



MARCO

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1 Program Description - MARCO

Introduction

This documentation describes the MARCO program module that can be used with EM Vision. The MARCO forward modelling program can simulate prismatic blocks embedded within a host of stratified layers (both with or without complex properties). The target bodies are inductively coupled so the computed response of one body is accounted for by the EM response of an adjacent body. The targets cannot have overlapping block volumes and the sides of the blocks MUST parallel to principal coordinate directions of the data (that is, east, north and vertical depth). MARCO accommodates almost all surface and downhole EM survey configurations.

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 MARCO modelling program.

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. This means that two modes of operation are necessary.

- Some algorithms can be implemented to operate interactively. Computed response 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 MARCO and LAYER.

Program MARCO

Description

The MARCO program was initially released in the late 1990's, originating at the Electromagnetic Modelling Group of the CRC For Australian Mineral Exploration Technologies (CRC AMET) located at Earth Sciences, Macquarie University, NSW, Australia and sponsored by a group of companies under Australian Mineral's Industry Research Association (AMIRA). The original formulation of MARCO was released to sponsors in March, 1990 but speed and accuracy improvements were undertaken and first released as MARCO in September, 1995.

Within a multi-layered earth, Marco computes the frequency domain and/or the time domain responses for any arbitrary structure that can be composed of multiple rectilinear prisms oriented parallel to the three component axes. Cole-Cole resistivities may be specified for targets and layers. Receivers may be in air, downhole, or on the surface of the earth.

Marco also computes high frequency radio imaging responses for grounded sources and downhole magnetic dipole sources.

Marco uses multiple prismatic blocks to simulate arbitrary structures. The conductivity in each block can be arbitrary or constant although only a constant property of conductivity is used in its implementation within EM Vision. The program also allows symmetric structures with two symmetry planes, the (XOZ) and (YOZ) planes, with the shape and conductivity of the structure in one quadrant being arbitrary. Symmetrical considerations greatly saves both computation time and storage requirements.

This program uses a system iterative method for solving the matrix equation, thus it allows a large number of cells to be handled for large and complex structures. The division of substructures is done automatically by the program itself if the number of cells for the structure or for one quadrant of a symmetric structure exceeds defined limits for a single scattering matrix. There is in fact no limit on the total number of cells to be computed by this program. If the structure is discretized into equal sized cells that fit in a uniform grid, the program will invoke spatial symmetry reductions to speed up the computation for the Green's functions.

The spatial symmetry reductions also enable fast re-computation of all matrix elements, in conjunction with the method of system iteration allows tens, or even hundreds of thousands of cells. Thus, there is no limit on the size of the models to be computed, as long as there is available computer time.

Limitations of MARCO

A number of limitations to the general operation of MARCO exist. These are:

- MARCO is compute intensive and can be slow to model soundings in complex situations. The program has been implemented using the Generic Model Interface to enable other operations to be undertaken while modelling continues.
- Memory requirements for the program are high. MARCO does not operate in less than 16 megabytes of available memory. 24 megabytes is a realistic minimum memory restriction, but the program operates more efficiently when 32 megabytes of RAM (or higher) are available.
- Complex earth (Cole-Cole) parameters can be implemented but their use adds a level of complexity that slows computation significantly.
- This current version of MARCO is restricted to conductivity contrasts of up to about 1000 to 1 between the 3D target and its immediate host.
- MARCO operates is operated in 32-bit mode. This operational mode is computationally efficient and uses whatever memory is available as per its modelling requirements.

Implementation of MARCO

The time-domain response is computed by first calculating the frequency-domain response from 0.1 Hz to 100 kHz at an interval of six frequencies per decade. A cubic spline interpolation of the imaginary component of the magnetic field is used to represent the frequency-domain response over the whole spectrum.

The time domain-magnetic fields are computed using digital filter coefficients that had been derived from the fast Hankel transform program of Johansen and Sorensen. A spline is fit to the time-domain magnetic fields and dB/dt is computed using the spline coefficients. This is then convolved with the source function to give the field voltages (area * dB/dt).

MARCO avoids a problem that can arise from using representing the normal

field from the transmitter loop as a line integration of horizontal electric dipoles. The dipoles on opposite sides of the loop contribute fields of opposite sign. At late times, these have the same magnitude so that the sum produces numerical chaos. Before this happens, the "smoke ring" passes the transmitter boundary which means that the transmitter acts like a single vertical magnetic dipole. An even more accurate approximation at this point is to use the response from a circular loop of equal area. These computations do not suffer from numerical instability at late times.

This version tests for this condition and switches representation before numerical chaos sets in. This affects the horizontal fields more than the vertical ones.

Operation of MARCO

Within EM Vision, access to MARCO is through the Generic Model Interface. Refer to the section describing the *Generic Model Interface* for additional information and operation of batch operated modelling programs. Where the Generic Model Interface is adopted, control of the modelling is passed from EM Vision to the model algorithm under control of specification control files (MCF Files).

MCF Considerations

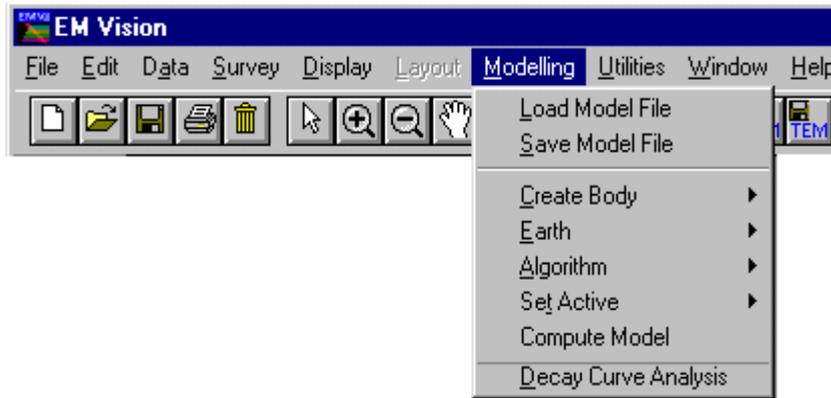
MARCO has a specific MCF control file to direct its operation under Windows[®] 95, Windows[®] 98 and Windows NT[™].

EM Vision is instructed to find the MARCO MCF file from the MCFDir parameter of the EMVIS.INI defaults file (see *The Defaults File*). An example of an appropriate MCF file is shown below:

```
[Interface]
Algorithm      = Marco
Description    = Marco: Blocks in layered host.
ModelClass    = Forward
DataType      = TEM
Executable    = c:\encom\emvision\MARCO.EXE
ExeType       = WIN32
StatusPoll    = 0.5
StatusAbort   = 1200
```

Note that the Executable entry refers directly to the 32-bit executable.

