Modeling of capacitance relaxation phenomena in a malignant membrane

T. K. Basak[1], K. Bhattacharya[1], S. Halder[2], S. Murugappan[3], V. Cyril Raj[4], T. Ravi[4], G. Gunasekaran[4] & P. Shaw[1]

[1]*Department of Electrical Engineering, Jadavpur University, Kolkata, India*

[2]*Department of Electrical & Electronics Engineering, ICFAI Tech, ICFAI University, Tripura, India*

[3]*Department of Computer Science and Engineering, Annamalai University, Chennai, India*

[4]*Dr. M.G.R. Educational and Research Institute, (Dr. M.G.R. Deemed University) Chennai, India*

Abstract

Electrical Impedance scanning (EIS) is a new technique in which moderate variations in capacitance values are reflected by the cells of various type of normal membrane. The malignant membrane, in contrast, in EIS demonstrates significant capacitance relaxation phenomena concomitant with α dispersion in the low audio frequency range. The author has endeavored to establish the above stated phenomena. In his experimental setup, the lipoprotein constituent of the membrane was dissolved in acetone solvent and the interaction of the dissolved lipoprotein in the presence of electrical stimuli in the lower audio frequency range at room temperature of about 25ºC was studied. The capacitance relaxation phenomena concomitant with α dispersion in the malignant membrane for subjects below and above 50 years has been simulated in MATLAB 6.5. The model incorporates a modified homeostat comprising of a homeostat and transduction phase in the feedback path and it represents the interaction of the lipoprotein in a malignant membrane associated with α dispersion mediated through capacitance relaxation phenomena. Results from the output of the model are in close conformity with the capacitance relaxation phenomena, which suggest an adjunctive detection modality in the differentiation of membrane malignancy that is equivocal on Ultrasonography.

Keywords: capacitance relaxation, malignant membrane, α dispersion, modified homeostat.

WIT Transactions on Biomedicine and Health, Vol 13,
www.witpress.com, ISSN 1743-3525 (on-line)
doi:10.2495/BIO090231

1 Introduction

This paper describes a comprehensive model [1] of capacitance relaxation phenomena concomitant with α dispersion. This α dispersion is linked with the interaction of lipoprotein mediated through α receptor proliferation (mR-α) in the malignant cell [1,12]. It adopts a new approach to modeling. Using artificial neural networks (ANN) it is not easy to obtain a dynamic model that reflects dependence on membrane dynamics. Therefore, the authors have endeavored to design a new approach in this respect based on criteria of electrical control system. The model has been simulated in MATLAB 6.5 R13. In the model (Fig 1) the homeostat is a controller that performs interactions with in a cell for maintaining a static or dynamic cooperation in the environment of the cell concerned [1]. The modified homeostat incorporates cellular transduction phase in a feedback path. Since the capacitance relaxation phenomenon [10] is dependent on age, the transduction of the malignant cell requires a modified homeostat. The block diagram of the modified homeostat is shown in the Fig1. The measurement of capacitance of bioelectric membrane has been widely used in morphological research [2,3]. As a means of assessing changes in lipoprotein organization, it is generally assumed that the dielectric properties of the normal membrane consisting of lipoprotein are constant in the lower audio frequency range, so that the changes in the membrane area reflect changes in the lipoprotein interactions [4,5]. From the classical papers of Debye, Cole and Cole and others, it transpires that the behavior of the dipoles associated with the integral lipoproteins of membrane is affected by the electric field with consequent on settings of α dispersions in the low audio frequency range which can be characterized by relative capacitive increment against frequency [5,8,9]. Taking into account of the finding described above and considering capacitive increment associated with α dispersion in the low audio frequency range, it can be stated the complex capacitance of the membrane has two parts namely a frequency dependent capacitance and a static d.c. capacitance associated with α dispersion. The capacitance measured in the lower audio frequency range can vary because of the change in membrane area concomitant with hydrophobic interaction characterizing the lipoprotein organization [6,7].

