Measurement Techniques for the Relative Power Absorption Ratio of Biological Tissues

P. S. N. Bharani[1]
PG Student [BME], Dept. of ECE, Andhra University College of Engineering (A), Andhra Pradesh, India[1]

Ch. Rajani Chandra[1]
PG Student [BME], Dept. of ECE, Andhra University College of Engineering (A), Andhra Pradesh, India[1]

Y. Ratna Kumar[2]
Assistant professor (c), Dept. of ECE, Andhra University College of Engineering (A),Andhra Pradesh, India[2]

***Abstract*-Electromagnetic energy is represented by electric and magnetic fields of electromagnetic waves. Its absorption in biological tissues is illustrated by the use of electromagnetic field adjacent tissues; it is possible to estimate relative absorption of electromagnetic energy from the knowledge of fundamental parameters of the tissues and of the wave. It is also dependent on the polarization of the wave. The direction of propagation can be either parallel or perpendicular to the common interface.**

It has been possible to find relative power absorption as a function of frequency. They are consolidated using the Debye equation. It is also well known that they vary with frequency and they are not scalar constants. The results on the relative absorption as the function of frequency for different tissue pairs are presented in this work.

Keywords- Electromagnetic waves; Electric and Magnetic fields; Relative power absorption; propagation; Debye equation; Frequency; polarization; scalar constants.

I. INTRODUCTION

The electromagnetic fields exist in the entire space and they are all around us. The radio waves and television signals, mobile phones, power lines, radar, radio broadcast transmission, electrical appliances etc. are basic sources of electromagnetic waves. They are also present in human bodies in the form of endogenous fields. These fields keep our hearts beating, brains thinking, eyes functioning and muscle moving[1]. Electromagnetic fields are also useful to visualize inner side of the body to diagnose illness in form of medical imaging, electrocardiography, electroencephalography, electromyography, EOG, ERG and electro physiological evaluations. They also have wide applications in treatment of cancer, pain control, bone growth, soft tissue repair and electro physiological stimulations. On the other hand, they have negative effects for example; they injure or even kill living beings through lightning strikes, and shock.

Electromagnetic fields have used in a number of medical devices. The other promising applications of electromagnetic fields are in the repair of damaged nerve paths to help the blind to get vision, the deaf to hear and the paralyzed to walk[2]. The main importance of electromagnetic fields is to explain how they interact with the body, how to measure them, how to create them, how to evaluate, and how to control them.

The electric field's concepts are explained by Coulomb in terms of electric charges and by Gauss in terms of electric flux. The electric field is expressed in terms of the coulomb force per unit test charge. It is represented by the units of Newton/coulombs or volts/meters[3].

Such an electric field is static in nature when the charge is stationary. When the field is expressed in terms of minus of potential gradient, these do not vary time with and voltage is DC and these fields are measured using antenna devices. Electrocardiogram measures potentials on the surface of the body produced by the beating heart. The electric fields picked up by the straight antennas are oriented parallel to antenna axis. It is difficult to measure the field near the body as the antenna made up of metallic material can perturb the fields. In such cases small dipole antennas are specially designed to receive the localized fields[4]. The fields of arbitrary polarization are measured independently to obtain the total electric field.

II. FORMULATION

For an electromagnetic wave propagating within a biological system, two adjacent tissues will absorb power per unit volume in the ratio[6].

$$\frac{A_{p2}}{A_{p1}} = \frac{\sigma_2}{\sigma_1}\left|\frac{E_2}{E_1}\right|^2 \qquad (1)$$

Here σ is the tissue electrical conductivity,
E, is the electric field intensity within the tissue, and the subscripts denote each tissue. At frequencies within the 100-500MHz range and below, the irradiated tissue will be within the near field of an applicator is not a uniform plane-wave. For noninvasive applicators, this approximation is expected to have a negligible effect upon the results obtained.

