PLASI/OZPLTE

Table of Contents

1   Program Description

Introduction

This documentation describes PLASI and OZPLTE, two 'plate-in-air' modelling program modules that can be used in conjunction with the software program EM Vision. These two modelling algorithms operate as forward programs only, but are fast to run and operate in most field survey configurations. Both modules calculate the TEM voltage response of a thin plate in air for coincident loop, in-loop, turam, downhole and slingram modes.

As implemented in EM Vision, both modules are capable of modelling multiple plates (in air). The method adopted is to compute the response of each target individually and then add the responses. No account is made for interactive EM coupling between the plates.

Time domain electromagnetic (TEM) modelling is best approached by applying relatively simple techniques and then refining the approach to gain more insight. It is important to initially understand the basic earth structure and in particular, if a 'target' style of EM modelling is appropriate for the data being simulated. The target model should, as much as possible, be consistent with known or expected geology.

EM Vision makes use of a number of modelling algorithms to accommodate different EM datasets and survey situations. Each algorithm can be purchased individually or collectively. The documentation available to describe and operate each module is presented individually and this manual relates only to the PLASI and OZPLTE modelling programs. These are supplied as required for the modules purchased.

Modelling within EM Vision can take one of two forms depending on the complexity of the modelling requirement, the simplicity of the algorithms available and the model types. Increasing model complexity usually results in increased computation times. The two modes of operation are:

- Some algorithms can be implemented to operate interactively. Computed responses from these modelling algorithms is fast enough that a model can be created, response calculated and displayed in a few seconds or minutes. Examples of these programs include PLASI, OZPLTE and SPASYM.

- Where computation times are longer (typically some minutes or even hours), the modelling algorithms are implemented to operate remotely from EM Vision. Control and user feedback is provided to EM Vision while the program executes but the user can continue with other operations while modelling executes in the background. Examples of these programs are GRENDL and BEOWLF.

Program PLASI

Description

The PLASI program was written in the early 1980's within CSIRO and sponsored by a group of companies under Australian Minerals Industry Research Association (AMIRA). PLASI is a simplified version of the University of Toronto program, PLATE, originally written by Dyck and Bloore (1980). Amendments to the original code were made at CSIRO to permit the more complex program to operate on then standard desktop computers. This new program was called OZPLTE. PLASI is a single eigencurrent version of OZPLTE (and PLATE) with some local approximations to increase the range of application. Corrections are made to improve the single eigenvalue approach. Coupling coefficients are calculated to account for general orientations of plate, transmitter and receivers.

Output is in terms of volts/amp rather than magnetic fields or dB/dt. PLASI operates much faster than OZPLTE and is reasonably accurate as long as the transmitter-receiver combination is not too close to the target plate conductor.

Program OZPLTE

Description

The OZPLTE program module is a variation of the University of Toronto PLATE (Dyck et al, 1980) program converted and improved at CSIRO and first released in 1984. As for PLASI, OZPLTE calculates the TEM voltage response of a thin plate in air for coincident loop, in-loop, turam, downhole and slingram configurations.

The difference between PLASI and OZPLTE lies in the more powerful and less restricted use of Chebychev polynomials to simulate secondary electric fields in each of the two plate directions and with variable polynomial order. The higher the degree of the polynomial, the more complex behaviour can be represented and

the more accurate the solution, in that the whole plate is represented with functions instead of individual bits. The secondary electric field is solved in the frequency domain and then a singular value decomposition is done so the X and Y time domain plate components are derived.

Computational Method - PLASI and OZPLTE

Annan (1974) published a numerical method for determining the EM response of a vertical rectangular thin plate conductor in air for any type of EM source. The method is a considerable improvement of the one used by Lamontagne and West (1971), but the basic idea is similar. The current induced in the plate by the EM transmitter is determined first; then the secondary field produced by the current system is calculated. Lamontagne and West describe the current system by a rectangular network of point values on the plate. In contrast, Annan computes a system of eigencurrents for the plate and then describes the induced current system as a summation of these eigencurrents. Finding the set of eigencurrents is complicated, but only needs to be done once for a plate of given length-to-width ratio. After that, any induced current system can be described in terms of only 10-20 coefficients in the eigencurrent summation. When this is compared with the several hundred point values of current that are required by Lamontagne and West's method, Annan's method becomes superior. Another great convenience of Annan's method is that each eigencurrent has a frequency response exactly like a simple loop circuit. It is therefore easy to calculate responses for a broad spectrum of frequencies or for time domain EM systems.

The originally coded version of the program by Annan has been expanded to handle various geometries of the plate and the coil configurations of practical EM systems. The waveforms of several common time-domain EM systems have also been accommodated. Lodha implemented the modelling system originally on the University of Toronto IBM 370 system and used it for several studies (Lodha and West, 1976).

CSIRO amendments corrected a number of problems associated with the original PLATE code that were evidenced when modelling in various surface configurations. Additional corrections were required for the computation of a unit delta function impulse of current where internal scaling terms were omitted.

There are four main processing stages in both PLASI and OZPLTE:

Stage 1
The eigencurrents must be prepared. This requires only the width-to-length ratio of the plate.

Stage 2
The coupling between the EM transmitter and the plate must be calculated. This is done by finding the normal component of the transmitter's magnetic field on a grid of points on the plate, and then performing numerical integrations (essentially 7 cross correlations) of the field and eigenfunctions. The field is calculated for a unit current in the transmitter loop if the transmitter is large, or for a unit dipole moment if it is small. The result is a 'primary field' coupling coefficient for each eigencurrent.

Stage 3
The coupling between the EM receiver and the plate is computed. Each eigencurrent system is subdivided into current elements and the magnetic field components computed for each of the receiver points. These are summed (integrated) for each eigencurrent giving a set of secondary field coefficients.

Stage 4
The total response is synthesized from the geometrical coefficients generated in the previous two steps and the frequency or time response of the eigencurrents computed. Since the eigencurrents behave like simple non-interacting loop circuits, this is quite a simple calculation and is easily redone for different plate conductance and frequencies, etc.

