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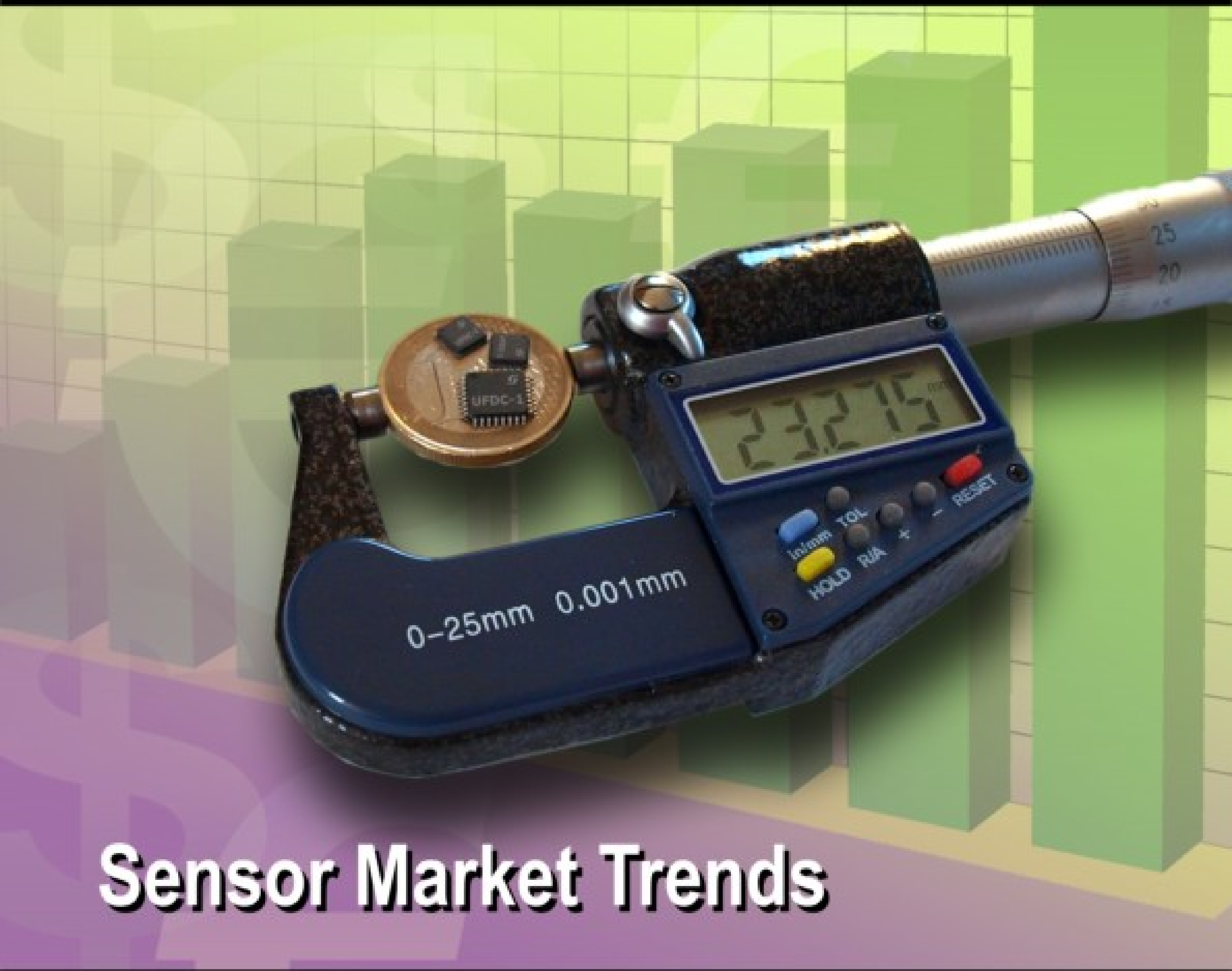

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Electrostrictive Effect in Cancer Cell Reflected in Capacitance Relaxation Phenomena

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Abstract: The present paper has focus on the composite dielectric property of the cancer cell on concomitant with the capacitance relaxation phenomena. In this respect it has been found from MAT lab simulation the electrostrictive process in cancer cell is a complex one for which the electrostatic surfaces surrounding the cell changes with the incremental changes in the capacitance present in the capacitance relaxation curve. From these incremental changes in capacitance it is also possible to find out the electrostrictive energy of the cancer cell. It is interesting to note that the electrostrictive energy corresponding to the cell incremental changes in the capacitance is more in the first order system than that present in the second order system representing the equivalent configuration of the composite dielectric associated with the cell membrane. This is due the fact that during the process DNA synthesis and cell division the change in capacitance of the membrane for the first order system is relatively slow. *Copyright © 2008 IFSA.*

Keywords: Electrosrictive energy, Cancer cell capacitance relaxation, Composite dielectric