2 Modeling and methods

The lipoprotein constituent of the membrane was extracted from the subject and preserved in formaldehyde. After taking out from the formaldehyde the membrane was cleaned and then dried. After that a small weighted amount of the membrane (10 mg) was dissolved in measured quantity (10 ml) of acetone solvent in a container fitted three electrode system made of silver–silver chloride. The capacitance measurement was done by a LCR Meter (HP 4284A) at temperature 25ºC corresponding to an excitation voltage of 100 mV [10, 11]. The relative capacitance of a membrane is the ratio of the measured value of capacitance of the solvent to that of lipoprotein extract in solvent. It has been established that in a malignant membrane, there is distinct relaxation jump, which is age dependent. It was observed during the experiment that α dispersion occurs in the malignant membrane in the lower audio frequency (around 200 Hz) at which the relative capacitance abruptly jumps to a high value. It is interesting to observe α dispersion concomitant with capacitance relaxation concerning the status of receptor proliferation [1] in malignant cell. The model (Fig 1) comprises of homeostat and a transduction phase in the feedback path through which the cellular transduction in membranes is reflected through α dispersion. The transduction phase [1] in the feedback path of the homeostat represents physiological status for subjects below and above 50 years in order to reflect α dispersion concomitant with respective capacitance relaxations. The input to the homeostat is an electrical signal, which is analog to the measured value of relative capacitance shown in the Fig 1.

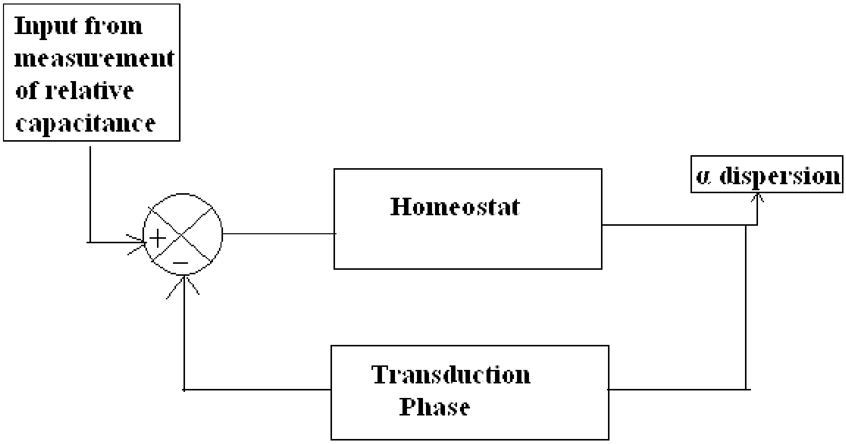

Figure 1: Block diagram of the modified homeostat.

3 Discussion and conclusion

In Fig 2, the input to the model is capacitance relaxation of the malignant cells for the subject below 50 years and corresponding α dispersion is the output of the model in Fig 3. In Fig 4 and Fig 5 the similar input and output data are represented for subject above 50 years. In the present experiment for subjects 6 out of 8 with malignancy were correctly detected and verified with Ultrasonography.

It has been established by the author that in a malignant membrane there is distinct relaxation jump, which is age dependent. This relaxation jump is concomitant with α dispersion in the lower audio frequency range (around 200 Hz), which is responsible for strong interaction of lipoprotein in malignant cells and this effect is reflected on the membrane transport and behavior associated