There are three main complexities in programming the Annan system.

- Handling the geometrical complexities of the relative positioning of the plate and the EM system that requires several coordinate transformations.

- Handling calculations for time domain EM systems with complicated transmitter current waveforms.

- Recycling the program to obtain outputs in the form of profiles or frequency spectra so that the presentation of results corresponds to the required format.

As can be appreciated from the basic program structure, the modelling system must be cycled in different ways if the transmitter and receiver move together or if the transmitter is fixed and the receiver alone moves.

Limitations of PLASI and OZPLTE

Both PLASI and OZPLTE are capable of computing responses to the same accuracy as physical scale model measurements in reasonably favourable situations. Errors may arise in two ways:

- Having an insufficent number of eigencurrents represent the actual induced current pattern.

- In numerical integrations that compute the coupling between receiver and transmitter and the various eigencurrents.

If the plate is very large, and the EM system is close to a part of it so appreciable induction occurs only in a very small part of the conductor, then high order eigencurrents will be necessary to describe the induction properly. This situation is especially important for downhole modelling. The current version of OZPLTE is limited to 7 eigencurrents and this is the main limitation of the algorithm.

WARNING

Problems are most obvious when computing responses near the inductive limit. As a rough guide, difficulties will arise when the quotient (plate length x plate width is divided by distance of receiver to closest part of plate x distance of transmitter to closest part of plate) is greater than 100.

For OZPLTE, errors in response may also arise if the plate strike length to plate width exceeds 10:1. For PLASI, errors can result if this ratio exceeds 3:1.

Comparisons have been made between analog scale models and numerical models of the same case for each of several EM systems and these are documented in Dyck et al, 1980 and Buselli and Thorburn, 1986. The comparisons show excellent agreement, to the point where it is uncertain whether the discrepancies were due to error in the analog or the numerical modelling.

Operation of PLASI and OZPLTE

Within EM Vision, access to PLASI and OZPLTE is not through the Generic Model Interface. Refer to the section describing the *Generic Model Interface* for additional information. Both programs operate fast enough that their responses can be computed interactively and batch operation is not necessary.
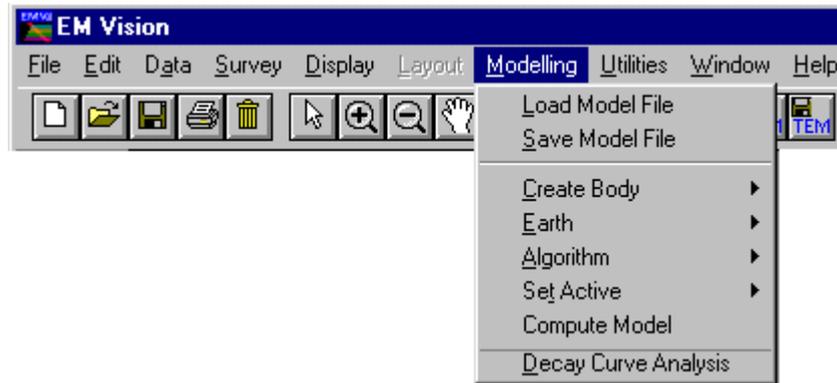
EM Vision model menu.

As for all modelling in EM Vision, a number of preparatory steps must be taken before a model response can be computed. These steps are sequentially listed in the Modelling menu. Initially, a modelling operation requires a response display, a profile (or station) for the reading locations, a representation of the model, plus the assignment of channels and stations to compute.

Initially data can be loaded from a saved model file (Load Model File option) or, after creation, a model can be saved by using the Save Model File menu item.

Create Body Option

This option is used to create a body for use with PLASI or OZPLTE forward modelling. In the case of profile modelling, a prerequisite for body creation is the display of a cross-section beneath a profile of data. See Cross-*Section Profile Displays* for additional information on creation of a profile display with cross-section. In the case of borehole modelling, display the borehole in a section (see *Borehole Displays*) prior to creation of a plate body. Also, note that no observed data need be displayed for a model response to be computed. Theoretical responses in the absence of observed data are often used for survey planning, response simulation and coupling studies.

For either profile or borehole modelling, the section area is used to create, edit and manipulate the individually modelled bodies. For PLASI and OZPLTE only, the Plate body type can be selected from the options of the Create Body menu item.

Interactive body control is available for creation and editing bodies. Double clicking the left mouse button while the cursor is positioned over a body will

display a dialog with options for controlling the body parameters and display. Refer to *Body Display Control* for additional information.

Plate Body Creation

After selecting the **Create Body>Plate** option, move the mouse cursor to the cross-section area of the profile or borehole display. The cursor will change to a '+'. Position the cursor where the top of the plate is required and click the left mouse button. Hold the mouse button down as you move the mouse to draw a dashed bounding box to define the top to bottom extents of the plate. To actually create the body using this technique, release the mouse button with the bounding box defining the depth extent of the plate. A second method of creating a plate is to position the cursor and then click the left mouse button. A default plate will then be created.

Editing a Plate in the X-Section Window

Selecting Bodies

All model editing is preceded by instructing EM Vision which body is to be edited. This is done by **selecting** the body. Bodies can be selected individually or multiply, although PLASI and OZPLTE can only model a single plate at a time. Once selected, the plate can be shifted, resized and have various parameters altered. Body selection operates identically both in X-Section and Map displays.

To select a body, ensure that EM Vision is in **Pointer** mode. If EM Vision is in the incorrect mode, select the **Pointer** push button on the toolbar (the Status Bar will report if EM Vision is in another mode). Position the cursor over the required body and click the left mouse button. To indicate a body is selected, four surrounding handles will be drawn around the body.

Interactive Body Shifting

To move an individual body in cross-section (or in map view), click the left mouse button to select the body. Hold the mouse button down as you move the mouse. This will 'drag and drop' the body to a new location when the mouse button is released.

The Plate Body

Editing a plate body and its parameters is done by using dialogs. By positioning the cursor over the plate and double clicking with the left mouse button, a configuration dialog will be displayed.

