SPASYM

Table of Contents

1   Program Description

Introduction

This documentation describes SPASYM, a forward modelling program module for simulating a conductive sphere in a conductive, uniform host. The module can be used in conjunction with the software program EM Vision. This modelling algorithm operates as a forward program only, but is fast to run and operate. SPASYM is limited to function with only the in-loop and coincident field survey configurations.

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 SPASYM modelling program.

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

- 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 the modelling executes in the background. Examples of these programs are GRENDL and FILAMENT.

Program SPASYM

Description

The SPASYM program was derived originally from formulation described in a number of papers by Terry Lee (1981, 1983). The program was implemented by CSIRO and first released in June 1984.

The assumptions made for SPASYM include:

- The sphere is of uniform size and has definable uniform internal electric properties (i.e. homogeneous).

- The surrounding host is also uniform but of a definable homogeneous electric property. For the purposes of implementation in EM Vision, the host is defined in terms of resistivity (ohm-metres).

- The transmitting primary field is created from a simulated circular loop.

The electric field inside a theoretical sphere is expanded into polynomial sets and boundary conditions are matched on the sphere boundary with the half-space solutions. The solution is obtained in the frequency domain and transformed to the time domain. If the host is resistive, considerable amplification of the sphere response can be derived in the algorithm.

SPASYM calculates the ramp function response (in microvolts per amp) for a coincident loop TEM system on the assumed conducting half-space containing the sphere. The calculation assumes that the response of a rectangular coincident loop system can be modelled by a circular loop transmitter system of the same area (turns moment). An approximation is also available in SPASYM to simulate a similar transmitter but localised dipole receiver, such that in-loop survey configurations can also be simulated.

The asymptotic calculation performed by SPASYM is assumed to be valid when:

$$T\rho_1 / (\mu L^2) > 3.3$$

where:

T = delay time in seconds

ρ_1 = resistivity of the host

$$\mu \quad = \quad 4*\pi*10^{-7}$$

$$L^2 \quad = \quad \text{square of distance between loop and sphere centres.}$$

The presence of a conducting environment surrounding a spherical conductive body is important when calculating the TEM response of a sphere due to a step current flowing in a transmitter loop at surface. Failure to do this can easily lead to response calculation errors in excess of 10% (Lee, 1983). Additionally, there is only a limited time interval with respect to the primary signal decay in which the response of the spherical conductor is observable.

In poorly conducting ground the resonance response of the sphere is the first to be excited. Later, the non-resonance or wave-type response is excited and becomes dominant. These waves destructively interfere and finally the response of the sphere decays with time as $t^{-7/2}$.

Note

Lee (1983) also determined the optimal response will be received for a loop size that is approximately the same size as the target sphere body. Empirically it can be shown that this choice of loop size appears to be independent of the depth of burial of the sphere.

Operation of SPASYM

Within EM Vision, access to SPASYM is not through the Generic Model Interface. Refer to the section describing the *Generic Model Interface* for additional information. The program operates fast enough that its response can be computed interactively and batch operation is not necessary.
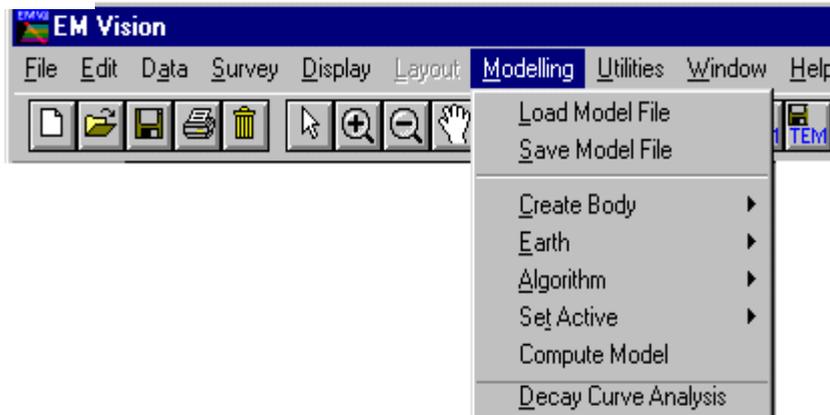
As for all modelling in EM Vision, a number of preparatory steps must be taken before a model response can be computed. These steps are sequentially listed in the Modelling menu. Initially, a modelling operation requires a profile display for the reading locations, a model, plus the assignment of channels and stations to compute.