MARCO Operation



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

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 block body for use with MARCO 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 block 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 cross-section area or the map displays can be used to create, edit and manipulate the individually modelled

bodies. Only the Block body type can be selected from the options of the Create Body menu item when it is to be used with MARCO.

Interactive body control is available both for creation and for editing the block. Double clicking the left mouse button while the cursor is positioned over a body displays a dialog with options for controlling the body parameters and display. Refer to *Body Display Control* for additional information.

Block Body Creation

After selecting the **Create Body>Block** option, move the mouse cursor to the cross-section area of the profile display. The cursor changes to a '+'. Position the cursor where the top of the block 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 top to bottom extents of the block. To actually create the body using this technique, release the mouse button with the bounding box defining the depth extent of the block. A second method of creating a block is to position the cursor and then click the left mouse button. A default block is created.

Editing a Block in the X-Section Window

Selecting Bodies

All model editing is preceded by instructing EM Vision that a body is to be edited. This is done by **selecting** the body. Bodies can be selected individually or multiply. Once selected, the block(s) can be shifted, re-sized and have various parameters altered. Body selection operates identically both in Cross-Section Profile and Map displays.

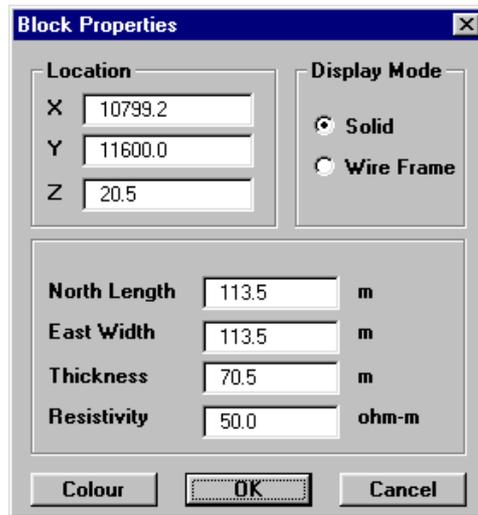
To select a body, ensure that EM Vision is in **Pointer** mode. If EM Vision is in the incorrect mode, select the **Pointer** push button (or icon) on the toolbar (the Status Bar reports the current mode). Position the cursor over the required body and click the left mouse button. To indicate a body is selected, four surrounding handles are drawn around the body. Use the SHIFT key with the cursor selection for selecting more than one block.

Interactive Body Shifting

To move a block or multiply selected blocks in cross-section (or in map view), click the left mouse button to select the block(s) as above. Hold the mouse button down as you move the mouse. This 'drags and drops' the block(s) to a new location when the mouse button is released.

The Block Body

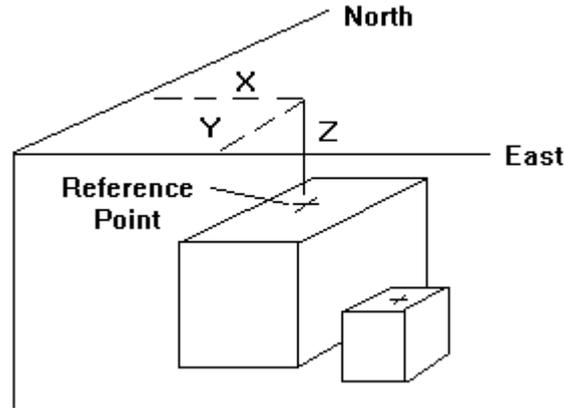
Editing a block and its parameters are done by using dialogs. By positioning the cursor over the block and double clicking with the left mouse button, a configuration dialog is displayed.



Block body properties dialog

The location of the reference point of the block is specified and can be edited if required. The other physical properties of the selected body defining the principal coordinate dimensions and length can be edited. Note there are no entries or controls for plunge, dip or down-dip depth extent. These parameters are not appropriate when the prism sides parallel the coordinate system.

Following is a diagram detailing the various parameters used to describe the block body type.

**Note**

The location of the block 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 block are:

Position (X,Y,Z)

The location of the reference point of the block relative to the local coordinates. Note that depth is negative down and the sides are parallel to the principal (East, North and Depth) coordinates.

Resistivity

The resistivity property of the volume contained within the block determined in ohm.metres.

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. In some instances, discrete body types, such as blocks can be contained in a homogeneous host, while in other instances, a layered Earth can be simulated.

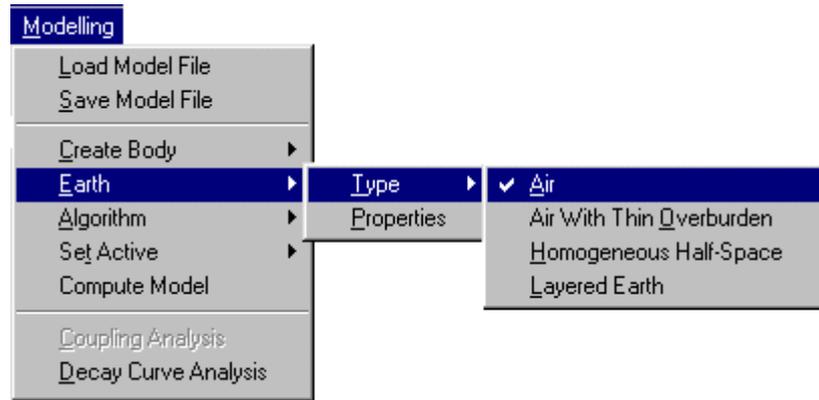
Note

Unless the correct information is specified in terms of model type, Earth host and defining parameters, MARCO is not accessible and appears 'greyed' out in the **Model>Algorithm** menu option.

When selected, the Earth option provides two alternatives - Type and Properties. Initially, Type should be selected to define the specific Earth host type to be modelled.

Earth Type

Options available from the Earth Type option are as shown below:



Only two Earth types can be used with MARCO. These are the Homogeneous (single layer) Half-space and the Layered earth.

Homogeneous Half-Space

This Earth type assumes a single, conductive earth volume lying beneath the survey area. The earth host has a definable resistivity. No complex resistivity parameters are available for use with MARCO when a Homogeneous Half-Space option is selected. A Layered Earth type can have complex earth models defined. The extent of the half-space is assumed infinite horizontally as well as vertically (depth) and the top of the half-space lies at the surface of the earth.