Plate body properties dialog

The location of the reference point of the plate is specified and can be edited if required. The other physical properties of the selected body defining the strike azimuth and length, plunge, dip and down-dip depth extent are available for editing. Following is a diagram detailing the various parameters used to describe the plate body type.
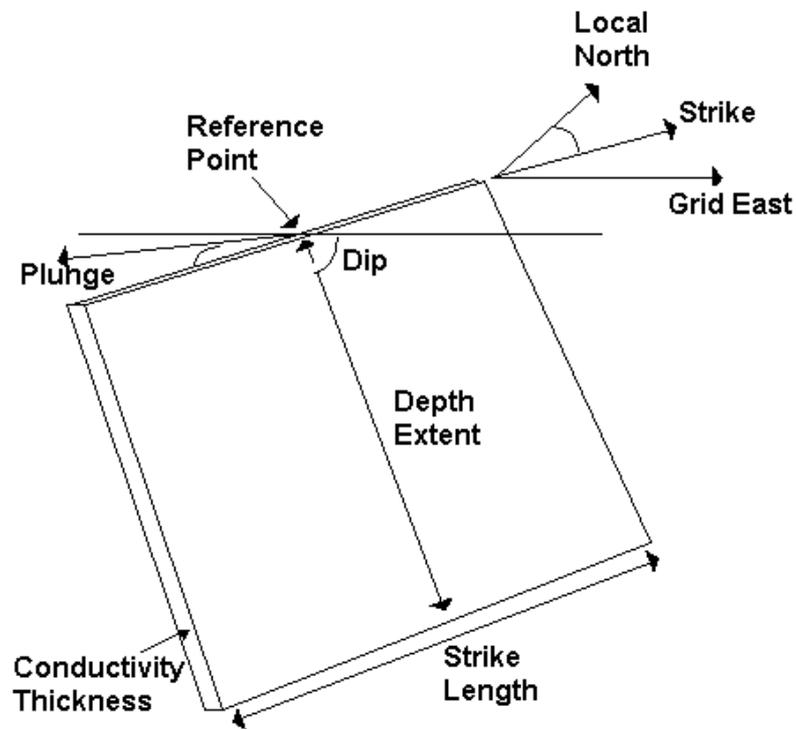
Note

The location of the plate body is defined by a reference point located at the centre of the top surface. Also, note that the depth position of the reference point is negative.

The parameters used to define the plate are:

Position (X,Y,Z)
The location of the reference point of the plate relative to the local coordinates. Note that depth is negative down.

Conductivity
The value determined by multiplying the

Thickness
Thickness of the plate (in metres) by the conductivity of the plate (in Siemens).

Depth Extent
The depth extent of the plate is the distance from the top to the base of the plate measured in the plane of the plate.

Dip

The dip angle is formed perpendicular to strike azimuth and measured in a vertical plane positively down from the local east axis to the plane of the plate. Dip range for the plate is $0^0 >= dip < 180^0$.

Strike Angle

The strike angle (azimuth) is formed by the rotation in the horizontal plane of the plate clockwise from local north. Strike has a data range of $0^0 >= strike < 180^0$.

Strike Length

The strike length is the distance from one edge of the plate to the opposite edge measured horizontally in the plane of the plate.

Plunge

Plunge is the angle of plate rotation about a horizontal axis and measured as the angle between the horizontal and the line of the top surface of the plate from the reference point. The range of the plunge is $-90^0 >= plunge < 90^0$.

Earth Option

The Earth option of the EM Vision Modelling menu is used to define the Earth structure and assign its properties. Various Earth types are required to satisfy the many host environments that can be modelled but in the case of PLASI and OZPLTE, the only available option is a body in Air.
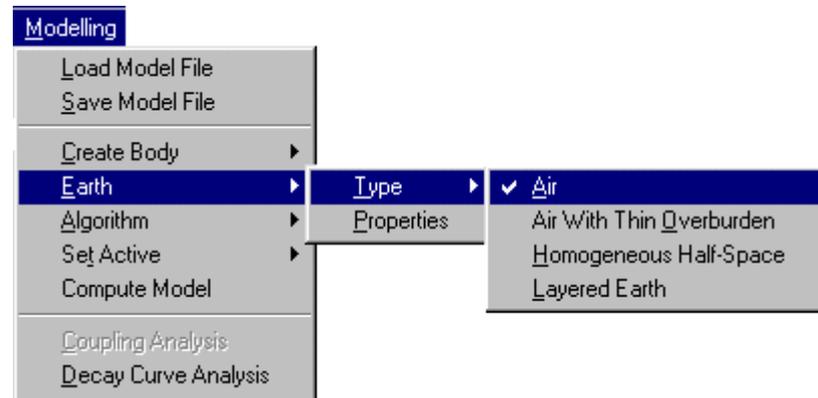
Algorithm Option
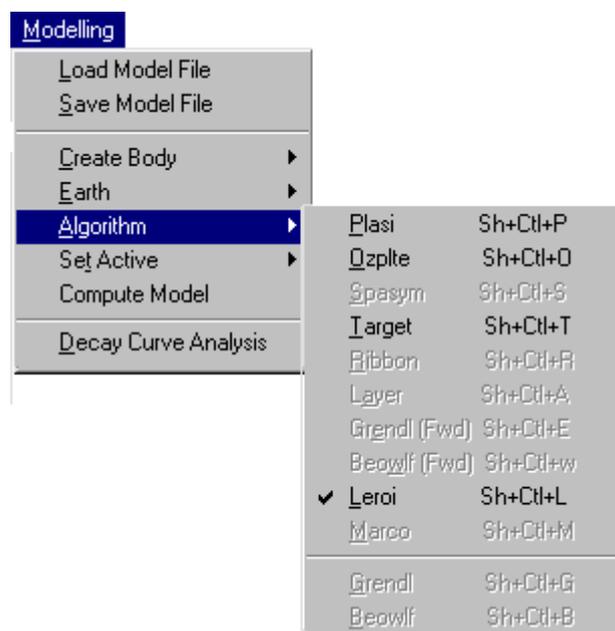
The Algorithm option in the Modelling menu is used to select either PLASI or OZPLTE programs. Note that other programs that have suitable model and survey configurations (e.g. LEROI) may also become available. However not all algorithms will be made accessible. When a program is unavailable or is not correctly configured, the entry on the Algorithm menu list is not highlighted and therefore not available.