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1 Introduction

This paper reflects the electrostictive energy variation in carcinogenic cell membrane during metastasis, concomitant with capacitance relaxation phenomena [united States patent No. 5691178,1997]]' The electrostrictive phenomena is due to composite dielectric property of the carcinogenic cell membrane for which there is excess negative charge on the outer surface of the membrane. It is well known that the cell membranes are composed of a bilayer of highly mobile lipid molecules that electrically behaves as an insulator (dielectric). The insulating properties of the cell membrane also restrict the movement of charged ions and electrons across the membrane except through specialized membrane spanning protein ion channels [9-16] and membrane spanning protein semiconductors [26] respectively. Thus the lipid structure of a cell membrane makes it relatively semiconductors [26] respectively. Thus the lipid structure of a cell membrane makes it relatively impermeable to the passage of charged molecules. As the cell membrane is a leaky dielectric, this means that any condition, illness or change in dietary intake that affects the composition of the cell membranes and their associated minerals can affect and alter the cellular capacitance. [1, 2, 4].

The major charge carriers of biological organisms are negatively charged electrons, positively charged hydrogen protons, positively charged sodium, potassium, calcium, magnesium ions and negatively charged anions particularly phosphate ions. As the cell membrane is selectively permeable to sodium and potassium ions, a different concentration of these ions and other charged mineral ions will build up on either side of the membrane. The different concentrations of these will cause the outer surface to have a relatively higher positive charge than the inner membrane surface and creates an electrical potential difference across the membrane. [18]. so this potential difference is due to the imbalance in *electrical charges* between the inside of the cell and the outside of the cell. Almost all normal cells have a membrane potential of about -60 to –100 mV.

Cancer cells also have different lipid and sterol content than normal cells [9-16, 27]. Cancer cells have altered membrane composition and membrane permeability, which results in the movement of potassium, magnesium and calcium out of the cell and the accumulation of sodium and water into the cell [28]. With The result of these mineral movements, membrane composition changes, leaving to energy abnormalities , and membrane charge distribution abnormalities falls there occurs a decline in the normal membrane potential and rise of membrane capacitance. [19-22].

The outermost electrically negative zone of cell membrane is composed of negatively charged sialic acid molecules that cap the tips of glycoprotein and glycolipids that extend outward from the cell membrane like tree branches. The outermost negative zone is separated from the positive cell membrane surface by a distance of about 20 micrometers. This outermost calyx zone of steady negativity that makes each cell act as a negatively charged body; every cell creates a negatively charged field around itself that influences any other charged body close to it [37]. Therefore the cancer cells exhibit both lower electrical membrane potentials and lower electrical impedance than normal cells [17, 21 ,29].The excessive amount of negative charge on the exterior surface of the cell responsible for carcinogenic change and genetic change result from development of cellular electrical abnormalities.[23] Also the depolarization (fall in membrane potential) of the cancer cell membrane due to the accumulation of excess negative surface charges may precede and create the reduction in intracellular potassium and the rise in the intracellular sodium ions[23].The cancer cells have significantly more sialic acid molecules in their cell coat and as a result cancer cells have a greater surface negativity. It has been found that the cells become more electronegative in the course of cancerization, that membrane degeneration occurs in the initial phase of carcinogenesis first in the external cell membrane and then in the inner mitochondrial membrane and these degenerative changes in the surface membrane causes these membranes to become more permeable to water-soluble substances so that potassium, magnesium, and calcium migrate from the cells and sodium and water accumulate in the cell interior. The degenerative changes in the inner membrane of the mitochondria cause loss of storage of critical mitochondrial enzymes, for which mitochondria cancer cells degenerate and are reduced in numbers [28].

Two of the most outstanding electrical features of cancer cells are that they constantly maintain their membrane potential at a low value and their intracellular concentration of sodium is of high magnitude [19-21]. This sustained elevation of intracellular sodium may act as a mitotic trigger causing cells to go into cell division (mitosis) [21]. In the resting phase normal cells maintain a high membrane potential of around -60 mV to -100 mV, but when cells begin cell division and DNA synthesis, the membrane potential falls to around –15 mV [24].During this process of DNA synthesis the composite dielectric property of cell the cell membrane has a different values of permittivity and conductivity for which the there is large variation of elecctrostrictive energy. [1, 24].

