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*“Flourish and Nurturing Sustainable
Innovation for a Prosperous Nation”*

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Preface

In the name of Allah, the Almighty who gives us the enlightenment, the truth, the knowledge and with regards to Prophet Muhammad (peace be upon him) for guiding us to the straight path. We thank to Allah for giving us guidance and strength to write this e-book.

This e-book compiles the extended abstracts that submitted to Johor International Innovation Invention Competition and Symposium 2024 (JIIICaS2024), where JIIICaS2024 is a virtual platform for all creative minds to share and present their invention and innovation. Each abstract gives a brief background on the innovation or project.

We hope that this e-book will help the readers to get to know the innovation done by the students and get some ideas to develop future innovation products.



Foreword Rector



Assalamualaikum warahmatullahi Wabarakatuh,
Salam Sejahtera, Salam Malaysia MADANI and
Salam UiTM Dihatiku.

In the name of Allah, the Most Gracious, the Most
Merciful.

It is a great honor to welcome you to the Johor
International Innovation, Invention, Competition, and
Symposium 2024 (JIIICaS 2024). This event

connects various disciplines, focusing on education and engaging educators,
students, researchers, and innovators from all walks of life.

Innovation is not just about ideas; it demands perseverance, creativity, and
determination to turn those ideas into reality. The remarkable projects
showcased today highlight the dedication and spirit of all participants.
Initiatives like this not only explore new technologies but also cultivate skills
and leadership among our youth. At Universiti Teknologi MARA (UiTM) Johor
Branch, we are fully committed to fostering a dynamic culture of innovation,
promoting the commercialization of new products, and encouraging
meaningful collaborations with industry and society.

As we celebrate this event, I would like to extend my heartfelt gratitude to all
sponsors, judges, the College of Computing, Informatics and Mathematics,
UiTM Pasir Gudang Campus as the event organizer, as well as to the
researchers and participants for their hard work in making this event a
success. Let us continue striving for innovation and excellence. May the
ideas presented today inspire us and lay the groundwork for future
achievements.

Thank you.

Associate Professor Dr. Saunah Zainon
Rector
Universiti Teknologi MARA (UiTM)
Johor Branch

(A-ST155) A MATLAB GUI FOR THE FIRST ORDER POLARIZATION TENSOR OF ROTATED SPHEROIDS

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ABSTRACT

When a conducting object presents in an electric or electromagnetic field, the perturbation on the field due to the presence of the object can be mathematically modelled as an asymptotic series, where, the dominant term of the series is called as the Polarization Tensor (PT). In the applications of electric and electronic, PT has been adapted for many purposes such as to improve reconstruction of image in medical scanning and geophysics, as well as, to enhance metal detection for security screening or landmine clearance. Besides, PT also appears in neuroscience after some researchers have used PT to study object recognition from electrical sense by electric fish. For each application, the PT might able to describe some physical properties of the presented object such as the size, material or orientation of the object. In this study, the PT, specifically the first order PT, when the conducting object is a spheroid, will be presented. First of all, given the conductivity and all semi axes of the spheroid, a method to determine the first order PT for the spheroid will be discussed. Then, a Matlab GUI that can easily execute the computation will be presented. We focus on spheroids as previous studies have shown that the first order PT for many objects in the related applications are actually similar to the first order PT for the spheroids. Thus, understanding the first order PT for spheroids could be useful to describe the actual objects. With the proposed GUI, the first order PT for any spheroid can be computed when the size and the conductivity that represents the material of the spheroid are specified. Not only that, if the spheroid is rotated around the vertical axis, the GUI is also able to compute the related first order PT if the angle of rotation is given. Finally, some examples will be also included in this study to demonstrate the capability of the recent developed GUI.