Even if a program is installed, access may be denied by EM Vision if an incorrect survey configuration or instrument combination has been set. For example, if a layered earth model is being used, both PLASI and OZPLTE is not available since it is unable to operate on a layer model.

Note	In the event that **NO** algorithm option, or the algorithm required is **not** available for selection when you think it should be, refer to *Algorithm Access Problems*.

Once the PLASI algorithm is selected, a dialog will confirm selection. In the case of OZPLTE, a dialog with OZPLTE specifications will be displayed.
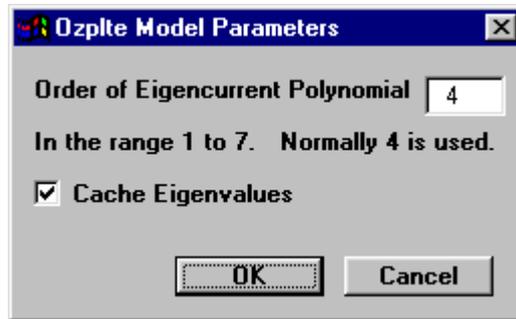
Dialog to control OZPLTE parameters.

Options available in this dialog enable the user to define the number of eigencurrents (Order of Eigencurrent Polynomial). Although a polynomial order of 7 is possible, 4 is usually used as a compromise between speed and accuracy. For accurate responses, but longer compute times, increase the polynomial order accordingly.

If no alteration to the geometry of the receiver positions relative to the transmitter setup is to be applied between OZPLTE runs, it is possible to cache the eigenvalues so they do not require recomputation. This speeds up successive OZPLTE computations such that the program can be used interactively.

Set Active Option

The modelling process involves creation of a model, data and survey plus the selection of an algorithm. The only remaining step prior to initiating either PLASI or OZPLTE is to define which delay channels and readings the modelling will compute. This is done by the Set Active option of the Modelling menu.

Channels and readings that are modelled are referred to as active. The Set Active option provides the facility of making channels and data stations either active or inactive.

Note

By default, EM Vision makes all data initially active.

Setting Channel Activity

The Set Active option for channels will present the Channel Selection dialog as below. Nominate the channels to be modelled by taking into account any early time noise or response behaviour which is uncharacteristic of expected decays.

Similarly, late time noise can be derived from instrumentation, geological and cultural sources.
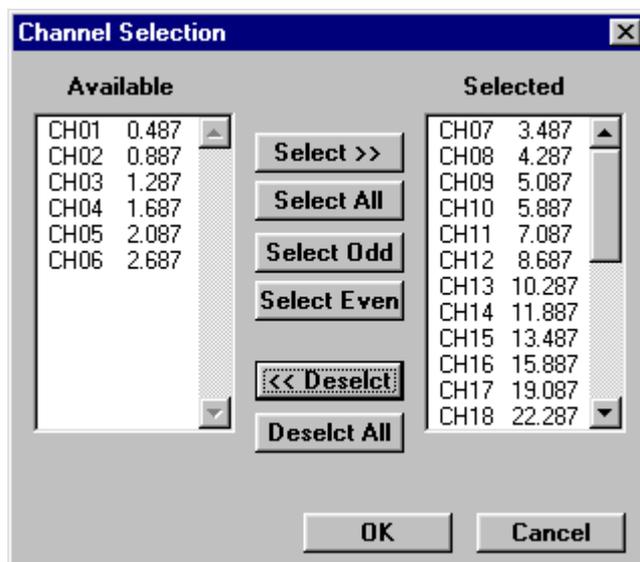
Channel selection dialog

The channels on the right scroll list will be regarded as active for the applied modelling.

Setting Reading Activity

Defining which data readings are to be modelled is controlled by the **Modelling>Set Active>Stations** option. When selected, a dialog accompanied by a survey map of the available station locations will be displayed. Initially all readings will be highlighted indicating their active state. Within the dialog you can **Select All** or **Deselect All** readings. Within the dialog you can choose to use the cursor to **Select** or **Deselect** station activity. To use this method, choose one of the two options and then move the cursor to the survey map. When the left mouse button is pressed and the cursor moved a dashed rectangle is drawn.
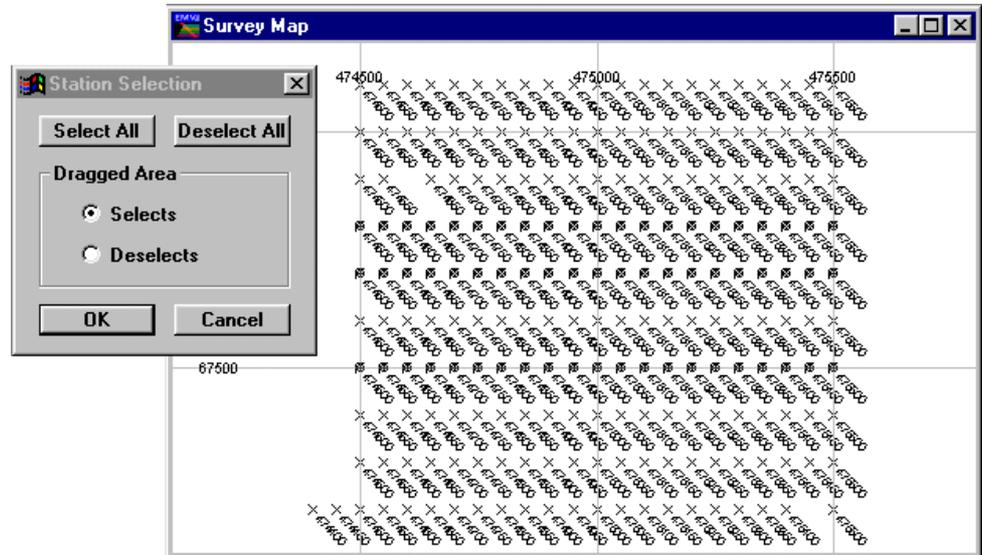
Station selection for modelling

When the mouse button is released, all the readings enclosed alter their activity state to match that set in the dialog.