Layered Earth

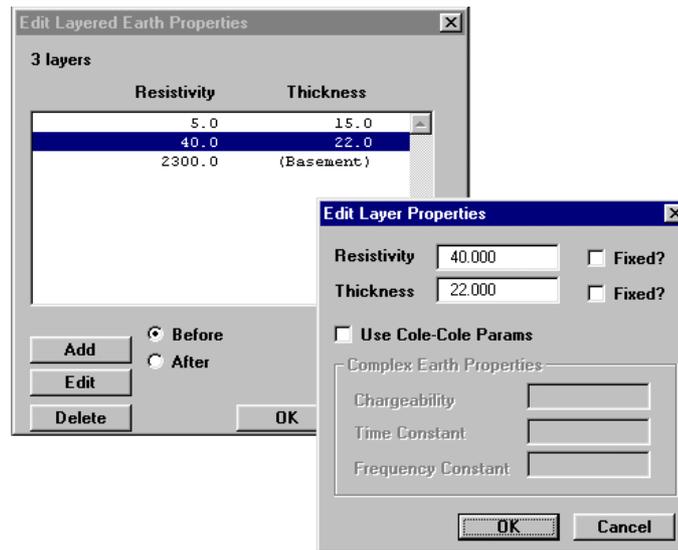
A Layered Earth model is comprised of a series of horizontal, stratified layers each of definable thickness and electrical property. The layered earth model can simulate a homogeneous half-space if only one layer is specified but usually more than one is defined. The extent of the layers is infinite laterally and defined by the thickness parameter vertically. The bottom layer is assumed to represent basement and so has resistivity properties but no thickness definition.

For MARCO the maximum number of layers is 16. Individual layers can be defined by thickness (which cumulatively represents depths to the top and bottom surfaces) and resistivity. Complex Cole-Cole earth parameters can be assigned to each layer.

Earth Properties

The Properties option is available from the Earth item of the Modelling main menu. This feature is used to define the properties used by the various Earth Types (see *Earth Type*). The dialog to control the various parameters of a layered earth will be displayed after selecting the Properties item.

For defining a **Layered Earth** model, a dialog controls the entry, editing and properties of the individual layers. The layers are presented within a scroll list as shown in the following dialog.



Editing the Layered Earth model.

When the dialog is initially displayed, EM Vision creates a single layer that it refers to as basement. No Thickness property is assigned to the bottom, basement layer of the list.

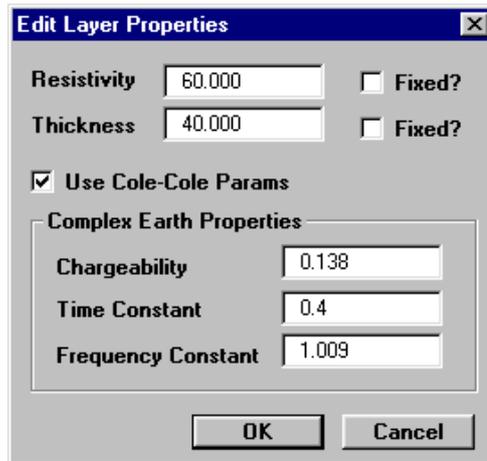
At the base of the dialog are three push buttons that control the creation, deletion and editing of layers. Associated with the **Add** push button are two options for

Before and **After**. These options enable creation of a new layer before (shallower) or after (deeper) the layer highlighted.

Note

It is not possible to create a layer after or below the basement layer.

Any layer that is highlighted can be edited by selecting the **Edit** push button while the required layer is highlighted. An alternative means of directly selecting and editing a layer is to position the cursor over the layer and double click with the left mouse button. By this method, or by using the **Edit** push button, an editing dialog for the selected layer is presented.



Editing dialog for layers including Cole-Cole parameters.

The resistivity and thickness can be edited in this dialog. Since MARCO is a forward modelling program, the **Fixed** option for modifying layer properties is not applicable. This feature only applies to inversion modelling.

The **Use Cole-Cole Params** option is available for MARCO. Complex resistivity Cole-Cole parameters are optional and in most cases are not applicable unless specific information relating to the complex resistivity and frequency dependence of the defined layers is known. This information is typically made available from IP surveys or laboratory sample analyses. Refer to *Complex Resistivity* for additional information.

Note

Access to the **Use Cole-Cole Params** option in the Properties dialog is only available after MARCO has been selected as the required algorithm. Refer to the *Algorithm Option* for this.

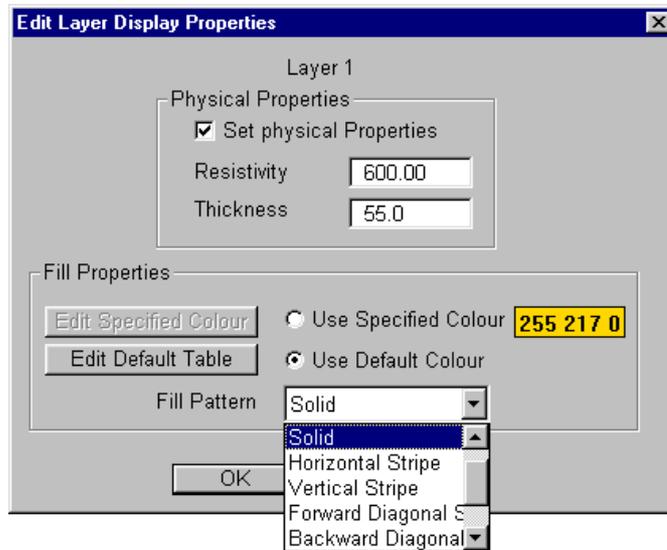
The use of Cole-Cole parameters relates to the frequency dependence of rocks. Frequency dependence of EM soundings is typically evidenced by the presence of negative values being recorded in field data. Rock conductivities are often weakly frequency dependent between excitation frequencies of 0.1 and 10,000 Hz. Rocks with this dependence are referred to as 'dispersive' (Smith, 1988). Qualitatively, the strength of the frequency dependence is the 'polarizability', a quantity that can be given a number of quantitative definitions. Commonly the polarizable dependency is measured over a frequency range of 0.1 to 10 Hz by the frequency domain induced polarization (IP) technique.

Controlling the Presentation of Layers

The section on *Earth Properties* and *Setting Individual Station Properties* describes the method of specifying a layer's thickness and resistivity properties. The appearance of layers, both on screen and in hardcopy can also be controlled by allocating colours or patterns to specific resistivities.

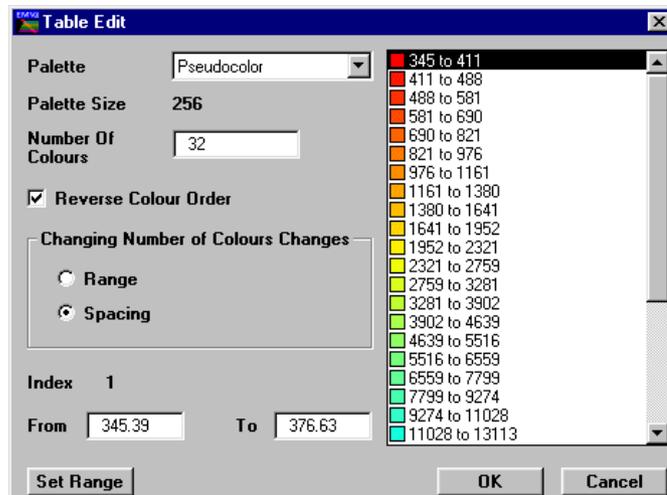
To graphically alter the properties, patterns or colour of a layer, move the cursor over the desired layer and while positioned there, double click the left mouse button. A dialog indicating the layer colour and the properties are displayed. The properties can be altered by editing the values displayed.