Keywords: prolate spheroids, oblate spheroids, conductivity, semi axes, matrices

1.0 INTRODUCTION

The PT can be used to improve electrical imaging or metal detection and also to study electric fish with a lower computational cost to characterize and describe objects in those applications (Ammari dan Kang (2007), Ahmad Khairuddin and Lionheart (2016), Ledger and Lionheart (2023)). This is because the PT does not require a full

image or object reconstruction. In this case, PT contains significant information about the object such as size, material and orientation of the object (Ammari and Kang, 2007). Moreover, it can be shown that, the first order PT of any object presented in the electric or electromagnetic field can be related to an ellipsoid, such the first order PT related to the ellipsoid is similar to the first order PT of that object (see Ahmad Khairuddin and Lionheart (2016) for example). Therefore, describing the ellipsoid could be useful in identifying the original object as they might have similar size or orientation when their first order PT is the same.

In this study, an invention that can easily calculate the first order PT of spheroids, which are a type of type of ellipsoid, is proposed. The invention as a MATLAB Graphical User Interface (GUI), is an extension of our previous intellectual property, copyrighted by MyIPO with reference number LY2024J02487. In this invention, a new feature is included that allows the calculation of the first order PT for a spheroid, after the spheroid is rotated one time around any of the coordinate axis. It is believed that there is no software or product in academia that allows with a single application for the calculation of the first order PT for an object and its rotation. Now, in the next section, the related formulation of the first order PT for spheroid will be presented.

2.0 MATHEMATICAL FORMULATION OF THE ROTATION OF THE FIRST ORDER POLARIZATION TENSOR

This section reviews the formula for the rotation of the first-order PT, specifically for the spheroid. The formula for the first order PT for a spheroid has been simplified by Mohamad Yunos and Ahmad Khairuddin (2017). According to them, that first order PT can now be expressed in terms of a function called as the depolarization factor. Assume that the object B is a spheroid, represented in the Cartesian coordinate system as $\left(\frac{x^2}{a^2}\right)^2 + \left(\frac{y+z}{b}\right)^2 = 1$, with the semi axes denoted as a and b such that they are either in the condition of $a > b$ or $a < b$. Then, the first order PT for B is given by

$$M(k, B) = (k - 1)|B| \begin{bmatrix} \frac{1}{(1-d_1)+kd_1} & 0 & 0 \\ 0 & \frac{2}{(1+d_1)+k(1-d_1)} & 0 \\ 0 & 0 & \frac{2}{(1+d_1)+k(1-d_1)} \end{bmatrix}, \quad (1)$$

where k is the conductivity of B that satisfies $k > 0$ and $k \neq 1$, $|B|$ is the volume of B and d_1 is the depolarization factor of B , as given by Stoner (1945) and it is restated here in Proposition 1.

Proposition 1 Let a, b and c be the semi principal axes of an ellipsoid given by $\left(\frac{x^2}{a^2}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2 = 1$.

i. If $a > b = c$, then $d_1 = \frac{1-\psi^2}{\psi^2} \left(\frac{1}{2\psi} \ln \left(\frac{1+\psi}{1-\psi} \right) - 1 \right)$, where $\psi = \sqrt{1 - \left(\frac{b}{a}\right)^2}$,

ii. If $a < b = c$, then $d_1 = \frac{1}{\varphi^2} \left(1 + \frac{\sqrt{1-\varphi^2}}{\varphi} \sin^{-1} \varphi \right)$, where $\varphi = \sqrt{1 - \left(\frac{a}{b}\right)^2}$,

where, d_1 is the depolarization factor for the spheroid.

Therefore, in order to determine the first order PT for spheroid using Eq. (1), the semi axes and the conductivity of the spheroid must be known. These values will become the inputs of our proposed GUI. In addition, the conductivity, k of B plays a crucial role in classifying either the first order PT for spheroid in the form of Eq. (1) is a positive definite or negative definite matrix (Ammari and Kang,2007), where, these conditions are explained here in Proposition 2.

Proposition 2 If $k > 1$, then the first order PT for any object is positive definite, whereas it is negative definite if $0 < k < 1$.