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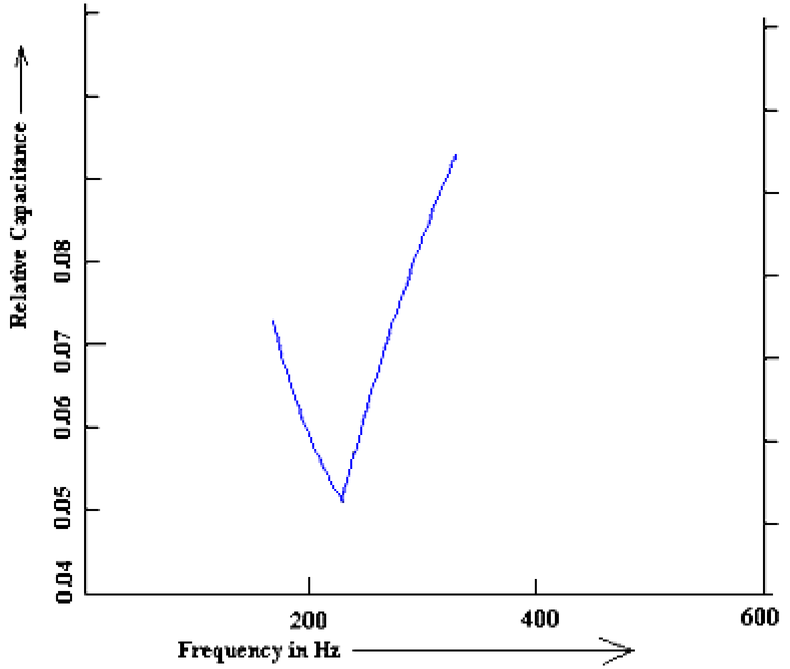

Figure 2: Capacitance relaxation phenomena for malignant subject below 50 years.

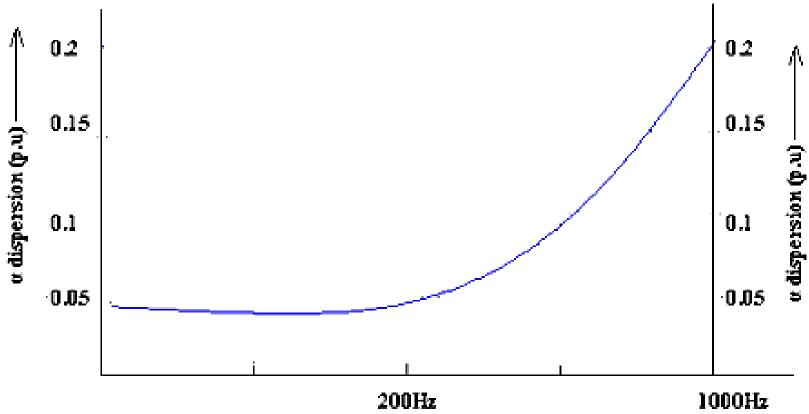

Figure 3: α dispersion concomitant with capacitance relaxation phenomena for malignant subject below 50 years.

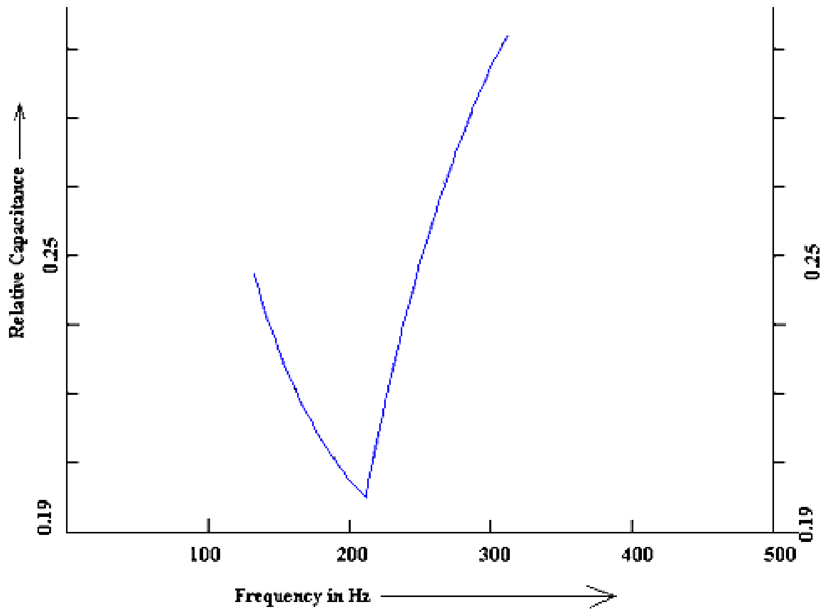

Figure 4: Capacitance relaxation phenomena for malignant subject above 50 years.