The electrical conductivity and permittivity of cancerous cells has been found to be greater than those of normal cells of normal tissues [25]. The cancerous cells demonstrate greater permittivity, and moreover cover a larger surface area for which there is large increase in capacitance concomitant with the Capacitance Relaxation phenomenon. [15]. The normal and carcinogenic cells may be thought of as a composite dielectric material with the relative permittivity

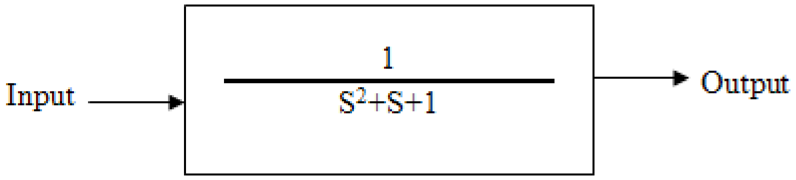
$$\varepsilon=\varepsilon_n+ \varepsilon_c$$

This composite dielectric property accounts for elecrtostrictive phenomenon [1].for which the surface with the negative charges increases during the growth of cancer cell concomitant with it increases the capacitance.

2. Modeling and Simulation

2.1. Modeling and Simulation of the First Order Composite Dielectric (Case 1)

The block diagram of the model is shown below. The transfer function of the composite dielectric will be represented by second order system shown in the block diagram:



From the US Patent [15] of Prof. T. K. Basak we have taken different values of capacitance as an input from capacitance from capacitance relaxation curve as shown below (Fig. 1).

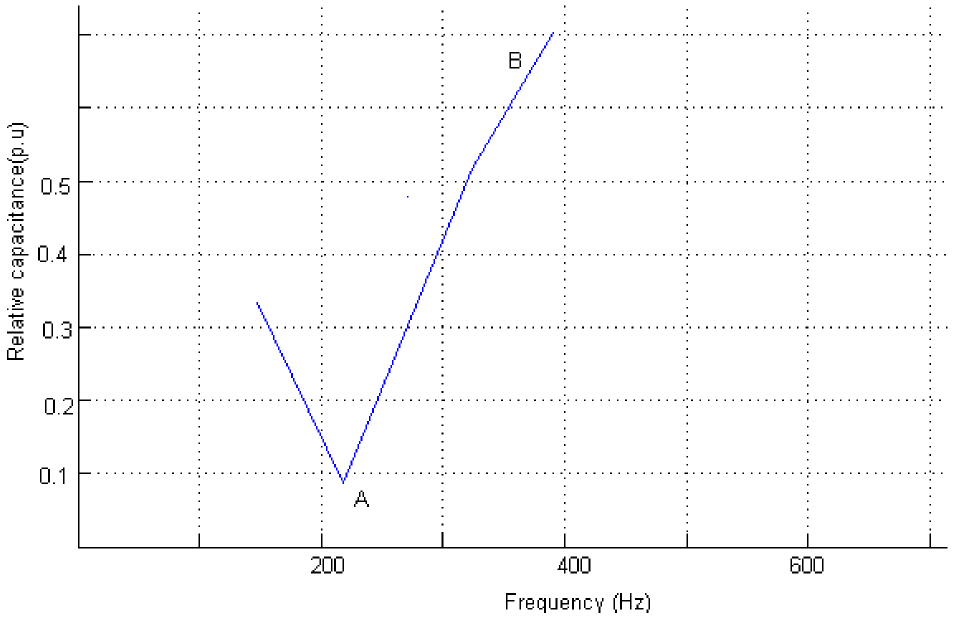


Fig. 1. Capacitance relaxation curve.

From the capacitance relaxation curve shown in the figure1, we have taken different values of capacitance as input of the model. Moreover, the input of the model is restricted to different values of capacitance in the rising part of the capacitance relaxation curve i.e. from the point A to B. For example we have taken the input as increase of capacitance from 0.1 p.u to 0.5 p.u in steps of 0.1 p.u in the forward path of the rising part of the curve i.e. from A to B. For the reverse path i.e. from B to A same process is repeated. The composite dielectric is regarded as 2nd order system having transfer function $(1/(S^2+S+1))$. The output is focused to trace out the locus for which it is possible to obtain electrostatic surfaces containing negative charges with different values of capacitances in the capacitance relaxation curve. The technique for tracing out the locus in real-imaginary axis, the Nyquist criterion has been used with the aid of MATLAB 6.5. In this way we have obtained different electrostatic surface for the forward and reverse path of the rising phase of the capacitance relaxation curve. The per unit values are taken for the normalization of a particular phenomena [8].

Let the capacitance change from 0.4 to 0.5 p.u is termed as ΔC1. The electrostatic surfaces obtained due to forward and reverse path of ΔC1 are given in Figs. 2-4.

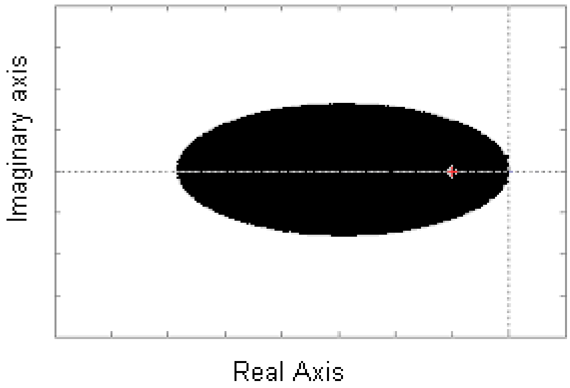


Fig. 2. Electrostatic surface containing negative charge in the forward path of ΔC1.