Furthermore, when a spheroid rotates, the first order PT for the spheroid also rotates. The relationship between the first order PT for an object before and after rotation is discussed by Ammari and Kang (2007) and is given here in Proposition 3. Based on Proposition 3, if the first order PT for a spheroid B before it is rotated is given by $M(k, B)$ then the first order PT for the spheroid after it is rotated can be obtained by multiplying $M(k, B)$ with the appropriate rotation matrix.

Proposition 3 Let B be a domain and $B' = RB$ where R represents an orthogonal matrix transformation and R^T represents the transpose of R . If $M(k, B)$ and $M(k, B')$ are the first order PT corresponding with domain B and B' respectively at any conductivity k such that $k > 0$ and $k \neq 1$, then $R^T M(k, B) R = M(k, B')$.

In our new GUI, the spheroid is allowed to rotate one time around any of the coordinate axes before the first order PT of the rotated spheroid can be computed. The rotation matrices with an angle θ° that represent rotation counterclockwise around x -axis, y -axis, and z -axis, denoted by R_x , R_y and R_z respectively, are given by

$$R_x(\theta^\circ) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta^\circ & -\sin \theta^\circ \\ 0 & \sin \theta^\circ & \cos \theta^\circ \end{bmatrix}, \tag{2}$$

$$R_y(\theta^\circ) = \begin{bmatrix} \cos \theta^\circ & 0 & \sin \theta^\circ \\ 0 & 1 & 0 \\ -\sin \theta^\circ & 0 & \cos \theta^\circ \end{bmatrix}, \tag{3}$$

$$R_z(\theta^\circ) = \begin{bmatrix} \cos \theta^\circ & -\sin \theta^\circ & 0 \\ \sin \theta^\circ & \cos \theta^\circ & 0 \\ 0 & 0 & 1 \end{bmatrix}. \tag{4}$$

Thus, if a spheroid is rotated one time around any of the coordinate axes, our GUI implements either Eq. (2), (3) or (4) to Eq. (1) to obtain the first order PT of the rotated spheroid based on Proposition 3.

3.0 THE MATLAB GRAPHICAL USER INTERFACE

The proposed invention as a MATLAB GUI is called as the Spheroidal First Order Polarization Tensor Calculator with One Time Rotation. Similar to our previous GUI, this new GUI is designed for spheroids with semi axes $a > b = c$ (prolate spheroids) or $a < b = c$ (oblate spheroids). It offers two main functions which are calculating the first order PT for both prolate and oblate spheroids, before and after the spheroids are rotated, as well as visualizing the original spheroid in a three-dimensional graph.

Figure 1 illustrates the overall layout of the Spheroidal First Order Polarization Tensor Calculator with One Time Rotation in MATLAB. The layout started from the

descriptions about the calculator at the top. Then, each function was separated using the panel for better interface and easy to understand by users.