The colour of a layer is indicated in the central indication box of the dialog and within this are Red:Green:Blue colours indicating the mix of primary colours used to display the layer. This Default Colour can be altered by selecting the **Use Specified Colour** button. When activated, this button causes the **Edit Specified Colour** push button to be available. Selecting this button provides a dialog enabling you to modify the layer colour as required.



Editing the property or display attributes of layers.

Control of the palette and the range of resistivities that can be presented is made available by the **Edit Default Palette** push button. This button is activated by selecting the **Use Default Colour** option. When the activated palette button is pressed a dialog that enables the mapping of resistivities to various colours is displayed.

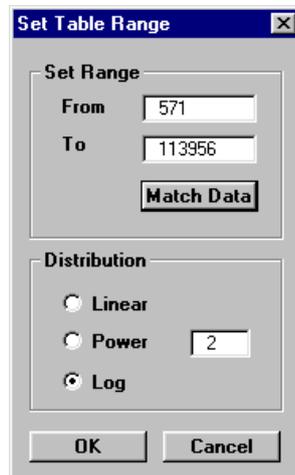


Editing layer resistivity colour mappings

This dialog allows standard colour palettes to be used to map the presentation colours of various layer resistivities. The Palette option specifies the standard palette files stored in the directory specified by the LUTDir parameter of the EMVIS.INI file (see *The Defaults File*). Note that these palettes are identical to the format used by ER Mapper (refer to the *ER Mapper Reference Manual* for details on look-up table specifications).

Palette sizes are composed of typically 16 or 256 colours and the number of colours derived from the palette is definable. The actual mapping of colours from the palette is seen on the right of the dialog in a scrollable list with the associated resistivity ranges. The list is made up of 'from and to' resistivity pairs which can be controlled specifically in the **From** and **To** entry fields. To modify a resistivity range for a specific colour mapping, position the cursor over the required colour entry and highlight it with a left mouse button click. The **From** and **To** resistivity range can then be altered in the entry fields.

If you wish to re-map the entire resistivity range to comply with a specific resistivity range, select the **Set Range** button.



Dialog to control the range and look-up table for colour mappings

The upper and lower resistivity range can be defined and the distribution method of mapping the resistivity range across the colour mappings can use one of three methods:

- Linear distribution from highest to lowest resistivity.
- Power distribution of nth power.

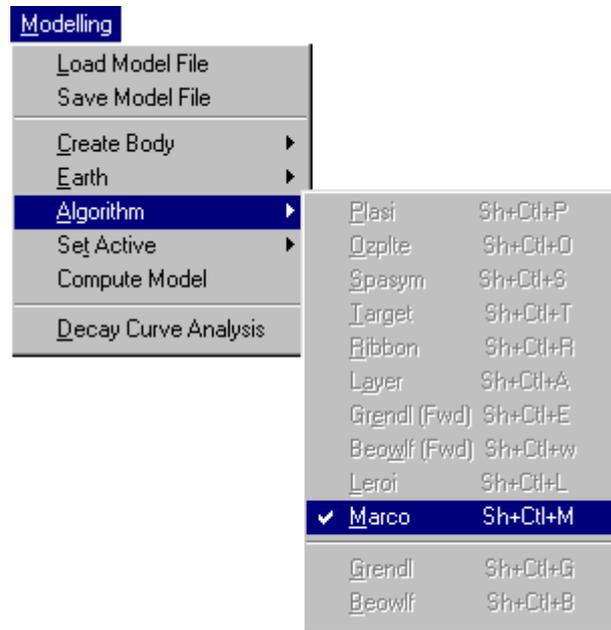
- Logarithmic distribution.

The **Match to Data** button will automatically select the minimum and maximum data values and place them in the **From** and **To** entry fields.

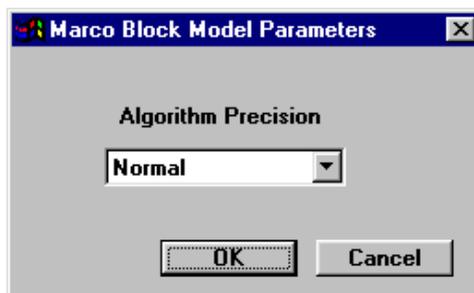
Algorithm Option

The Algorithm option in the Modelling menu is used to select MARCO.

All implemented modelling programs are contained in the displayed menu list but not all algorithms will have been made accessible. 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.



When initially selected (from the **Modelling>Algorithm** option), MARCO



displays a window to define block body computation method. In its theoretical implementation, MARCO three algorithm approaches are available (Quick, Normal and High precision). These algorithms differ

only in their precision in solving the theoretical frequency domain field computation matrices. The precision is a compromise between accuracy of results and speed of calculation.

Even if a program is installed, access may be denied by EM Vision if an incorrect survey configuration or instrument combination has been set.

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 *Non Accessible Algorithms*.

Once the MARCO algorithm is selected, a dialog confirms it.

Set Active Option

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

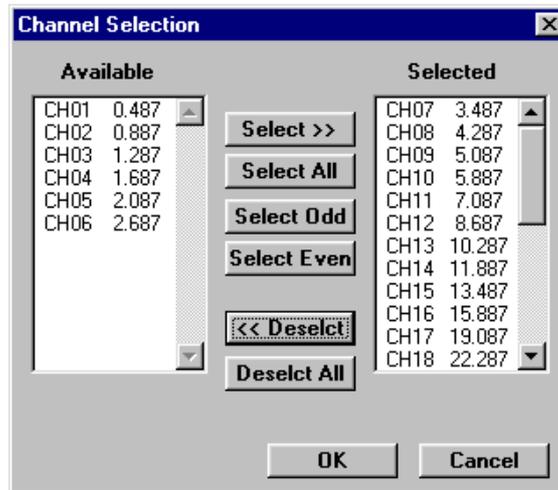
Modelling computations can be restricted to user defined delay channels and data readings. Channels and readings available for modelling are referred to as active. The Set Active option provides the facility of making channels and data stations inactive.

Note

By default, EM Vision makes all data initially active.

Setting Channel Activity

The Set Active option for channels presents 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.