Initially data can be loaded from a saved model file (Load Model File menu item) 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 SPASYM 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.

Note

SPASYM cannot simulate the response of a sphere in a borehole survey.

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 profile modelling, the section area is used to create, edit and manipulate the modelled sphere. For SPASYM, only the Sphere body type can be selected from the options of the Create Body menu item.

Interactive body control is available for creating 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.

Sphere Body Creation

After selecting the **Modelling>Create Body>Sphere** option, move the mouse cursor to the cross-section area of the profile display. The cursor will change to a '+'. Position the cursor where the centre of the sphere is required and click the left mouse button. Hold the mouse button as you move the mouse to draw a dashed bounding box to define the outer perimeter of the sphere. To actually create the body using this technique, release the mouse button with the bounding box defining the diameter of the sphere. A second method of creating a sphere is

to position the cursor and then click the left mouse button. A default sphere will then be created.

If the sphere does not appear circular when created, the vertical to horizontal aspect ratio of the cross-section is distorting the display. Use the cross section configuration dialog and increase the depth range to reduce the distortion.

Editing a Sphere 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 SPASYM can model only a single sphere at a time. Once selected the sphere 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 are drawn around the body.

If the sphere is contained in a half-space, it may be difficult to select. In these circumstances, press the CTRL key while selecting the sphere with the cursor.

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 'drags and drops' the body to a new location when the mouse button is released.

The Sphere Body

The sphere is conductive and can be modelled in air or in a conductive homogeneous host. The sphere can be positioned as required and the radius is definable. The internal resistivity defined for the body is uniform through the sphere.
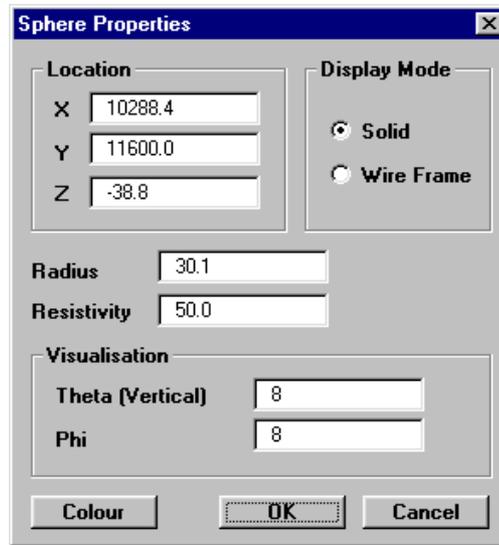
Sphere property dialog

Parameters that can be defined for the sphere include:

Location (X, Y ,Z)
The location values describe the centre point of the sphere relative to the local grid. The coordinate position uses depth values with increasing depth being increasingly negative.

Radius
The sphere radius is the distance from the centre location to its outer margin. Note that the radius can have a depth greater than the radius. In this case the upper surface will rise above the surface. This is not recommended as erroneous responses are computed

Sphere Resistivity
The resistivity of the sphere in ohm.metres.

Host Resistivity
The resistivity of the host must be defined for this body type.

Refer to the section on *Earth Type Options* for additional information and setting of host properties.

Rendering Sections
This parameter is used to control the smoothness with which the sphere is drawn

in displays. The higher the number of sections used, the smoother the shape displayed. Two directions (Theta - Vertical and Phi - Horizontal) are used to define the facets of the drawn sphere