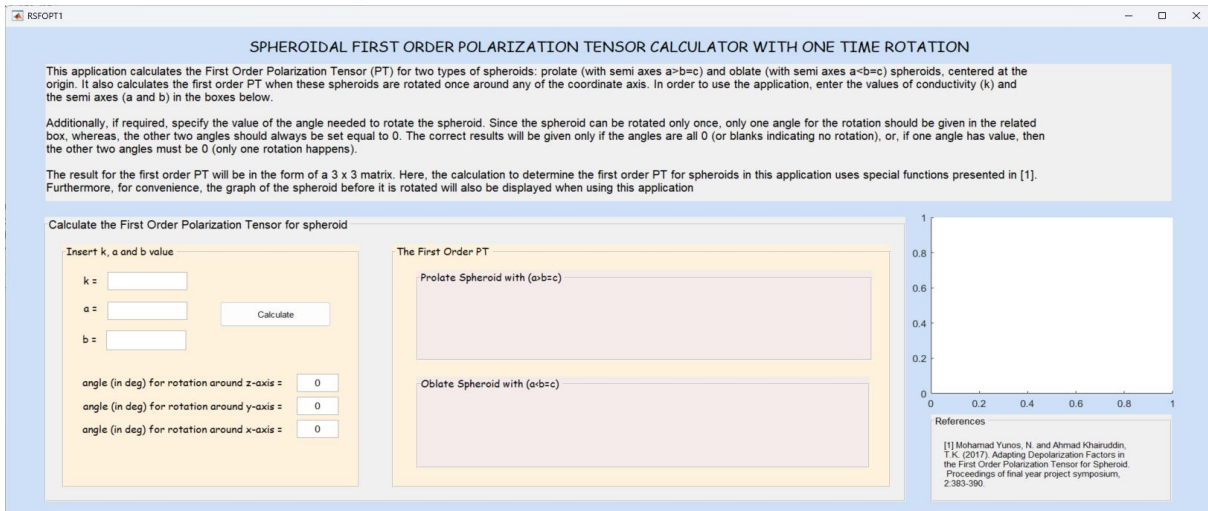


Figure 1: The overall layout of the Spheroidal First Order Polarization Tensor Calculator with One Time Rotation in the MATLAB

Meanwhile, Figure 2 briefly describes all three functions of each panel. In order to compute the first-order PT for a spheroid using this GUI, the values for the semi axes (a and b) and also the conductivity, k must be inserted. Additionally, if the spheroid is rotated one time around one of the coordinate axes, user also need to specify the angle (in degree) of the rotation. By the default, all angles are set equal to 0 so that, user can straight away calculate the first order PT for a spheroid without rotation by clicking the button Calculate after the values for a , b and k are given. Note that the GUI only allows one rotation for the spheroid along any of the coordinate axes so, to get the correct result for the first order PT, if one angle is specified in the GUI then the other two angles must be set equal to 0.

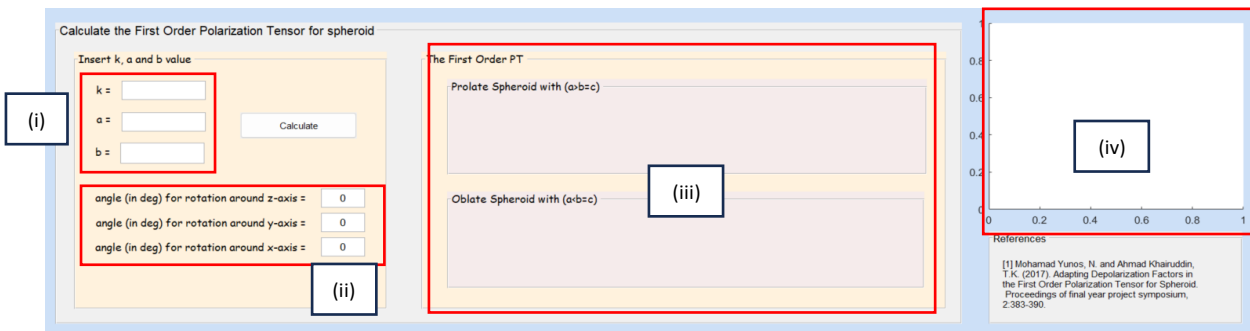


Figure 2: The interface of the Spheroidal First Order Polarization Tensor Calculator with One Time Rotation that includes the following functionality: (i) Users are required to insert the values of conductivity, k and semi axes, a and b . (ii) Users are required to insert the angle of rotation (in degree) if necessary. (iii) The output which is the first order PT is displayed according to the type of the specified spheroid, after all the required information, either in (i) only (no rotation) or in both (i) and (ii) (has rotation) are given. (iv) The 3-dimensional graph is plotted based on the input inserted in (i), which is the graph of a spheroid before it is rotated.

After the button Calculate is clicked, the values of the first order PT will be displayed based on the type of the spheroid, which is either prolate or oblate. If no rotation happens, the first order PT will be a diagonal matrix, as depicted by Eq. (1) whereas the first order PT could be a non-diagonal matrix if the spheroid is rotated. In addition, the graph of the spheroid without rotation will also be displayed by the GUI to further clarify the type of spheroid that is related to the computed first order PT.