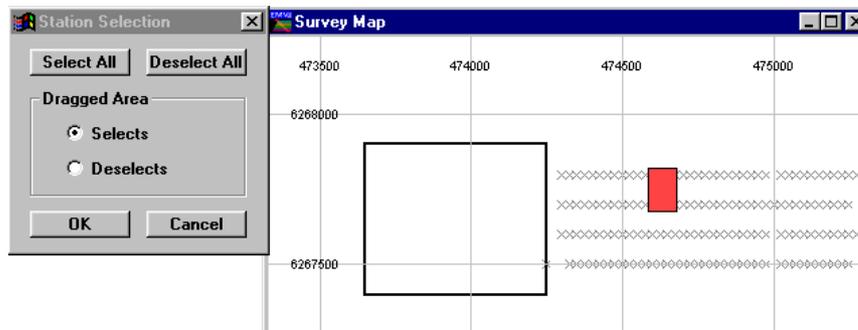


Channel selection dialog

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

Setting Station Activity

Defining which data readings are to be modelled is controlled by the Set Active Stations option. When selected a dialog accompanied by a survey map of the available station locations are displayed. Initially all readings will be highlighted indicating their active state. Within the dialog you can **Select All** or **Deselect All** readings. Also within the dialog you can 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. 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 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 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, MARCO can be initiated. 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.

MARCO uses the Generic Modelling Interface to operate and so is executed externally from EM Vision. In these cases, an icon will appear in the Windows status bar that indicates that EM Vision has initiated the program in an external portion of memory. This icon should not be selected while the program is running. For additional information on the icon settings and its operation, refer to *Controlling Algorithm Access*.

WARNING

MARCO is a program that requires large amounts of RAM memory to load and execute. On machines having only 16 megabytes of RAM, the program may not load and execute. No progress is noted in the slider bar while this is happening. On machines with increased memory, loading and operational times are reduced.

Progress of modelling is indicated by a slider bar with a percentage of completion. In cases where MARCO 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 has aborted, status files and results to that point will be available for examination. These files along with control and model files will reside in the project directory as defined by the import data.

Once a program has been halted, modifications to the model, channel and station activity can be made and the program re-initiated. Halting and re-executing the program can be undertaken any number of times.

Multi-Body Modelling with MARCO

MARCO permits inductively coupled blocks to be included in the basement of a layered model. Additional detail may be found in the *MARCO Program*

Description. No blocks are permitted to have overlapping adjacent block volumes, but their respective sides can be in contact. Blocks can span layers but when this is done, computation time is increased. Cole-Cole resistivities may also be specified for layers.

Multiple block bodies for MARCO are created and manipulated as described in *Block Body Creation*. Defining layers and their properties that enclose the target block is presented in subsequent sections.

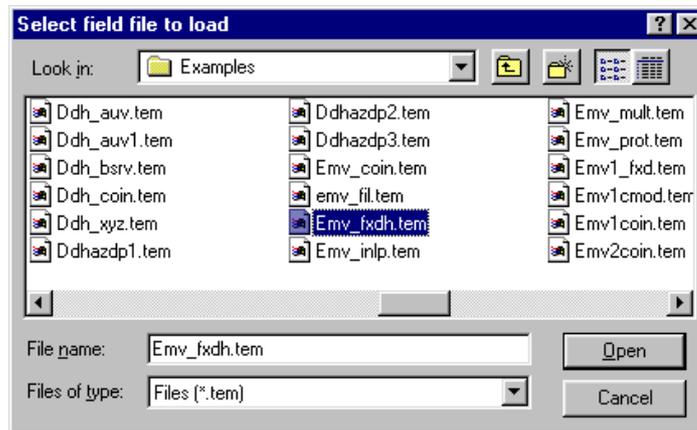
It is not recommended that blocks have resistivities with contrasts of physical properties greater than 100 to 1 with its enclosing, immediate host. As an example, erroneous results can be expected if simulating the EM response of a block of high conductivity (resistivity of 1 ohm.metre) when enclosed in a layered half-space of resistivity 1000 ohm.metres.

2 MARCO Tutorial

The following section is a brief tutorial to explain the normal methods of operating MARCO. The dataset to be used for this exercise is supplied with EM Vision and is called EMV_FXDH.TEM. The file is read into the EXAMPLES subdirectory during installation of EM Vision. The tutorial is presented as a number of steps. Within each step, additional information is provided to assist you in understanding alternative analysis or display options.

Step 1 - Import the data

Import the EMV_FXDH.TEM data file using the **Data>Open Field Data** option as shown below:

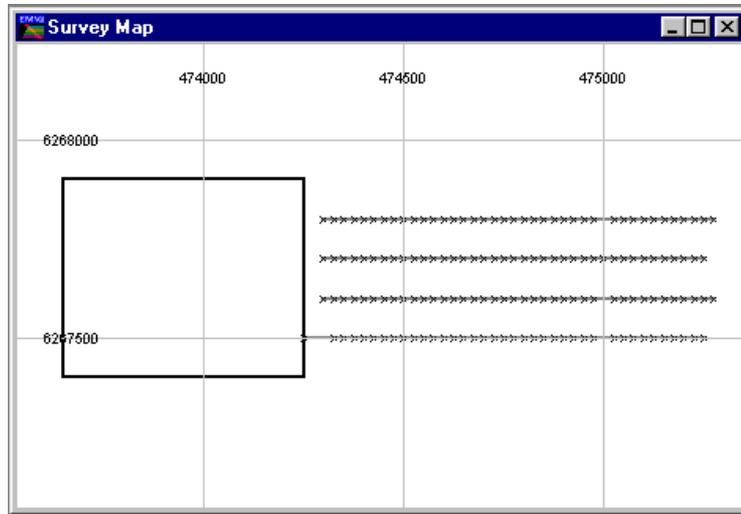


MARCO data file definition.

The data are read in (indicated by a progress bar) and an explanatory dialog describing the data is presented. The data file has been acquired using composite time channels on a Sirotek Mk3 with a 400 x 500 metre fixed transmitter (Turam) survey configuration. Four lines of data are contained in the file. All readings have been taken outside the transmitter loop.

