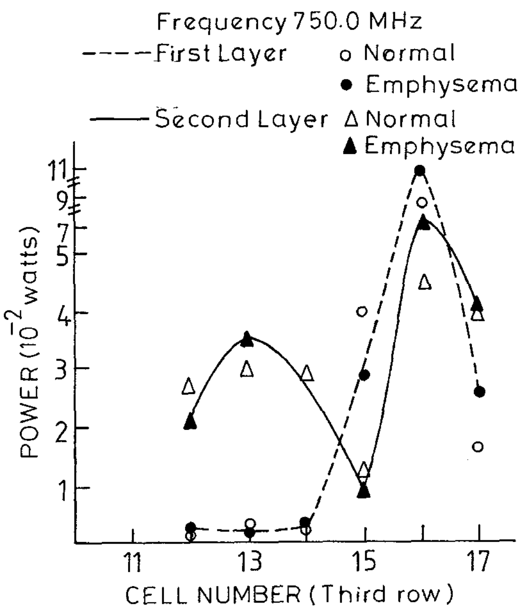

Fig.3. Power deposited in third row cells

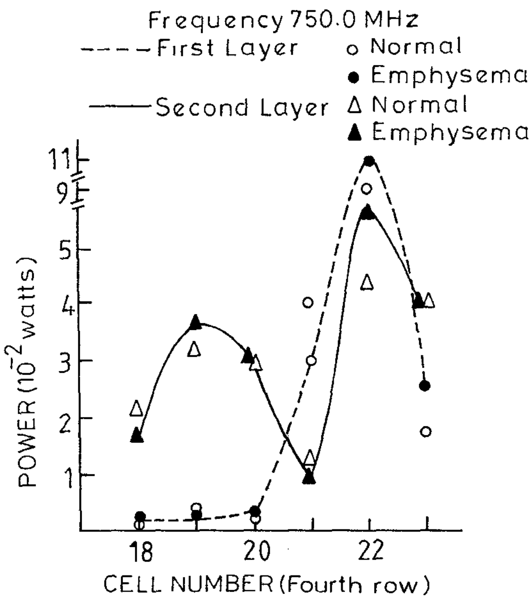

Fig.4. Power deposited in fourth row cells

first and second layers are presented in the third (12-17) and the fourth (18-23) row cells. In normal and pathological state (emphysema) (Figs. 3 and 4). It is found that the magnitude of the power distribution gets selectivity altered in emphysema. Phase angle apparently has no correlation with the electrical property change of the medium under study. It can be seen that the power deposition is highest around cell No.16 and 23. Also the total power deposited in the first layer is lower than in the second. However, the total power dissipated in the two layers are not very different inthe two cases (Table 1).

Table 1

	Total power deposited	(10^{-5} watt)
	First layer	Second layer
Normal	1.49	1.79
Emphysema	1.44	1.77

Though the pattern of Power dissipation in the two cases is similar but offers some dissimilarities when compared to pulmonary edema (Behari, 1986).

It is concluded that the pattern of power deposition can be a reliable parameter in estimation of pathological state of human body.

References

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