Earth Option

The Earth option of the EM Vision Modelling menu is used to define the host in that the sphere is to be modelled. Various Earth types are required to satisfy the many host environments are can be modelled but in the case of SPASYM, the only available option is a Homogeneous Half-Space.
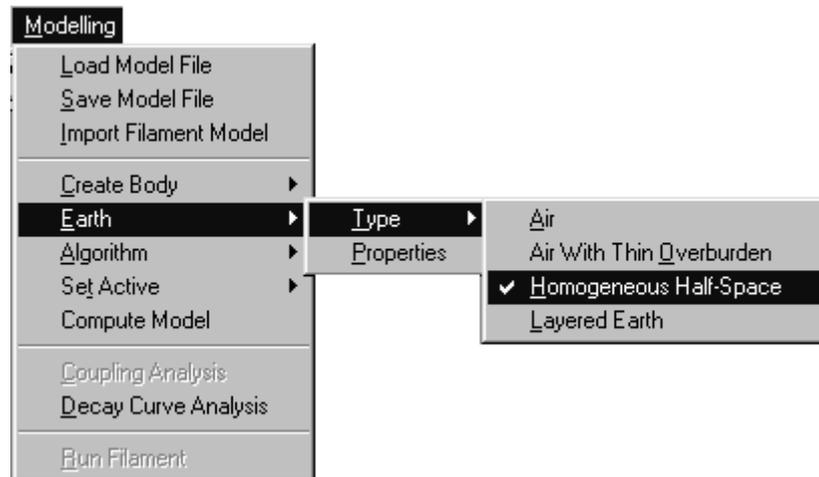

Once the Earth option has been chosen and the Homogeneous Half-Space selected, any profile which is displayed with a cross-section has the half-space automatically displayed along with the observation points for the profile (marked with an '**X**' marker symbol). To define the resistivity property of the host, select the **Modelling>Earth> Properties** option. A dialog enabling you to define the host resistivity is presented.
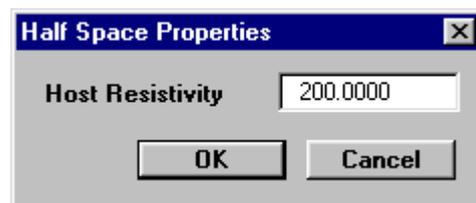
Defining the half-space resistivity

Host resistivity is defined in terms of ohm-metres.

Algorithm Option
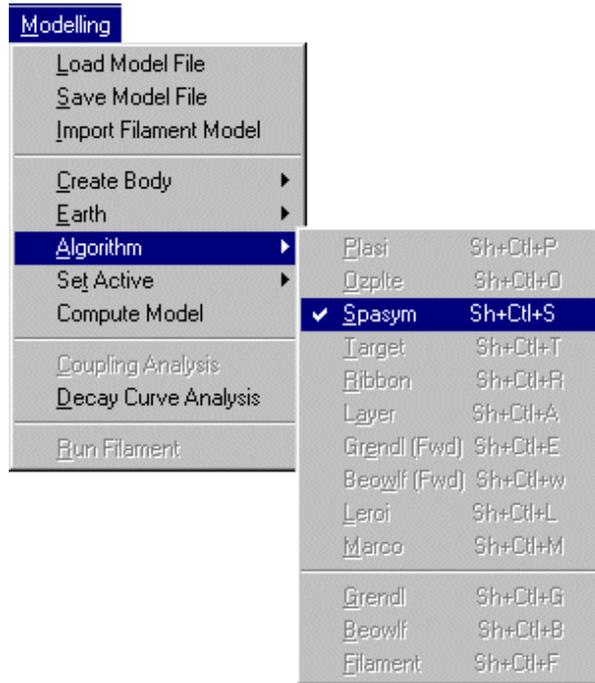
The Algorithm option in the Modelling menu is used to select the SPASYM program. No other program has the model type of a sphere and so if all other criteria for selection are met, SPASYM should be the only program available. When a program is not available or is not correctly configured, its entry on 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, SPASYM will not be 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 section on *Controlling Algorithm Access*.

Once the SPASYM algorithm is selected, a dialog confirms its selection.

Set Active Option

The modelling process involves creation of a model, data, survey definition and
selection of an algorithm. The only remaining step prior to initiating SPASYM is
to define over which delay channels and readings the modelling operates. This is
done by the Set Active option of the Modelling menu.