Step 2 - Examine the data by survey map

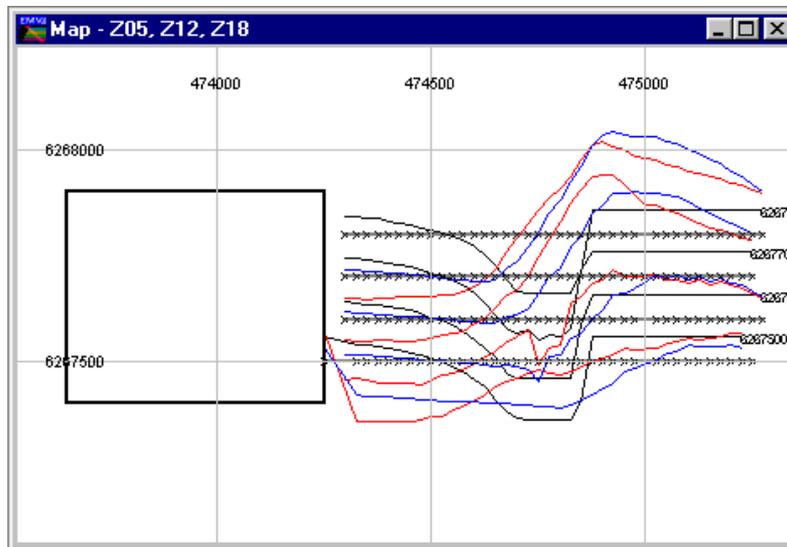
To initially examine the data and the location of data lines relative to the transmitter loop, select the **Display>Survey Map** option.



Survey map of station locations and transmitter loop

The above window has been configured from the initial display. Altering the appearance of a map window can be done by positioning the cursor in the display and pressing the right mouse button. The Station Posting Configuration dialog will be presented. Control of the reading symbols and assignment of posting values is done from the **Station Labels** push button.

To view data on the Survey Map, contours or stacked profiles of nominated channels can be added. In the map configuration dialog, press the **Add** button while the object type is set to Stacked Profile. Choose 2 or 3 channel delays to be representative of the data (for example early, mid and late time channels) and display these. You may need to configure their vertical scaling to optimally show the data. Different colours could also be used to discriminate between the channels.



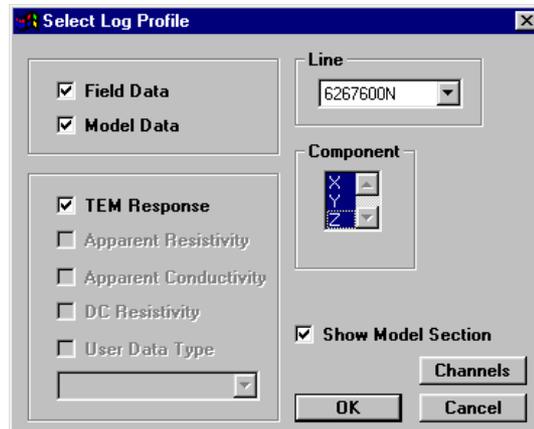
Survey map with three data channels as stacked profiles

The data responses from each traverse are similar with a migrating crossover being observed. The early time channel (Channel 5) is saturating the negative and positive values.

Step 3 - Display a Line of Data as a Profile

A profile needs to be displayed to create layers for modelling with MARCO. Select the **Display>Profile>Log-Linear** option. To present the profile with a cross-section area beneath, the **Show Model Section** checkbox needs to be enabled.

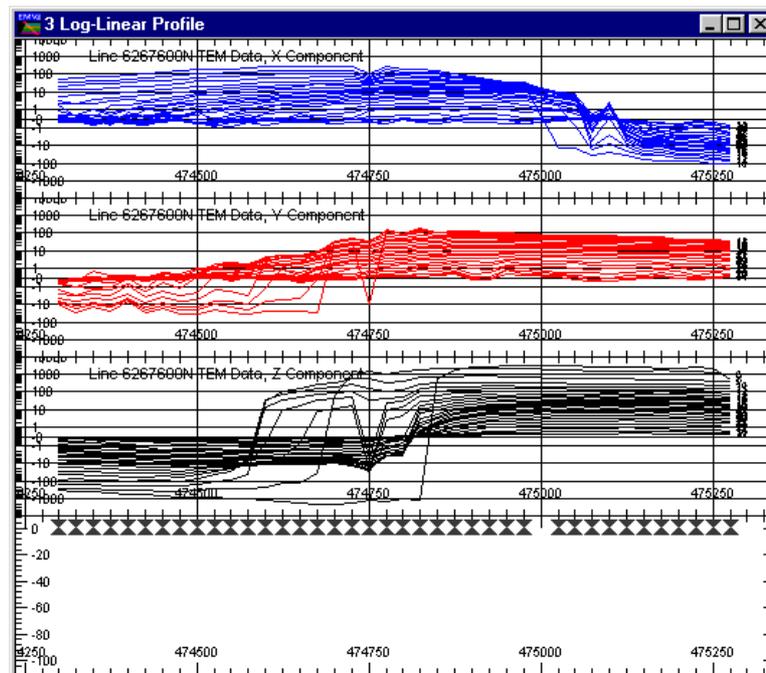
The data being used in this example has three components (X, Y and Z). It is possible to display all three components, as well as a cross-section track. Use the CTRL or SHIFT keys to nominate all three components.



Profile selection dialog with three-components chosen

It is also advisable to enable the **Model Data** checkbox, since as MARCO creates theoretical responses, these data are automatically appended to the display.

Once these items have been selected and **OK** pressed, the display is presented.



Profile of 6267600N with three components and cross-section

In this display an empty cross-section beneath the data is provided. The three X, Y and Z components, are displayed with all channels but it is apparent that some early time channels should be removed from the display. This can be done by displaying the Profile Configuration dialog and choosing the **Channels** push button.

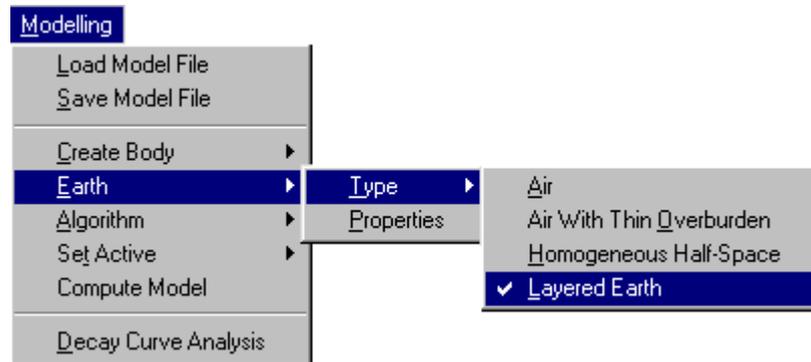
Step 4 - Define the Earth Type

The Earth option of the Modelling menu is used to define the Earth Type and assign its properties. Various Earth types are available to satisfy the many host environments that can be modelled. In the case of MARCO, the only Earth Type available is the Layered Earth.