To reverse the activity of individual stations, despite the **Dragged Area** selection, you can position the cursor over a reading and then click the left mouse button. This technique toggles the activity state of the station.

Compute Model

Once the data, survey, algorithm and model have been defined and the desired channels and data readings made active, either PLASI or OZPLTE can be executed. EM Vision can execute the program by selecting the Compute Model option of the Modelling menu, or by pressing the **Compute** button on the Tools toolbar.

Modelling progress is indicated by a slider bar with a completion percentage and the operational phases that the program is performing. In cases where either program is to be halted during execution, the progress bar has a **Cancel** push button. If you select this button, the program will abort. After the program is aborted, no modelled output will be produced or displayed since response results are only derived in the final stages of the modelling run.

2   **Tutorial of Plasi and Ozplte**

For this tutorial, a theoretical response over a number of synthetic data readings will be created. The aim of the study will be to determine the response of a dipping plate from a series of traverse lines and compare the response characteristics.

Step 1 - Create the Instrument and Survey Configuration

To initially create the Instrument and Survey Configurations, let us assume a Zonge GDP-16 instrument is to be used with an 1Hz cycle frequency and with In-loop survey mode. The entry dialog from **Survey>Create Loop Configuration** would appear as:

Creation of In-Loop survey configuration for Zonge synthetic survey

Note the receiver and transmitter area, delay and ramp times have been entered.

Step 2 - Create the Synthetic Data Reading Locations.

The **Survey>Create Lines** option is used to create the data recording locations for the synthetic survey. Fifteen east-west data lines have been created with line and station separation of 100 metres.
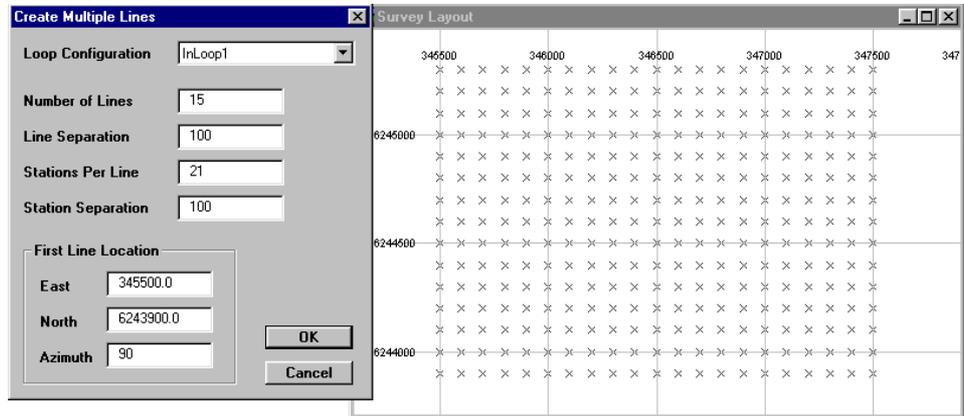
Entries for creation of the synthetic survey data recording locations

As entries are altered in the dialog, the graphics survey map will update when alternative fields in the dialog are accessed. Realistic easting and northing values have been included for comparison with field results.

Step 3 - Create the Model in a Profile

Select a line for the creation of the plate model. Use the **Display> Profile>Log-Linear** option (for this example, line 6244600N has been selected). Ensure that the **Model Data** and **Show Model Section** options have been enabled in the initial Profile Display dialog as these ensure that the computed response and a cross section display are presented (see *Cross Section Display Profiles*). Also, enable the display of the X, Y and Z components.

When the **OK** button is pressed an empty profile track and cross-section is displayed.
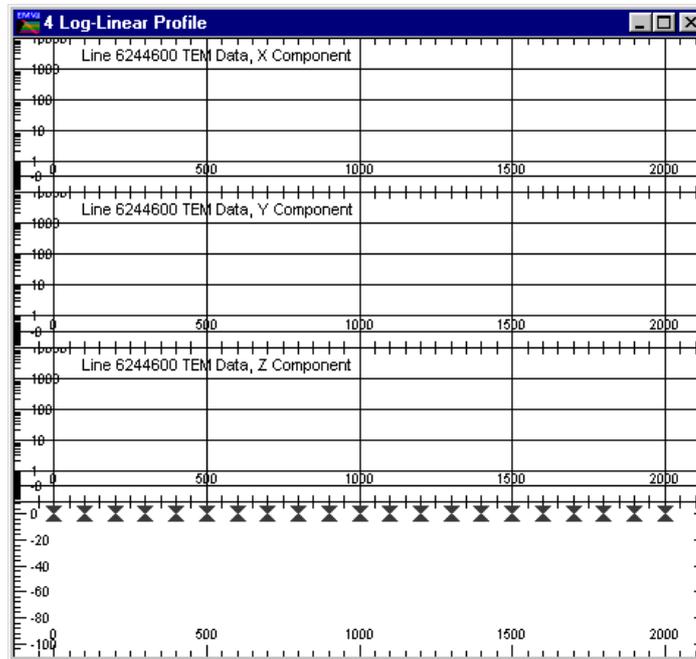
Empty profile and cross section area for model creation