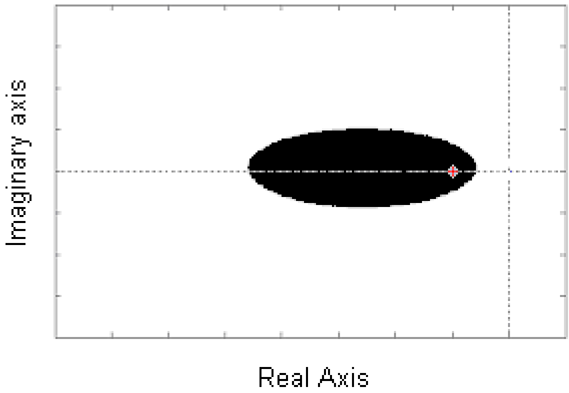


Fig. 3. Electrostatic surface containing negative charge in the reverse path of ΔC1.

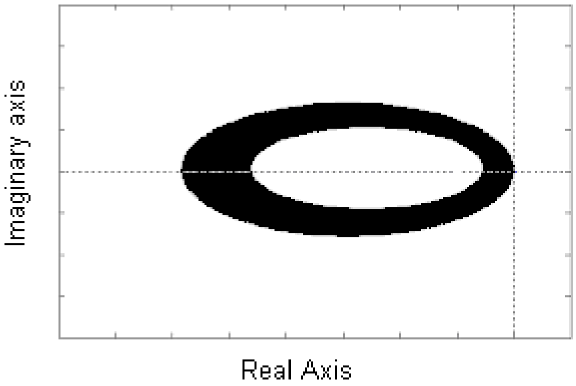


Fig. 4. Shaded area representing the variation in electrostatic energy indicating difference in electrostatic surfaces due to ΔC1.

The change in electrostatic energy due to ΔC1 is calculated as 0.15 p.u.

Let the capacitance change from 0.3 to 0.4 p.u is termed as ΔC2. The electrostatic surfaces obtained due to forward and reverse path of ΔC2 are given in Figs. 5-7.

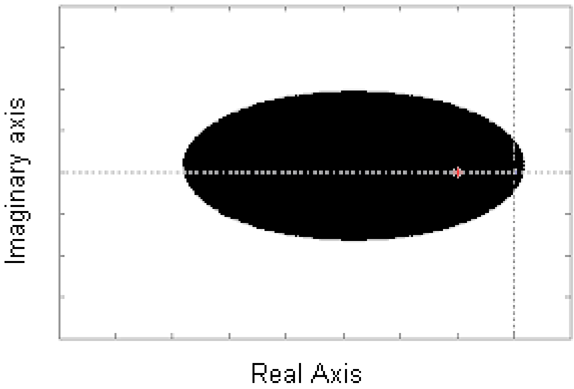


Fig. 5. Electrostatic surface containing negative charge in the forward path of ΔC2.

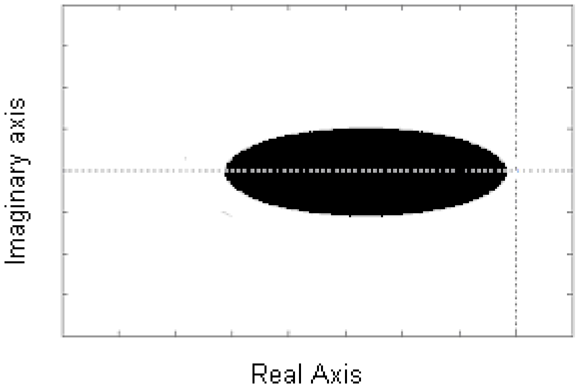


Fig. 6. Electrostatic surface containing negative charge in the reverse path of ΔC2.

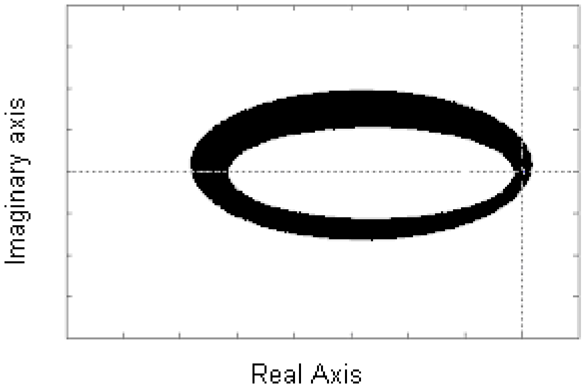


Fig. 7. Shaded area representing the variation in electrostatic energy indicating difference in electrostatic surfaces due to ΔC2.