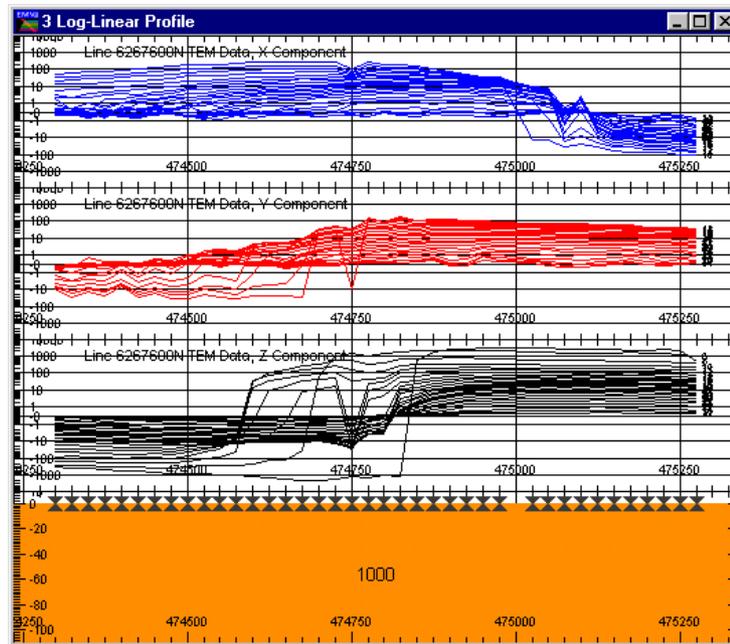
Note

Unless the correct information is specified in terms of model type, Earth host and defining parameters, the MARCO algorithm is not accessible and appears 'greyed' out in the **Model>Algorithm** menu option.

When selected the Earth option provides the alternatives of Type and Properties. Type should be set to Layered Earth as shown.



When the Layered Earth option is set, the station locations and a single basement 'half-space' layer is drawn.

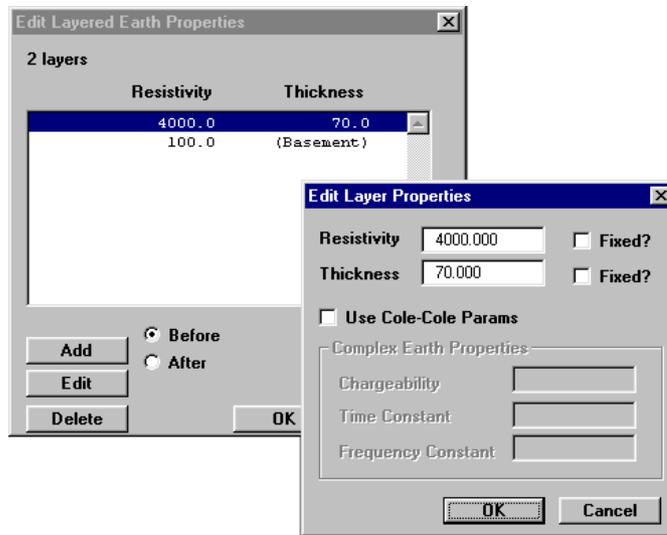


Profile with basement layer and reading locations (X-symbols)

On the surface of the basement layer are a number of 'X' marker symbols. These locations mark the position of each individual reading for this profile.

Step 5 - Defining the Layer Properties

A second (or third) layer with individual resistivity properties can be added above the basement by selecting the **Modelling>Earth>Properties** menu option. When this is done, a dialog is presented that describes the existing layer properties of Thickness and Resistivity (initially for only the Basement layer). To add the second layer, press the **Add** push button and enter new resistivity and thickness properties. When adding a layer, it is added before the highlighted layer depending on the **Before** or **After** button selected.



Adding and editing Layered Earth properties

After a layer has been created, it can be edited by either highlighting it in the Edit Layered Earth Properties dialog and selecting the **Edit** push button, or positioning the cursor over the desired layer and double clicking with the left mouse button.

A layer can be removed by highlighting it and then pressing the **Delete** push button. For MARCO applications, only 2 individual layers can be used with conductor(s).

Note

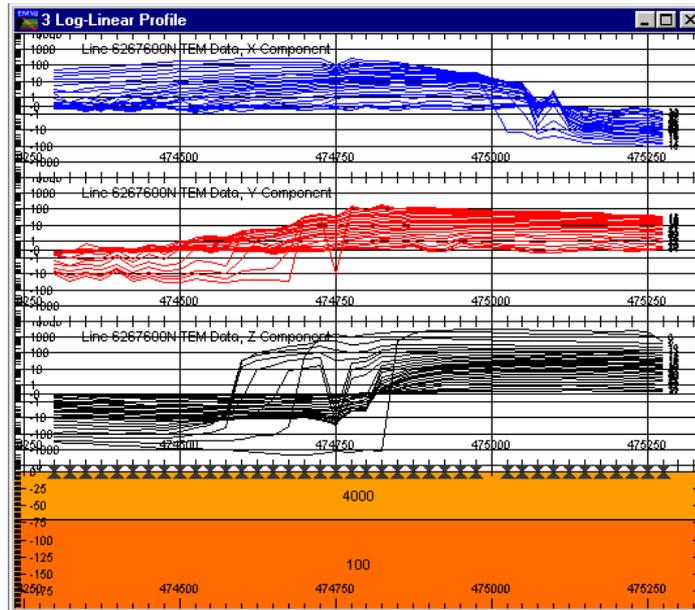
Complex resistivity properties can be entered into the Properties option dialog if required. These can only be enabled if the MARCO algorithm is enabled. Refer to Step 10 for selection of the algorithm to enable Cole-Cole parameters to be entered. When available, enable the **Use Cole-Cole Params** button to access the entry fields.

Step 6 - Modifying Layer Properties and Colour

After defining two layers, the properties and appearance of each layer can be altered graphically. In the diagram below, two layers with different resistivity and thickness properties are shown. Note that the bottom layer represents the basement and so has infinite thickness.

To graphically alter the properties or colour of a layer, move the cursor over the desired layer and while positioned there, double click the left mouse button. A

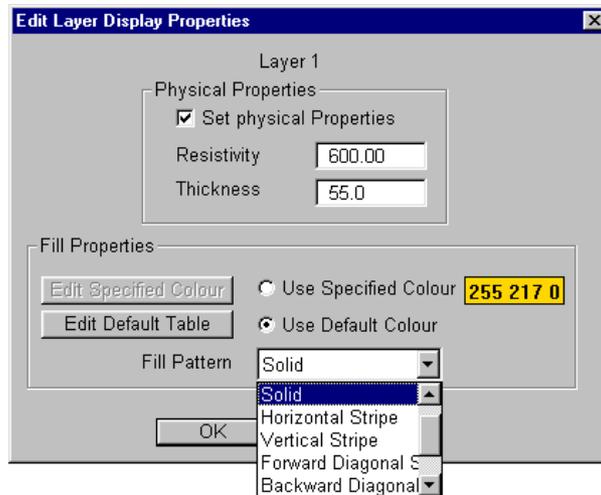
dialog indicating the layer colour and the properties are displayed. The properties can be altered by editing the displayed values.