Channels and readings available for modelling 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.
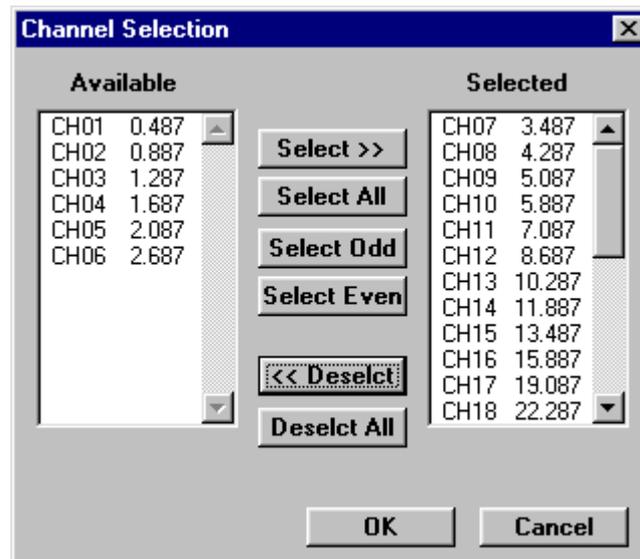
Channel selection dialog

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

Setting Station 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. You can also choose to use the cursor to **Select** or **Deselect** stations to be active. To use this method, choose one of the two options and then move the cursor to the survey map. As you click the left mouse button and move the cursor a dashed rectangle is drawn.
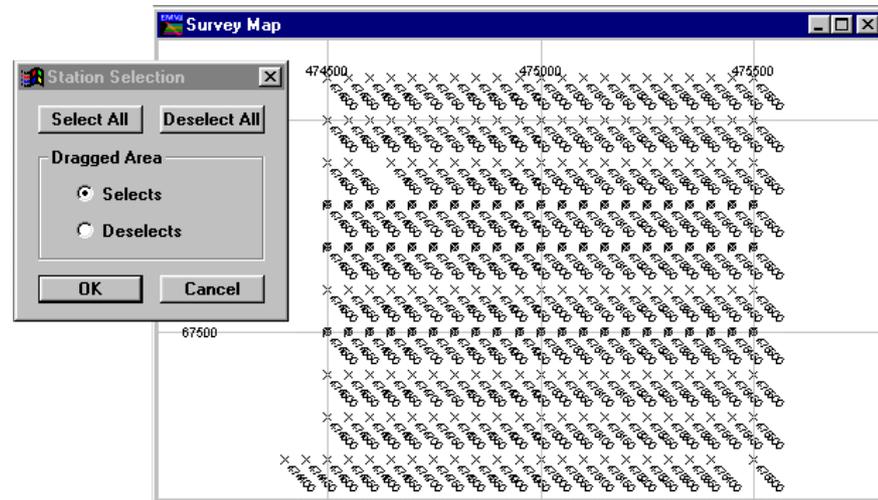
Station selection for modelling

When the mouse button is released, all the readings enclosed alters 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 click the left mouse button. This technique will toggle 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, SPASYM 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 toolbar or icon.

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

2   SPASYM Tutorial

Operation of SPASYM

For this tutorial a theoretical SPASYM response over a dataset supplied with EM Vision is used. The dataset, EMV1COIN.TEM, is suitable since it was acquired using a coincident EM survey. The aim of the study is to determine the response of a sphere contained in a conductive host and compare this response with the observed data.

Step 1 - Import the Field Data

To import the dataset, initiate EM Vision and select the **Data>Open Field File** option. Using the file specification dialog, choose the EMV1COIN.TEM dataset (which should be installed in the \ENCOM\EMVISION\EXAMPLES directory). After selecting the file, and pressing **OK**, EM Vision reads and report on the listed AMIRA settings defining the survey, instrument and data.

Standard Field Data reporting dialog. Check all entries

The dataset is for a single coincident line of data only. Multiple readings (repeats) can be processed according to one of four duplicate policies (refer to the *Open Field File* section for an explanation of options associated with importing field data). Ensure that the receiver and transmitter area, delay and ramp times have been read with the dataset.

Step 2 - Create the Model in a Profile

Select the line for creation of the sphere model. Use the **Display>Profile>Log-Linear** option (for this example, line 11600N 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*).
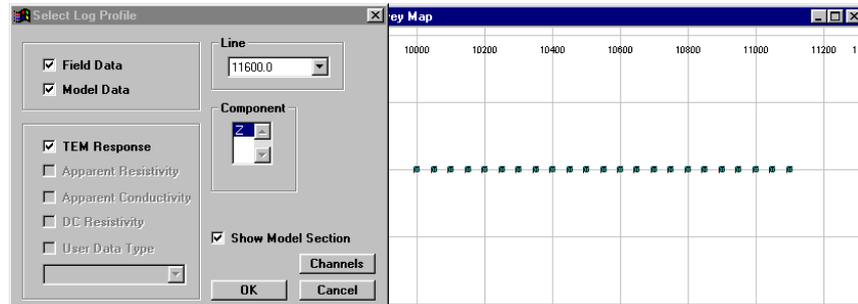
Select the profile but ensure **Show Model Section** and **Model Data** options are enabled.