The change in electrostatic energy due to ΔC2 is 0.12 p.u.

Let the capacitance change from 0.2 to 0.3 p.u is termed as ΔC3. The electrostatic surfaces obtained due to forward and reverse path of ΔC3 are given in Figs. 8-10.

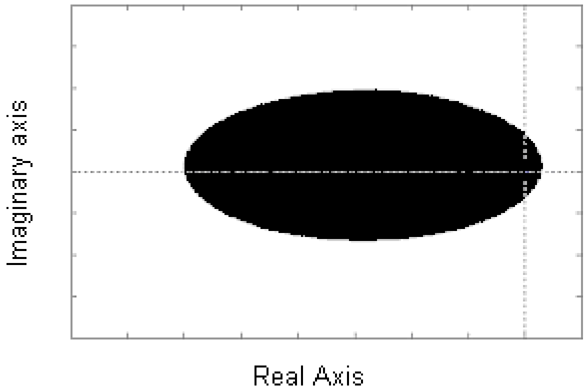


Fig. 8. Electrostatic surface containing negative charge in the forward path of ΔC3.

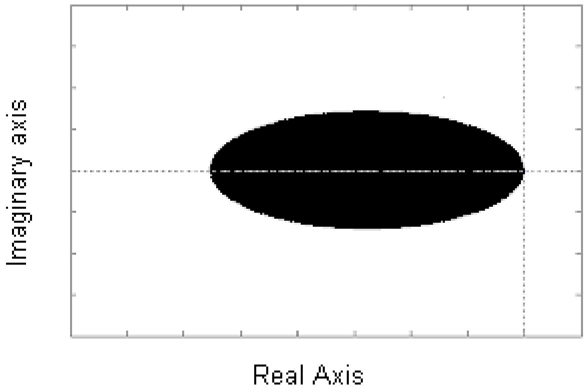


Fig. 9. Electrostatic surface containing negative charge in the reverse path of ΔC3.

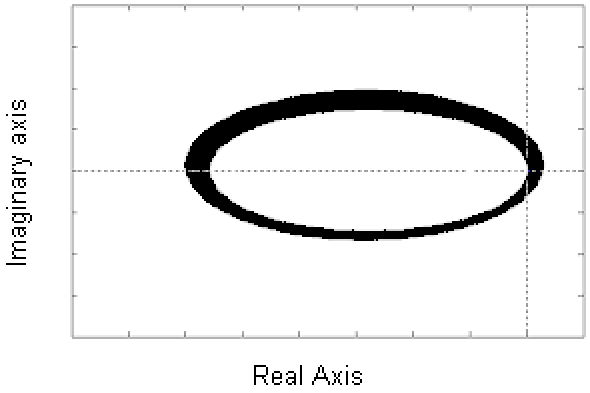


Fig. 10. Shaded area representing the variation in electrostatic energy indicating difference in electrostatic surfaces due to ΔC3.

The change in electrostatic energy due to ΔC3 is 0.06 p.u.

Let the capacitance change from 0.1 to 0.2 p.u is termed as ΔC4. The electrostatic surfaces obtained due to forward and reverse path of ΔC4 are given in Figs. 11-13.

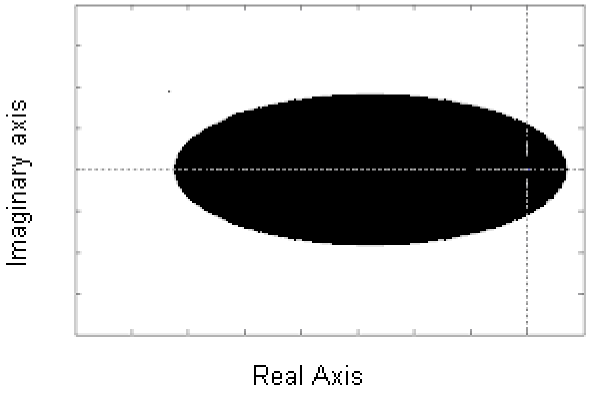


Fig. 11. Electrostatic surface containing negative charge in the forward path of ΔC4.

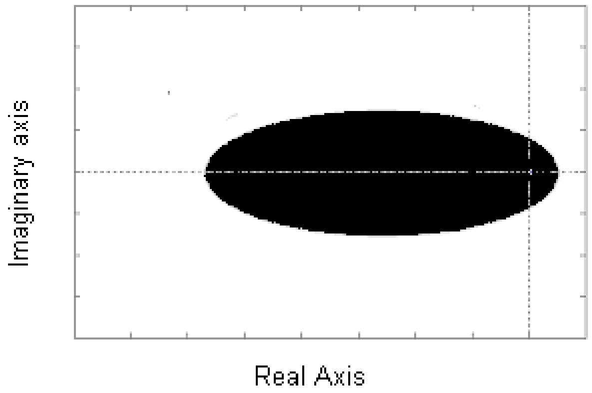


Fig. 12. Electrostatic surface containing negative charge in the reverse path of ΔC4.