With the profile displayed and the window active, select the **Modelling >Create Body>Plate** option. The cursor alters to become a '+' when inside the profile window. Position the cursor where required for one end of the plate, click the left mouse button and drag the mouse with the left button still pressed. A rectangular bounding box is drawn and within the box, a plate is created when the left mouse button is released.
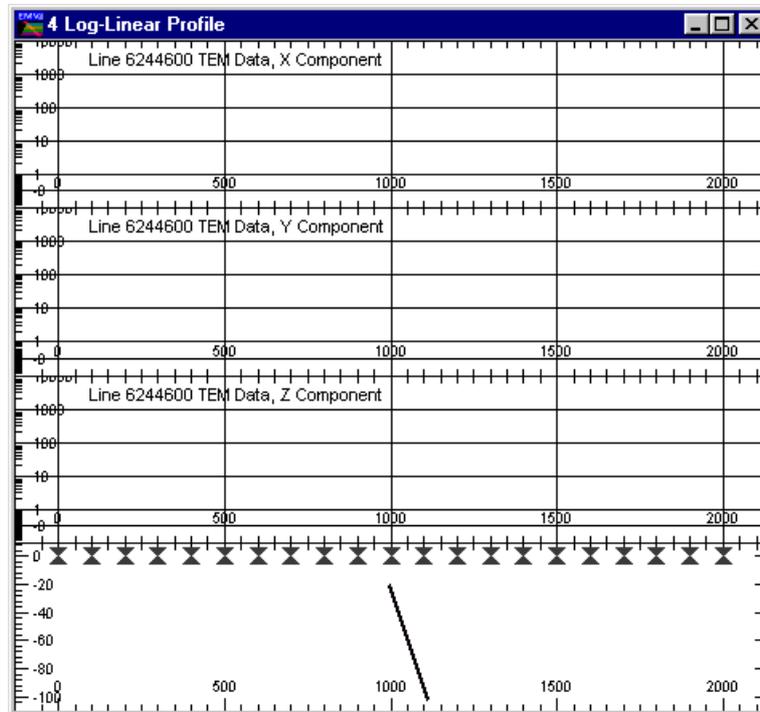
Profile after creation of a plate body

When the body is created, the observation points for the line is also displayed as a series of '**X**' marker symbols on the surface of the profile section. Note that the vertical depth scale of the section is negative, increasing down the plot. This convention is adopted for all EM Vision section plotting and relates to the reference depth locations of the various bodies created.

Step 4 - Viewing the Plate in Plan

To view the location of the plate in plan (map view), select the **Display >Survey Map** option.
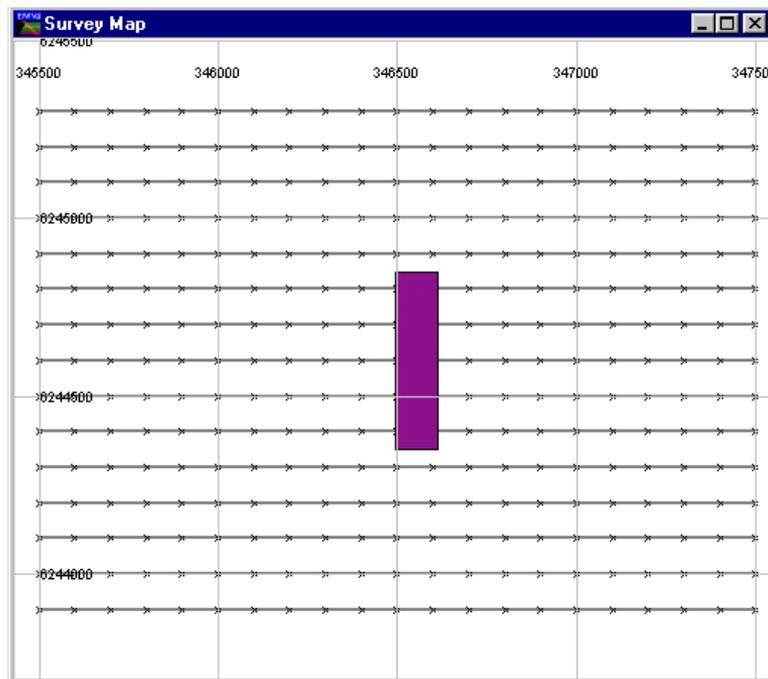
Survey map of plate and observation points

By clicking the right mouse button while the cursor is in the window the, Survey Map Configuration dialog is presented. This can be used to adjust the sizes and styles of data and symbols. The plate is shown as a tabular style of body when viewed from the top since it is dipping to the east. Other presentation formats such as solid or wire frame display formats are also available.

Step 5 - Edit the Plate Model

The plate can be selected in either the plan or profile windows by positioning the cursor over the body and then clicking the left mouse button. Four 'handles' is displayed to indicate the body has been selected. Once selected, the body can be 'dragged and dropped' to a new location by using the mouse.

To edit specific plate parameters such as length, azimuth, dip etc, position the cursor over the body and double click the left mouse button. A Plate Properties dialog is then presented.

Editing of the Plate configuration dialog

In the dialog, the depth to the plate is negative and that conforms to the profile cross section location. Conductivity-thickness is used for the plate physical property attribute.

Edit the values of the various entries as desired.

WARNING

As detailed previously, be aware of the limitations applicable to both PLASI and OZPLTE. As a rough guide, difficulties arises when the quotient (plate length x plate width is divided by distance of receiver to closest part of plate x distance of transmitter to closest part of plate) is greater than 100.

Also note that for OZPLTE the plate strike length to plate width should not exceed the ratio of about 10:1. For PLASI, this ratio should not exceed 3:1.

When the **OK** button is selected the Survey Map redraws and use the newly modified properties of the plate.
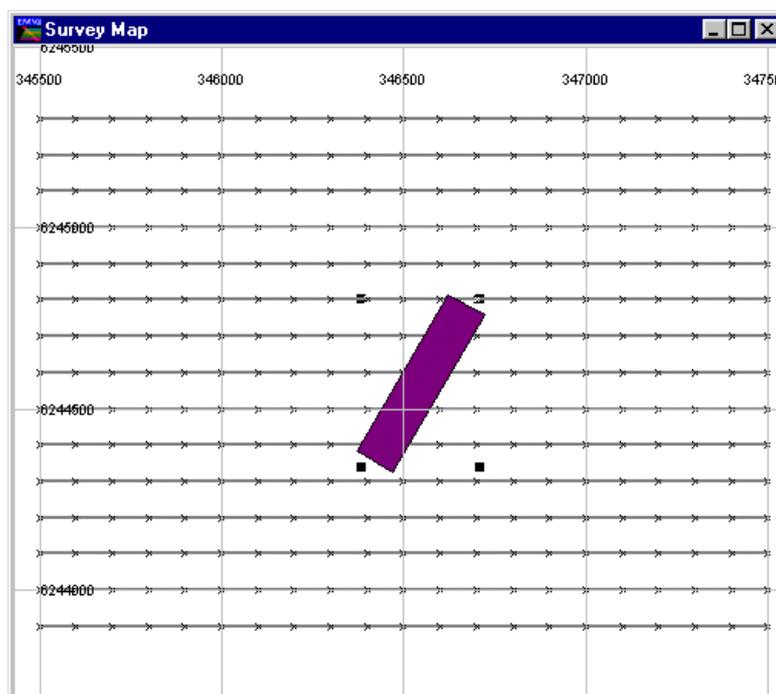
Edited properties of the plate to reflect different strike length, azimuth and dip