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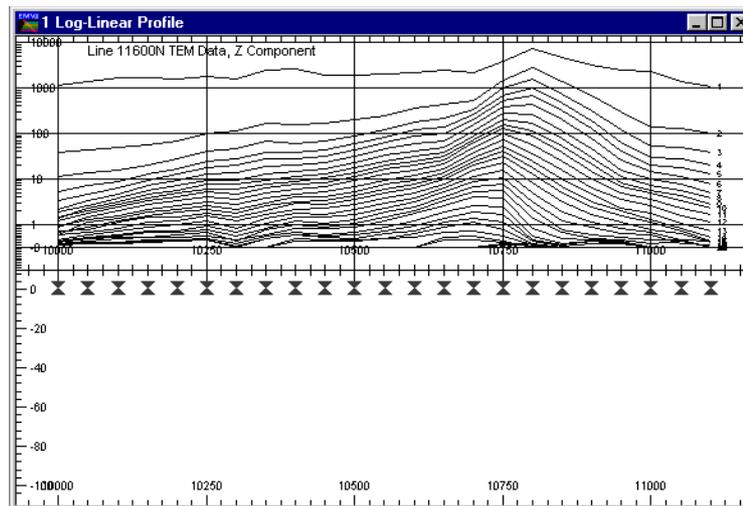
*Empty profile and cross section area for model creation*

With the profile displayed and the window active, select the **Modelling >Create Body>Sphere** option. The cursor alters to become a '+' when inside the profile

window. Position the cursor where required for the centre of the sphere, 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 sphere is created when the left mouse button is released. The longer dimension (either horizontal or vertical) of the drawn boundary box is used by EM Vision to define the sphere diameter.

Note

In some representations of profiles, a severe horizontal to vertical exaggeration in aspect ratio can be present in the window displayed. In these cases, the sphere does not appear round, but as an ellipse. Use the profile configuration dialog to increase the depth range and so correct the aspect ratio.

When the sphere is created it will appear in the profile cross section as below:
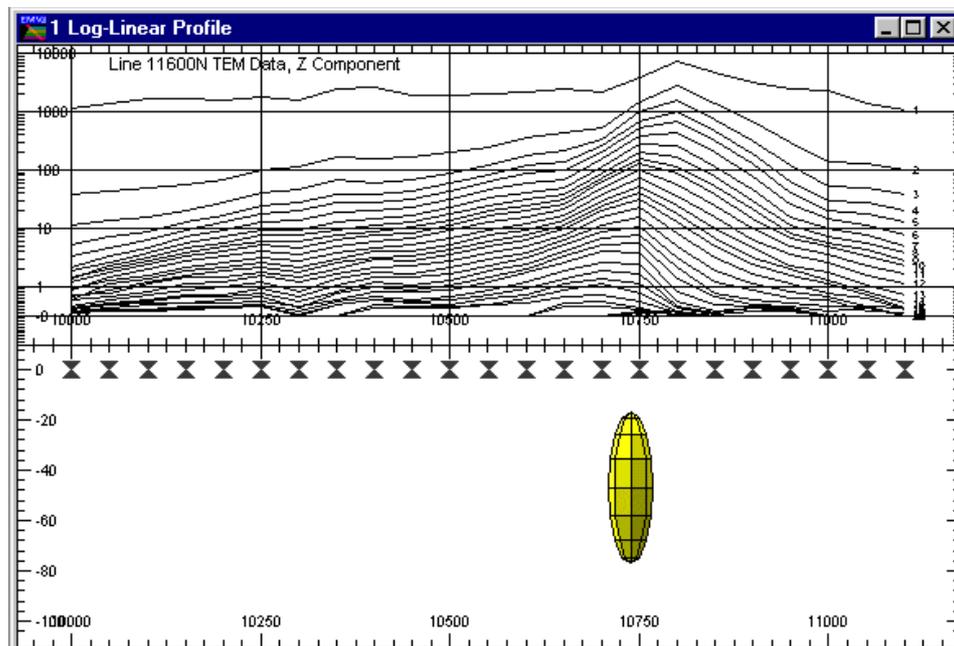
Profile after creation of a sphere body. Note the sphere distortion due to the horizontal to vertical aspect ratio

When the body is created, the observation points for the line is also displayed as a series of '**X**' points on the surface (station marker symbols) of the profile section. 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.