4.0 SOME EXAMPLES

In order to demonstrate the reliability of this GUI, we firstly consider the first order PT of a spheroid with semi axes and conductivity given by $a = 1$, $b = 2$ and $k = 0.05$, respectively, with no rotation happens to the spheroid. Figure 3 illustrates the interface after the button Calculate is clicked with all specified inputs and calculated outputs. As can be seen in the figure, the first order PT calculated, that is negative definite according to Proposition 2, is actually for the oblate spheroid.

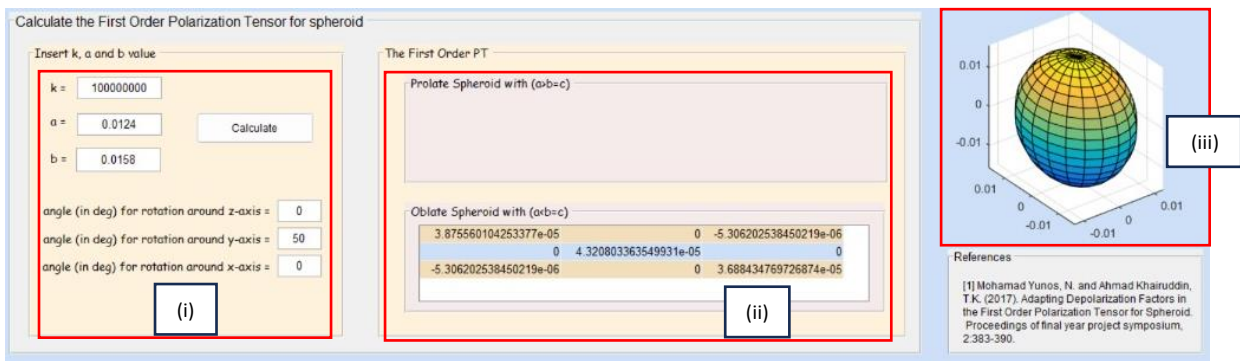


Figure 3: The interface when using the GUI. (i) A user inserts the values for conductivity, $k = 0.05$ and semi axes, $a = 1$, and $b = 2$ with no rotation happens such that all angles equal to 0. (ii) Upon clicking the Calculate button in (i), the first order PT is displayed and classified as an oblate spheroid. (iii) Additionally, upon clicking the Calculate in (i), a 3-dimensional graph for the spheroid is also generated.

Besides, a cone is considered for the next example, where, the cone and the spheroid (with semi axes $a = 0.0140$ and $b = 0.0128$) has the similar first order PT at $k = 100000000$. These objects are based on the studies by Ahmad Khairuddin and Lionheart (2016). Now, if the cone is rotated 120° around the z -axis, the first order PT of the cone after the rotation can be obtained by using the first order PT for the related spheroid and Proposition 3. Figure 4 illustrates the interface for calculating the first order PT for the rotated prolate spheroid, which is the desired first order PT for the cone, after the cone is rotated. In this case, the GUI can help to easily and quickly determine the first order PT for the cone if a spheroid that is related to the cone is known.

Finally, a pyramid also from Ahmad Khairuddin and Lionheart (2016), that is related to the spheroid with semi axes $a = 0.0124$ and $b = 0.0156$, is considered. Figure 5 shows the first order PT of the spheroid after at conductivity $k = 100000000$, after the oblate spheroid is rotated 50° around the y -axis. This first order PT is also the first order for the pyramid after it undergoes the same rotation.



Figure 4: The interface when using the GUI with inputs conductivity, $k = 100000000$, semi axes, $a = 0.014$, and $b = 0.0128$ with $\theta = 120^\circ$.



Figure 5: The interface when using the GUI with inputs conductivity, $k = 100000000$, semi axes, $a = 0.0124$, and $b = 0.0156$ with $\theta = 50^\circ$.

5.0 CONCLUSION

As a summary, the GUI provides a faster way to compute the first order PT for a spheroid, whether or not the spheroid is rotated. The GUI can also be used to compute the first-order PT for other objects, provided that the spheroid with the same first-order PT is known. Thus, the GUI could be useful in ongoing research or related applications of PT.

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