III. MEASUREMENT OF RELATIVE POWER ABSORPTION RATIO OF TWO ADJACENT TISSUES WITH BOUNDARY CONDITIONS

The relative absorption of electromagnetic energy is found out by considering the below cases[5].

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CASE 1: The electric field vector of EM energy parallel to the interface between tissues1 and 2.
The boundary condition is $E_1=E_2$
Relative absorption power ratio in equation (1) becomes,

$$\frac{A_{p2}}{A_{p1}} = \frac{\sigma_2}{\sigma_1} \qquad (2)$$

CASE 2: The electric field vector of EM energy perpendicular to the interface between tissues. The conduction and displacement currents must be continuous across the interface as [7].

$$\left|\frac{E_2}{E_1}\right| = \frac{\sigma_1^2+\omega^2\epsilon_1^2}{\sigma_2^2+\omega^2\epsilon_2^2} \qquad (3)$$

Where Є is the electrical permittivity of the respective tissue and ω is the radian frequency. Now,

$$\frac{A_{p2}}{A_{p1}} = \frac{\sigma_2}{\sigma_1}\left(\frac{\epsilon_1}{\epsilon_2}\right)^2 \frac{1+(\sigma_1/\omega\epsilon_1)^2}{1+(\sigma_2/\omega\epsilon_2)^2} \qquad (4)$$

CASE 3: EM energy incident upon tissue 2 from tissue 1, the tissue2 is a sphere and its radius □, small compared to the wavelength in tissue 1 [8] is,

$$\frac{E_2}{E_1} = \frac{3}{2+\frac{\epsilon_2^*}{\epsilon_1^*}} \qquad (5)$$

Here,

$$\frac{A_{p2}}{A_{p1}} = \frac{\sigma_2}{\sigma_1} \frac{9[1+(\sigma_1/\omega\epsilon_1)2]}{\left(2+\frac{\epsilon_2}{\epsilon_1}\right)2\left(\frac{2\sigma_1}{\omega\epsilon_1}+\frac{\sigma_2}{\omega\epsilon_1}\right)} \qquad (6)$$

CASE 4: EM energy incident upon tissue 2 from tissue 1, the tissue2 is a long Cylinder of radius.

$$\frac{E_2}{E_1} = \frac{2}{1+\frac{\epsilon_2^*}{\epsilon_1^*}} \qquad (7)$$

and,

$$\frac{A_{p2}}{A_{p1}} = \frac{\sigma_2}{\sigma_1} \frac{4\left[1+\left(\frac{\sigma_1}{\omega\epsilon_1}\right)^2\right]}{\left(1+\frac{\epsilon_2}{\epsilon_1}\right)^2+\left(\frac{\sigma_1}{\omega\epsilon_1}+\frac{\sigma_2}{\omega\epsilon_1}\right)^2} \qquad (8)$$

The frequency dependence of energy absorption directly related to the polarization of molecules and structural interfaces as a result of the applied electric field with in the biological tissue.

IV. RESULTS

For different tissues, the relative abortion is computed and they are presented in the figures. The variables of conductivity and permittivity as a function of frequency are also presented.

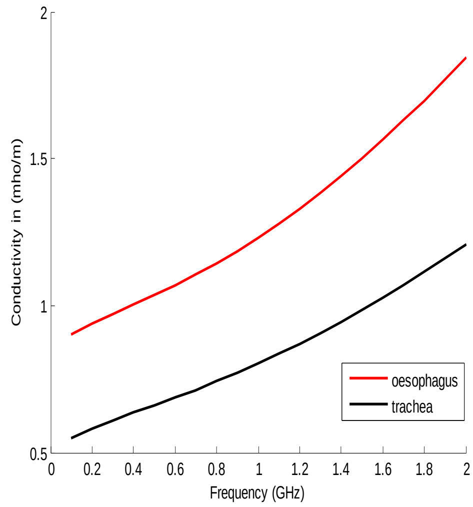

Fig. 1: The fundamental properties of Conductivity (σ) of adjacent tissues Oesophagus and Trachea variation with Frequency.