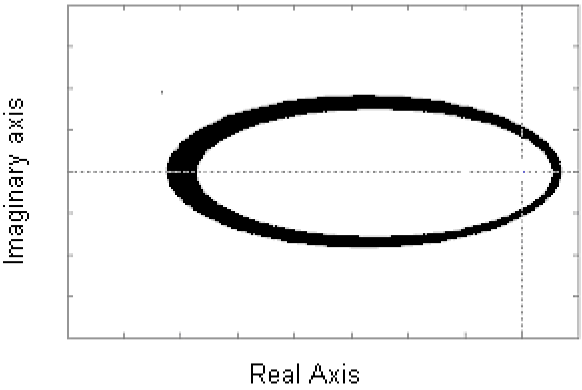


Fig. 13. Shaded area representing the variation in electrostatic energy indicating difference in electrostatic surfaces due to ΔC4.

The change in electrostatic energy due to ΔC4 is 0.03 p.u.

The difference in electrostatic energy due to difference in values of the capacitance is a measure of electrostrictive energy. Variation of electrostrictive energy with respect variation of incremental capacitance is shown in Fig. 14.

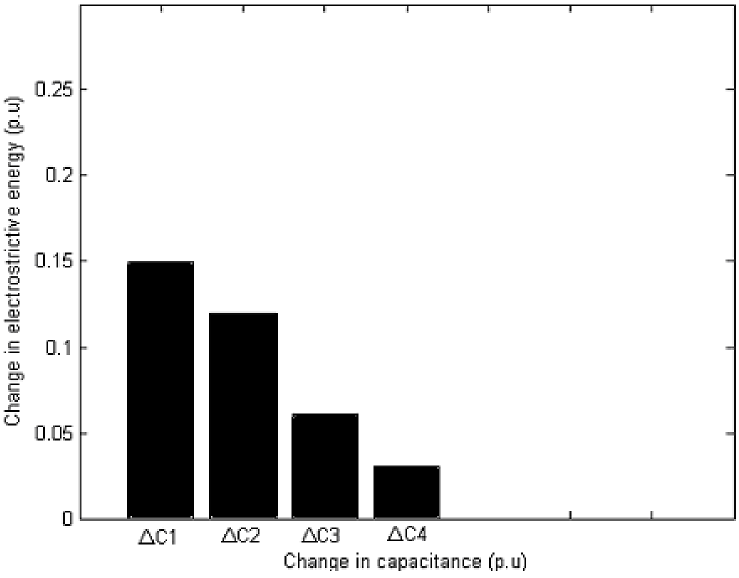
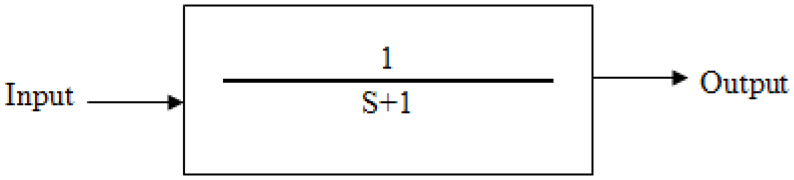


Fig. 14. Representation of electrostrictive energy due the variation of capacitance.

As the capacitance changes from ΔC1 to ΔC4 the surface area indicating electrostrictive energy decreases which results in decrease of negative charge on the surface of the cell, which indicates probable transformation from carcinogenic state to normal state.

2.2. Modeling and Simulation of the First Order Composite Dielectric (Case 2)

It has been mentioned in the introduction that when the cell division’s complete (mitosis) is complete. The membrane potential regains the normal value. At this stage the nature of the composite dielectric returns to the normal stage by can be first order transfer function shown in the block diagram:



From the US Patent [15] of Prof. T.K.Basak we have taken different values of capacitance as an input from capacitance from capacitance relaxation curve as shown in Fig. 15.