Note that the sphere (as drawn) is not circular. This is due to a different vertical to horizontal scaling. The V/H ratio can be forced to be equal from the Drawing Configuration dialog and selecting the Scale 1:1 push button.
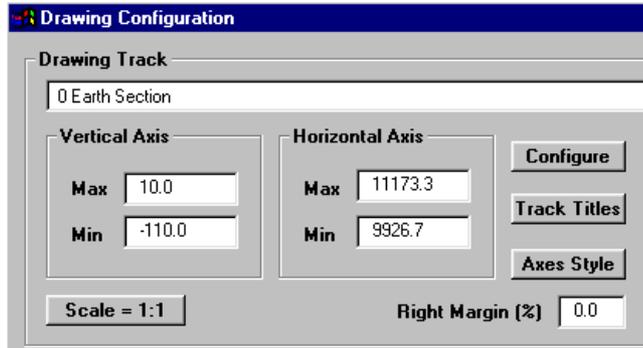
Step 3 - Edit the Sphere Model

The sphere can be selected by positioning the cursor over the body and then clicking the left mouse button. Four 'handles' are displayed to indicate the body has been selected. The body can now be 'dragged and dropped' to a new location by using the mouse and left mouse button.

To edit specific sphere parameters such as radius, resistivity, location etc, position the cursor over the body and double click the left mouse button. A Sphere Properties dialog is then presented.
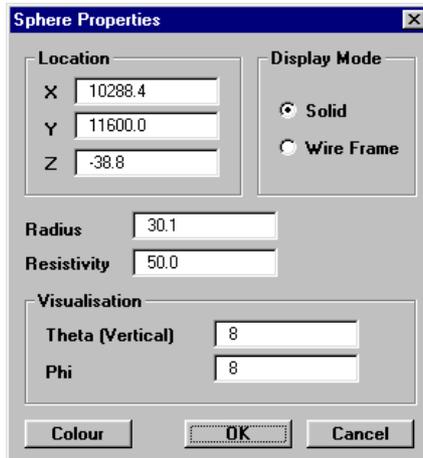
Editing of the Sphere configuration dialog

In the dialog, the depth to the plate is negative and defines the cross section location to the reference point (the centre) of the body. Resistivity in ohm-metres is used for the sphere physical property attribute.

Additional attributes define the various controls for colour, display mode and rendering of the body in the display. Edit the values of the various entries as desired. See *The Sphere Body* for more information.

Step 4 - Specify the Algorithm and Earth Type

Selection of the Modelling > Algorithm option will indicate SPASYM is available for selection. If it is not, refer to the *Controlling Algorithm Access* section. Select the SPASYM algorithm.

Step 5 - Create the Host

The host surrounding the sphere can be added by choosing the **Modelling>Earth >Type** option. Ensure you select the Homogeneous Half-Space option for the Earth type. After defining the half-space, select the **Modelling>Earth>Properties** option and a dialog is presented to specify a host resistivity. Units for the host are ohm-metres.

Note

If the host is displayed with the sphere, it can sometimes be difficult to select the sphere within the host. This selection is required when the body properties are to be edited. To achieve a selection, place the cursor over the sphere, with the CTRL key depressed, click the left mouse button until the body is selected.

The colour and resistivity properties of the host can be graphically edited by placing the cursor over the layer and double clicking the left mouse button. The dialog displayed enables control of the colour rendition and the resistivity of the host.
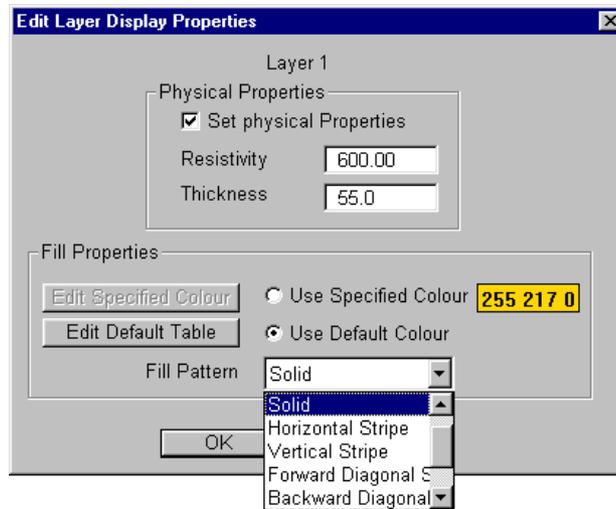
Controlling the host resistivity and presentation