As the map is being redrawn, the profile cross section also updates to reflect the new plate parameters.

Step 6 - Specify the Algorithm and Earth Type

The Earth Type (**Modelling>Earth>Type** option) defaults to Air when EM Vision is initially executed. If previous modelling with other Earth Types has been used then it is wise to check that the Earth Type is correctly set.

Selection of the **Modelling>Algorithm** option will indicate that either PLASI or OZPLTE are available for selection. If they are not, refer to the *Controlling Algorithm Access* section of the Reference Manual.

Select either PLASI or OZPLTE. Initially, PLASI can be used as an approximation and it is useful since it is rapid to execute, but it should not be relied upon to produce final results.

Step 7 - Select the Active Channels and Stations

In circumstances where no data (either observed or modelled) is available, it is not possible to select which channels are to be made active. This feature is used

primarily in inversion modelling where certain 'noisy' channels are to be excluded from the inversion process since they can distort results. By default, all channels is set active and included in the PLASI or OZPLTE computation of response.

Station activity is selected from the **Modelling>Set Active>Stations** option. When this menu item is selected, a dialog and a survey map is displayed which initially has all data reading locations active. In this case, we require all stations to be left active, however they can be deactivated if required. Selected parts or the entire survey can be deselected. Use the **Select** or **Deselect** options on the dialog to choose readings that require their activity state altered.
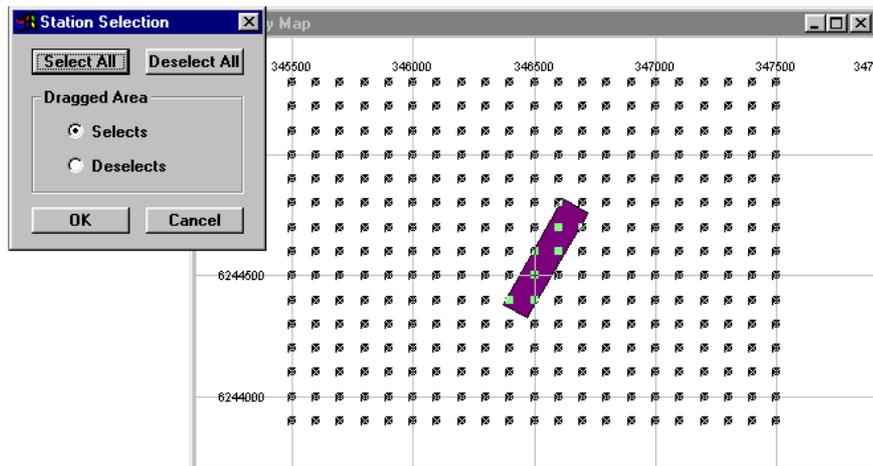
Select the readings to be made active for response computation

Step 8 - Compute the Model

Computation of the model can be undertaken once the model, observation locations, algorithm and activity are specified. To initiate the modelling, press the **Compute** button on the toolbar (or icon), or select the **Modelling>Compute Model** item.

Once initiated, a progress bar indicates the advance of the program through the active data lines. At any time you can select the **Cancel** button to abort the computation. For large datasets, the computation time can be relatively high for OZPLTE.

Step 9 - Examine Model Results

A fast way to examine model results is to select the **Utilities>Statistics** option. In the dialog presented, either the total project results for the various channels can be examined, or individual line statistics can be displayed.

Statistics of computed model response

Graphically, the results can be viewed in a variety of ways. Since the data is well distributed for map-style presentations, either contour or stacked profiles would be suitable. Some examples of these are presented.
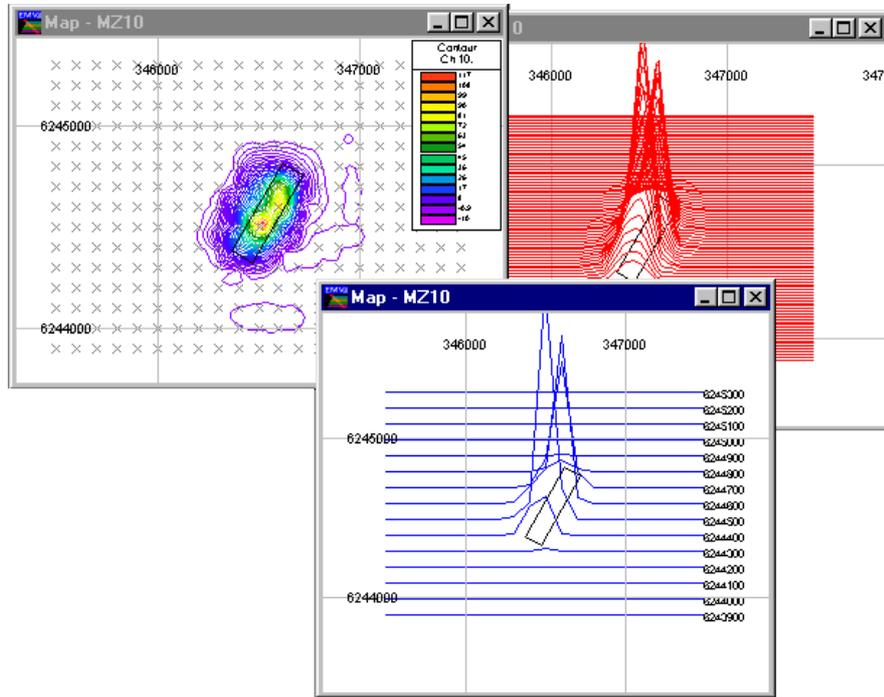
Examples of display of plate model responses

Step 10 - Saving (or Loading) a Computed Model.