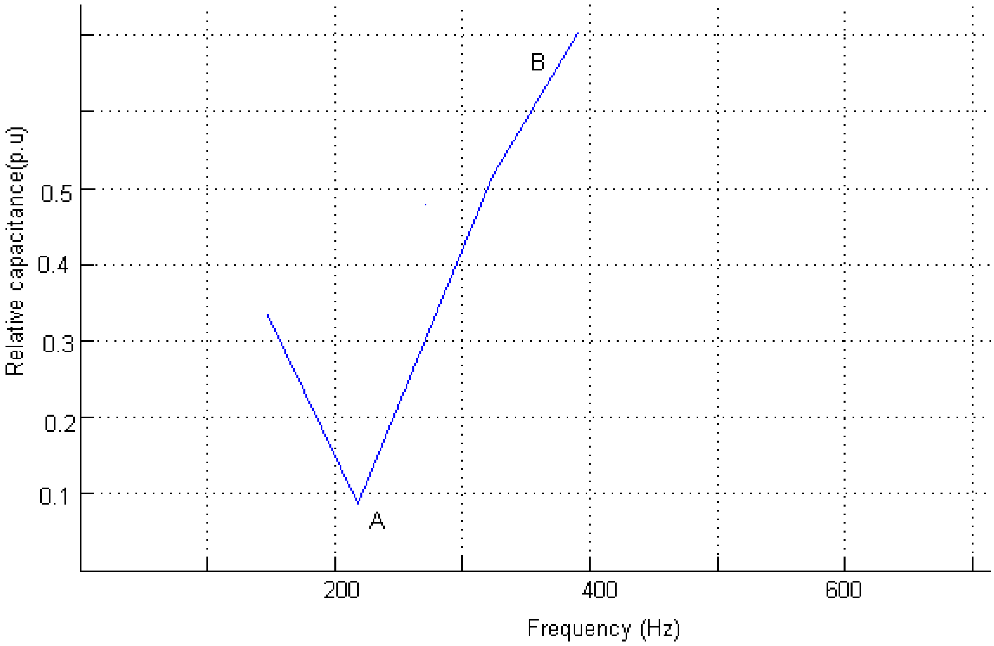


Fig. 15. Capacitance relaxation curve.

The input of the model is restricted to different values of capacitance in the rising part of the capacitance relaxation curve i.e. from the point A to B. Here we have taken the input as increase of capacitance from 0.4 p.u to 0.5 p.u in the forward path of the rising part of the curve for the reverse path i.e. from 0.5 p.u to 0.4 p.u same process is repeated. At the initial phase of metastasis the composite dielectric is regarded as 1st order system having transfer function (1/(S+1)). The output is focused to trace out the locus for which it is possible to obtain electrostatic surfaces containing negative charges with different values of capacitances in the capacitance relaxation curve. The technique for tracing out the locus in real-imaginary axis, the Nyquist criterion has been used with the aid of MATLAB 6.5. In this way we have obtained different electrostatic surface for the forward and reverse path of the rising phase of the capacitance relaxation curve. The per unit values are taken for the normalization of a particular phenomena [8]

It is stated earlier that capacitance change from 0.4 to 0.5 p.u is termed as ΔC1. The electrostatic surfaces containing negative charges obtained due to forward and reverse path of ΔC1 for the 1st order system are given in Figs. 16-18.

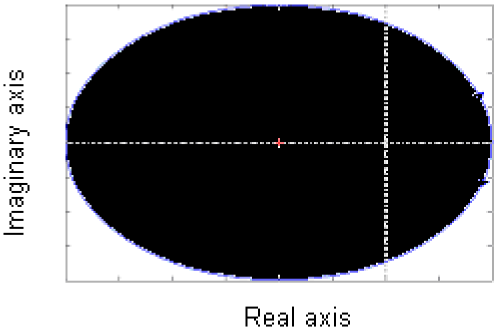


Fig. 16. Electrostatic surface containing negative charge in the forward path of ΔC1.

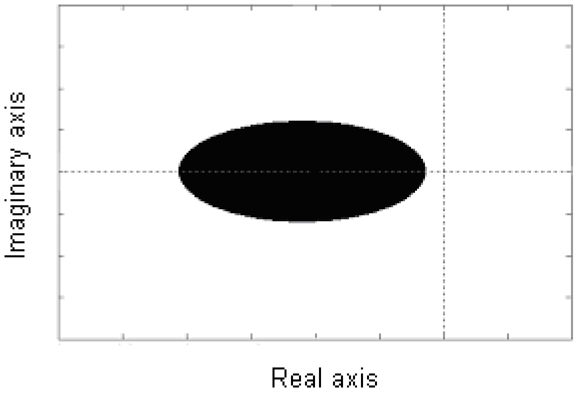


Fig. 17. Electrostatic surface containing negative charge in the reverse path of ΔC1.

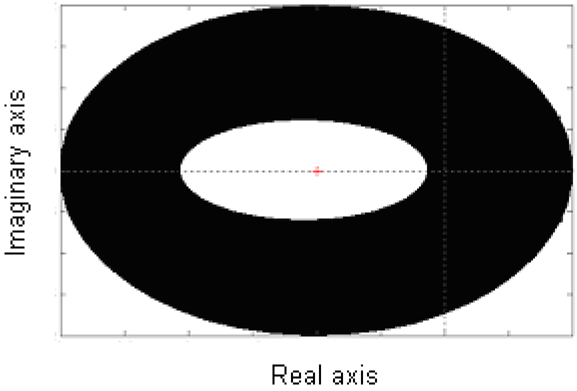


Fig. 18. Shaded area representing the variation in electrostatic energy indicating difference in electrostatic surfaces due to ΔC1.