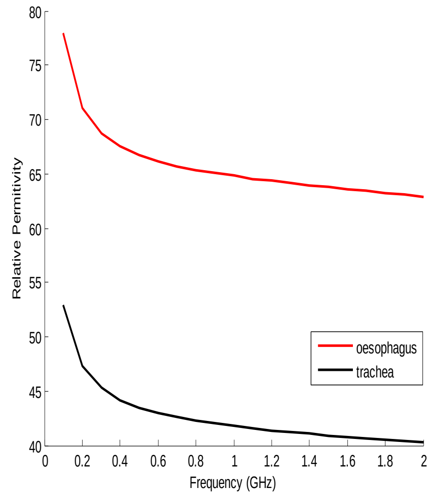

Fig. 2: The fundamental properties of Relative Permittivity ($\square_r$) of adjacent tissues Oesophagus and Trachea variation with Frequency.

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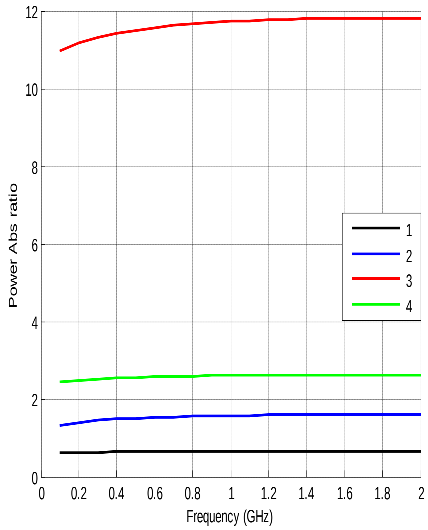

Fig. 3: plot of Power absorption ratio P_{a2}/P_{a1} vs. Frequency with Oesophagus and Trachea for the irradiation conditions:

1) E parallel to interface
2) E Perpendicular to interface
3) Trachea sphere within Oesophagus, and4) Trachea cylinder within Oesophagus

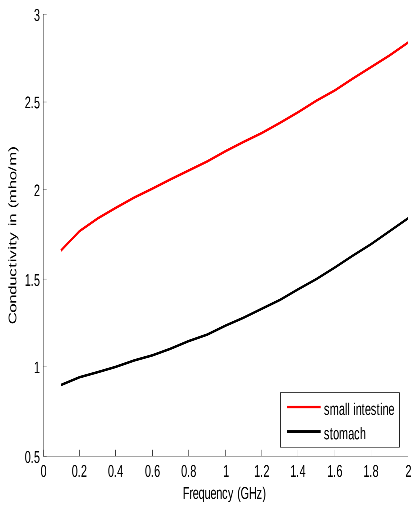

Fig. 4: The fundamental properties of Conductivity (σ) of adjacent tissues Small intestine and Stomach variation with Frequency

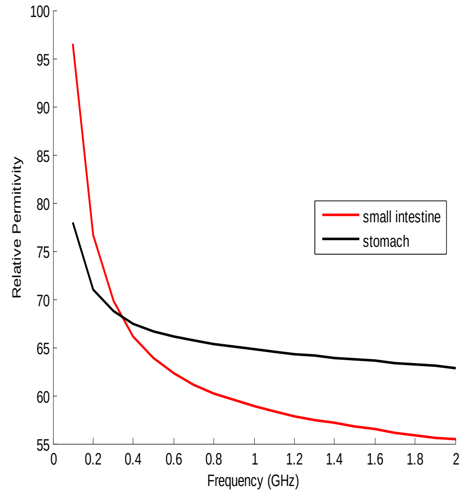

Fig. 5: The fundamental properties of Relative Permittivity (ε_r) of adjacent tissues Oesophagus and Trachea variation with Frequency.