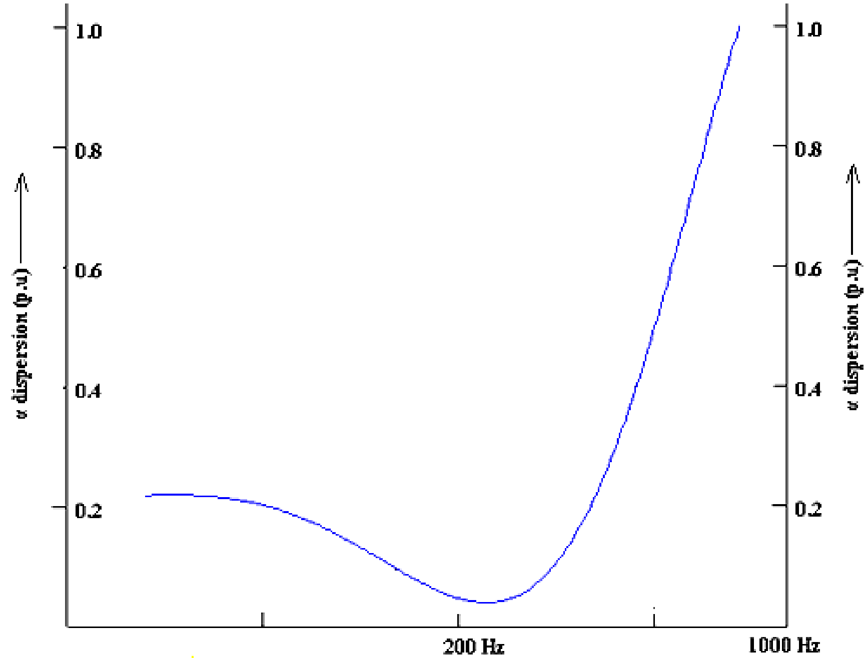

Figure 5: α dispersion concomitant with capacitance relaxation phenomena for malignant subject above 50 years.

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hydrophobic interaction. It is interesting to note that the α dispersion with the corresponding capacitance relaxation are different for subjects with malignancy below 50 years and above 50 years. The p.u. (per unit) scale values signify normalization of the curve to correlate a particular physiological phenomenon.

Results of the model concomitant with capacitance relaxation suggest the potential usefulness of EIS with the corresponding α dispersion as an adjunctive imaging modality in the differentiation of lymphadenopathy that is equivocal on Ultrasound.

From capacitance relaxation associated with α dispersion it is possible to determine the signaling pathway in tumor growth and angiogenesis. The vascular endothelial growth factor is dependent on α dispersion. It is well established that it is one of the key regulator of the tumor growth and meta- static dissemination for which molecular basis of tumor angiogenesis has been of keen interest in the field of cancer research [12].

It is experimentally observed that for normal membrane there is no capacitance relaxation phenomena with the significant rise of capacitance values present in the malignant membrane and as such α dispersion will almost remain constant [10].

4 Authors' contributions

Professor T. K. Basak received a third world scientist award from ICTP, Trieste, Italy and worked with Professor A. Glilozzi in the Dept of Biophysics, University of Genoa, Italy in 1985. He furnished the innovative idea in the present paper. Mr. Suman Halder, S. Murugappan, V. Cyril Raj, T. Ravi, and G. Gunasekaran are the registered Ph.D. candidates in Jadavpur University under Prof. T. K. Basak. Prof. K. Bhattacharya is also the co guide of Mr. Suman Halder. Dr. P. Shaw has completed PhD. Under Prof. T. K. Basak and now he is associated with research activities with Prof. T. K. Basak.

Acknowledgements

The authors are grateful to the authorities of Jadavpur University. Prof. T. K. Basak is particularly indebted for inspiration received from his late wife, Mala Basak who is in the heavenly abode of Shree Shree Ramakrishna Paramhansa.

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www.witpress.com, ISSN 1743-3525 (on-line)