Prior to, or after running PLASI or OZPLTE, it is wise to save the created model. Use the **Modelling>Save Model File** (or Load Model File) option to write or retrieve a model file. By default, EM Vision model files have the file extension .MOD. Once saved, these ASCII files become a valuable resource.

Step 11 – Adding Additional Plates

Additional conductors can be added for modelling situations such as this and both PLASI and OZPLTE can simulate the responses. As implemented in EM Vision, both modules are capable of modelling multiple plates (in air). The method adopted is to compute the response of each target individually and then add the responses. No account is made for interactive EM coupling between the plates.

To test the multiple response computations, return to Step 3 and add another plate with different orientation and properties. Continue forward and recompute the EM response as previously.
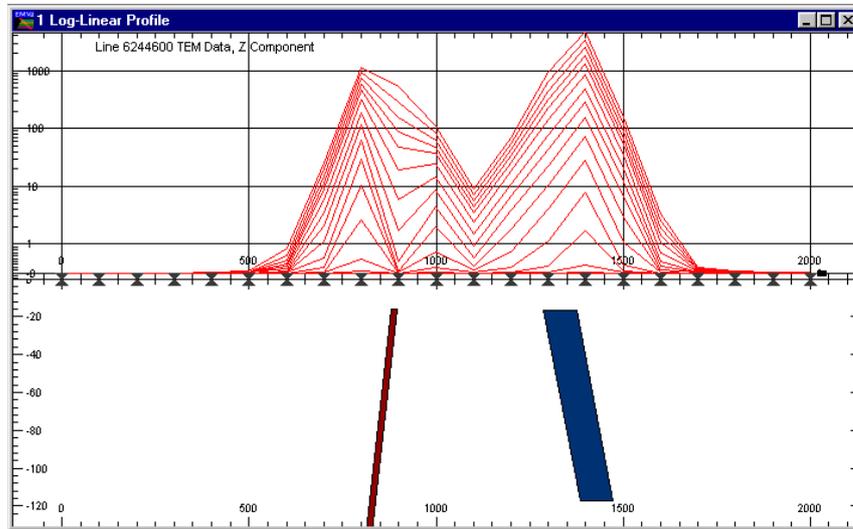
OZPLTE response derived from two separate conductor plates.

3 References

Annan, A.P. 1974 The equivalent source method for electromagnetic scattering analysis and its geophysical application. Ph.D. Thesis, Memorial University of Newfoundland, 242p.

Buselli, G., 1980 The application of Sirotem in weathered terrain. Bull. Aust. Soc. Explor. Geophys., 11(3), pp 99-109.

Buselli, G. 1981 The effect of near-surface superparamagnetic material on electromagnetic measurements. Geophysics, v. 47 pp 1315-1324.

Buselli, G. & Thorburn, M. 1986 Transient electromagnetic model profiles for a thin dyke using coincident loop geometry. Investigation Report 143, CSIRO, Div of Mineral Physics and Mineralogy.

Bulgakov, Yu. I 1971 Interpreting surveyed results by the single loop transient process method. *In* Fokin,A.F.,ed *The Method of Transient Process in the Search for Sulphide Ore Deposits*. USSR Ministry of Geology, Leningrad.

Dyck, A.V. Bloore, M. Vallee, M.A. 1980 User manual for programs PLATE and SPHERE. Research in Applied Geophysics University of Toronto, No. 14.

Flood, N. 1990 CSIRO EM Modelling Suite. TEM Data file format. AMIRA CSIRO Research document.

Lamontagne, Y. West, G.F.	1971	EM response of a rectangular thin plate. Geophysics, v36, No. 6 pp 1204-1222.
Lee, T.	1981	Transient response of a polarizable ground. Geophysics, v.46, pp 1037-1041.
Lohda, G.	1977	Time domain and Multi-frequency Electromagnetic responses in Mineral Prospecting. Ph.D. Thesis, Uni.of Toronto, Canada, 182 p.
McNeill, J.D.	1980	The application of transient electromagnetic techniques. Tech. Note 7, Geonics Ltd.,Ontario, Canada.
Nabighian, M.N. Macnae, J.C.	1991	Time domain EM prospecting methods in Electromagnetic Methods in Applied Geophysics. Vol 2A, Ch 6, pp 430-446.
Smith, R.S. West, G.F.	1988	Inductive interaction between polarizable conductors: an explanation of a negative coincident-loop transient electromagnetic response. Geophysics, v.53, pp677-690.
Staltari, G.	1986	The Que River Test Case. Explor. Geophys.v.17, pp125-128.

Raiche, A.P.   1989   Manual for the EM/IP modelling
Sugeng, F. &   and inversion workshop - A
Flood, N.   workshop description and guide.
                              August 1989. CSIRO Div.
                              Explor.Geoscience. AMIRA Project
                              P223. Restricted Report 54R.

Smith, R.S.   1987   Electromagnetic induction in an
West, G.J.   inhomogeneous conductive thin
                              sheet. Geophysics, v.52, pp 1677-
                              1688.

Smith, R.S.,   1988   A plausible mechanism for
                              generating negative coincident-loop
                              transientelectromagnetic responses.
                              Ph.D Thesis No. 44 (unpubl.)
                              Uni. of Toronto, Canada.

Smith, R.S.   1988   An explanation of abnormal TEM
West, G.J   responses: coincident loop negatives
                              and the loop effect. Aust. Soc.
                              Explor. Geophys., 19(3) pp 435-446.

Vozoff, K.   1975   Joint inversion of geophysical data.
Jupp, D.L.B.   Geophys. J. Roy. Astr. Soc.
                              v.42 pp 997-991.

Index