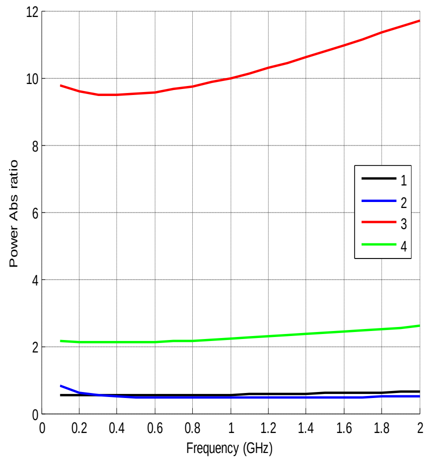

Fig. 6: plot of Power absorption ratio P_{a2}/P_{a1} vs. Frequency with Small intestine and Stomach for the irradiation conditions:

1) E parallel to interface 2) E Perpendicular to interface 3) Stomach sphere within Small intestine and 4) Stomach cylinder within Small intestine

V. CONCLUSIONS

Thus the fundamental properties such as conductivity and permittivity of the tissues like the Trachea, Oesophagus, small Intestine, Stomach were obtained. From these properties the power absorption ratio of adjacent tissues such as Trachea, Oesophagus and Small intestine, Stomach were obtained. Here we observed the higest Power absorption ratio in the case of Trachea sphere within Oesophagus when compared to the case of Trachea cylinder within Oesophagus. Similarly the power absorption ratio of the tissues is high in the case of Stomach sphere within Small intestine when compared to the case of Stomach cylinder within Small intestine.

VI. REFERENCES

[1] John W Strotech, "Hyperthermia and cancer therapy, "IEEE, BME-31, No. 12, December 1984".
[2] H.C. Nants, "Pyrogen therapy of cancer", Proc. Int Symp. Cancer therapy by hyperthermia and radiation, 1976, pp 239-250.
[3] G.M. Hahn, "Hyperthermia and cancer", New York, Planum, 1982.
[4] N.B. Hornbeck, Hyperthermia and cancer: Human Clinical trail experience, Vol. I and II, FLCRC Press, 1984.
[5] G.S.N. Raju, "Electromagnetic Field Theory and Transmission Lines,"Pearson Education (Singapore)Pte.Ltd.,New Delhi,2005.
[6] William T.joines,"Frequency dependent absorption of electromagnetic energy in biological Tissue,"IEEE Trans.On biomedical engineering,Vol.BME- 31 No.1,January 1984.
[7] S.A.Schelkunoff, Electromagnetic Fields. New York:Blasdell,1963.
[8] W.T.Joines,C.F.Blackman,and M.A.Hollis,"Broadening of the RF power-density window For calcium-ion efflux from brain tissue,"IEEE Trans.Biomed.Eng.,vol.BME-28,pp.568-573,August 1981 New Delhi, 2005.

AUTHORS DATA

P. Siva Naga Bharani did her B.TECH in Vignan's Institute of Information Technology affiliated by JNTU Kakinada. At present she is pursuing her M.TECH in Biomedical Engineering in the Centre for BioMedical Engineering, Dept. of Electronics and Communication Engineering, AU College of Engineering (A), Visakhapatnam.

CH. Rajani Chandra did her B.TECH in Visakha Institute of Engineering & Technology affliliated by JNTU Kakinada. At present she is pursuing her M.TECH in Biomedical Engineering at the Centre for BioMedical Engineering, Dept. of Electronics and Communication Engineering, AU College of Engineering (A), Visakhapatnam.

Y. Ratna Kumar did his B.Pharmacy in JNTUH and M.Tech (Biomedical Engg.) in Andhra University. At present, he is Assistant Professor (c) in the Centre for BioMedical Engineering, Dept. of Electronics and Communication Engineering, AU College of Engineering (A), Visakhapatnam, and Ph.D. under the guidance of Prof. G.S.N. Raju. He has published 7 International Journals/ Conferences. He is a life member of PCI, SEMCE (I), BMSI, and ISB