Refer to the section on *Individual Layer Presentation* for a description of editing the default colour table.

Step 6 - 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 will be set active and included in the SPASYM computation.

Station activity is selected from the **Modelling>Set Active>Stations** option. When this menu item is selected, a dialog and a survey map are displayed that 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 by using the dialog options. The entire survey, or selective parts of it, can be deselected. Use the **Select** or **Deselect** options in the dialog to choose readings that require their activity state to be altered.
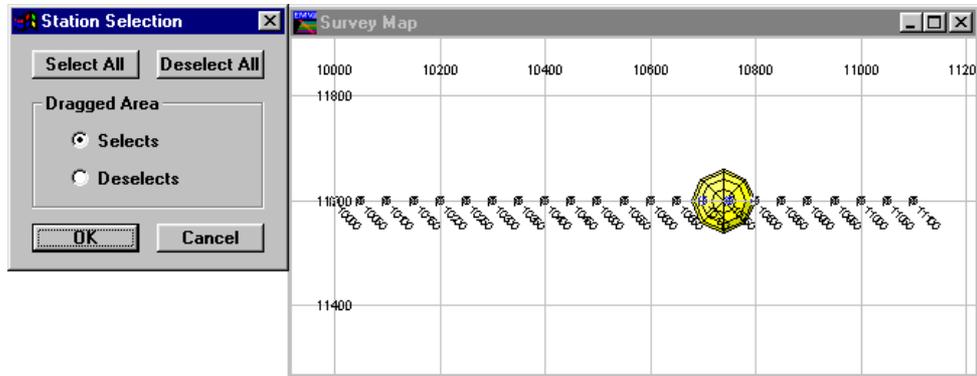
*Select the readings to be made active for response computation*

Step 7 - Compute the Model

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

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.

Step 8 - Display Model Results

If the original display of the cross-section profile had the Model Data option enabled, on completion of the SPASYM computation, the modelled response is automatically displayed with the observed data.
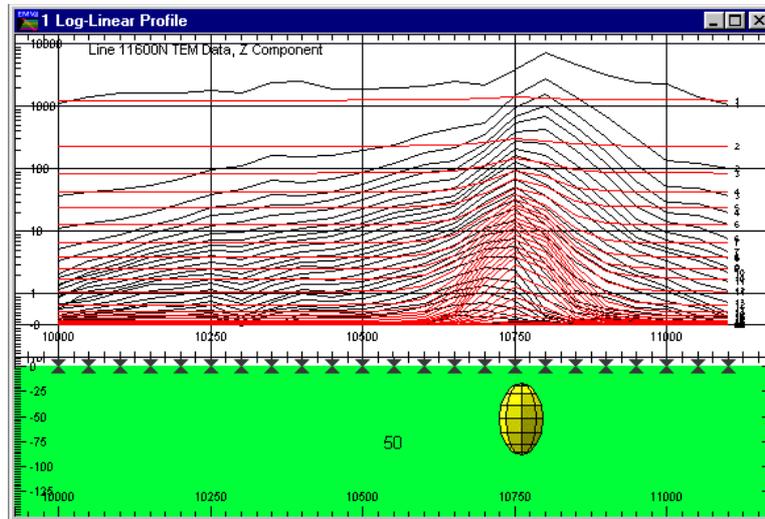
Display of model and observed response

As SPASYM operates quickly, it is a simple matter to revise the properties of
either the sphere or host (using the **Modelling>Earth>Properties** option) and
then re-run the model. An estimate of background and target properties can be
determined quickly.

Step 9 - Saving (or Loading) a Computed Model.

Prior to, or after running SPASYM, 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.

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Index