The change in electrostatic energy for the 1st order system due to ΔC1 is calculated as 0.4 p.u.

Therefore it has been found from the results of simulation, that the electrosrisrictive energy due to ΔC1 for the 1st order system is 0.4 p.u where as in 2nd order system the electrostrictive energy due to ΔC1 is 0.15 p.u. as the system order increases the electrostrictive energy decreases concomitant with capacitance relaxation phenomenon.

Therefore as the system order increases the electrostrictive energy decreases. As the electrostrictive energy is higher in 1st order system therefore capacitance phenomena have more impact on 1st order system than 2nd order system.

3. Conclusion Discussion

The electrostrictive effect in cancer cells concomitant with capacitance relaxation phenomenon arises out of the composite dielectric property of the cell membrane. The figures from no.1 to 14. Corresponds to a composite dielectric material represented by second order transfer function i.e. $1/ (S^2 +1)$ and in this respect the elestrostrictive energy decreases with differential changes in the capacitance. It is to be further noticed that the composite dielectric material during the process of cell division and DNA synthesis is assumed to be of the first order since the process is relatively slow and it is interesting to observe that the electrosrictive energy corresponding to the same incremental change in capacitance is much higher than that presented in the second order system.

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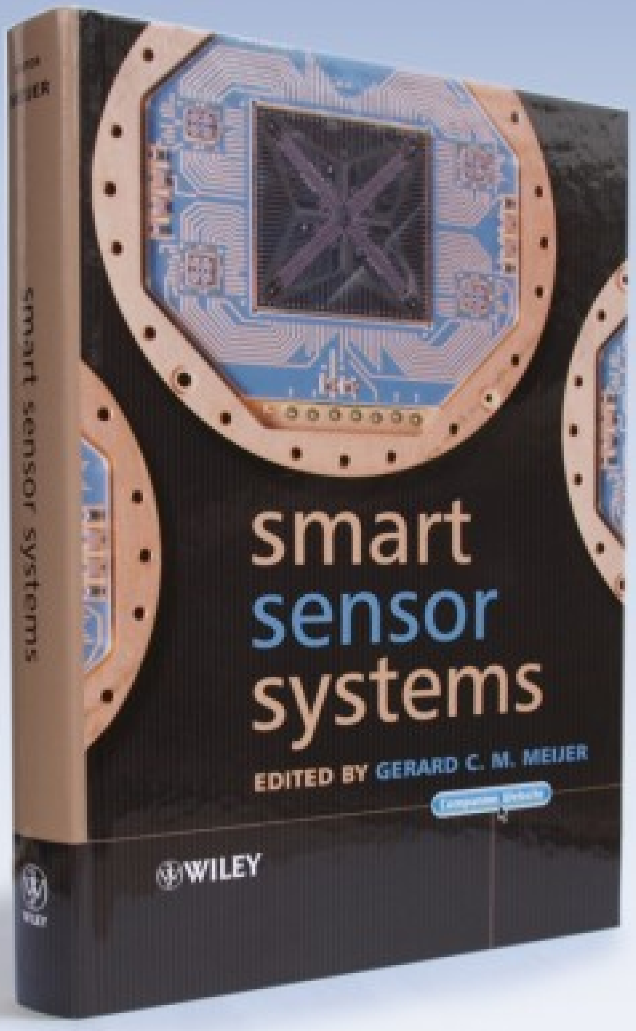
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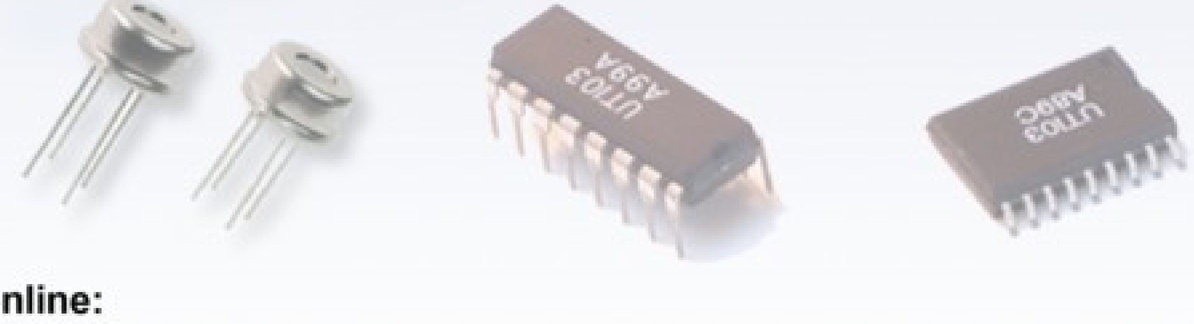
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