Two layers of different resistivity and thickness properties

The colour of a layer is indicated in the central indication box of the dialog and within this are Red:Green:Blue colours indicating the mix of primary colours used to display the layer. This Default Colour can be altered by selecting the **Use Specified Colour** button. When activated, this button will cause the **Edit Specified Colour** push button to be available. Selecting this button provides a dialog enabling you to modify the layer colour as required.

For additional information on controlling the appearance of layers, refer to *Individual Layer Appearance Control*.

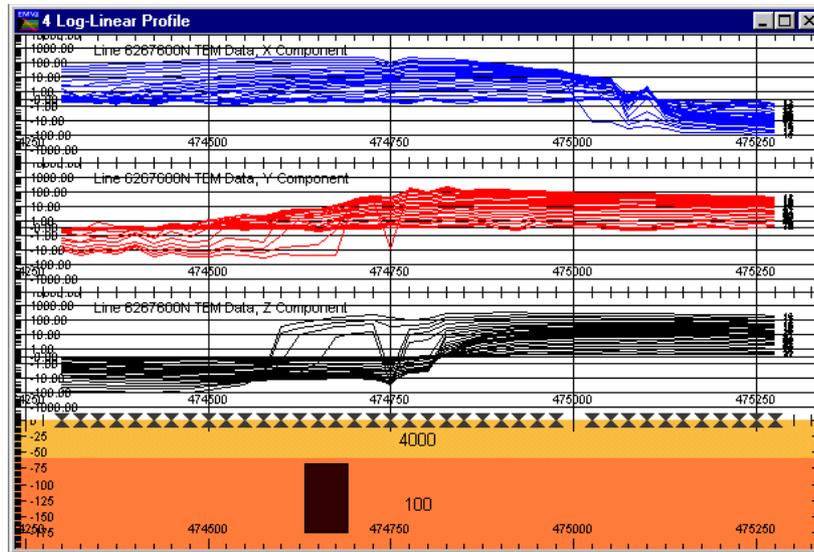


Dialog for graphically editing a layer's properties

Step 7 - Insert a Block Conductor

With the profile displayed and the window active, select the **Modelling > Create Body > Block** option. The cursor alters to become a '+' when inside the profile window. Position the cursor where required for one edge of the block, 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 block is created when the left mouse button is released. The block is symmetrically positioned about the line of the profile.

Note that the vertical depth scale of the section is negative, increasing down the plot. This convention is adopted for all EM Vision cross-section plotting and relates to the reference depth locations of the various bodies created.



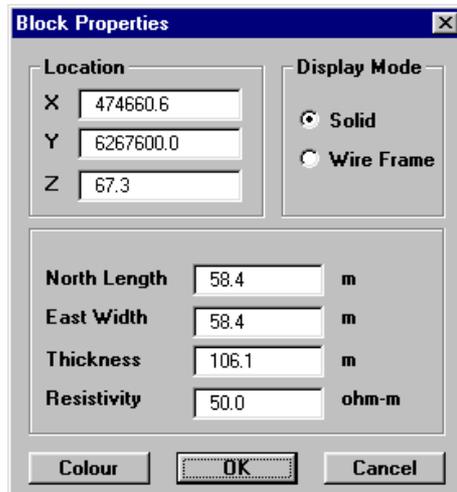
Profile with a target conductor placed in the section

If need be, create the target, then by ‘dragging and dropping’ the block, move it to a position that suits your observed data. Refer to Step 9 for information on editing the block.

Step 8 - Edit the Block Model

The block can be selected in the profile window 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. Once selected, the body can be ‘dragged and dropped’ to a new location by using the mouse.

To edit specific block parameters such as length, thickness etc, position the cursor over the body and double click the left mouse button. A Block Properties dialog is then presented.



The image shows a 'Block Properties' dialog box with the following fields and options:

Field	Value	Unit
X	474660.6	
Y	6267600.0	
Z	67.3	
North Length	58.4	m
East Width	58.4	m
Thickness	106.1	m
Resistivity	50.0	ohm-m

Display Mode options: Solid, Wire Frame

Buttons: Colour, OK, Cancel

Editing of the block configuration dialog

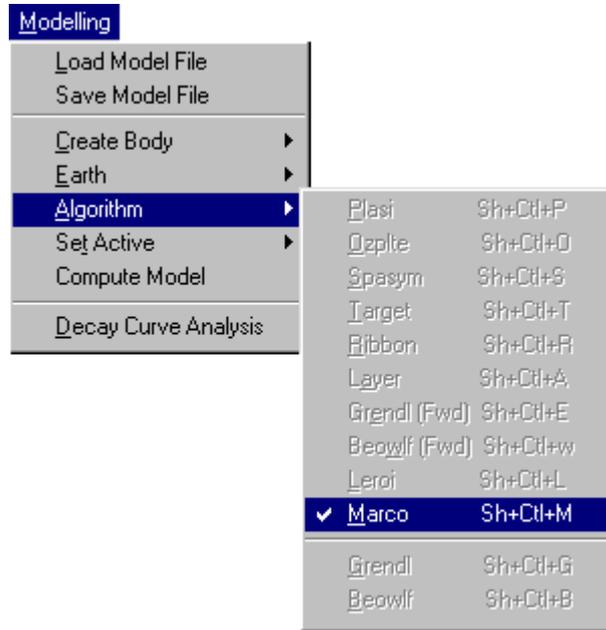
In the dialog, the depth to the block is negative and conforms with the profile cross-section location. Resistivity is used for the block physical property attribute. Edit the values of the various entries as desired.

Note

To select a target block contained in a layered background, simple mouse double clicking may be difficult. To ensure you can select the block, use the CTRL key in combination with the cursor location and the left mouse button.

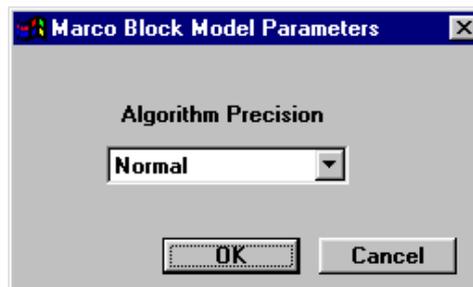
Step 9 - Define the Algorithm

Once the earth model and target block are defined (see Steps 4-8), you must specify MARCO as the modelling algorithm. To set the algorithm, select from the menu **Modelling>Algorithm**.



Note that many algorithm names are not available for selection. If MARCO is not available, refer to the section on *Non Accessible Algorithms* and the *Algorithm Option* of the EM Vision Reference Manual. Some typical causes of an algorithm not being available include:

- Algorithm option not purchased or licensed.
- Inappropriate survey configuration for algorithm required. For example, MARCO does not operate without a block target being present in an earth model.
- Incorrect settings of the Generic Model Interface. For details of this refer to the *Generic Model Interface*.



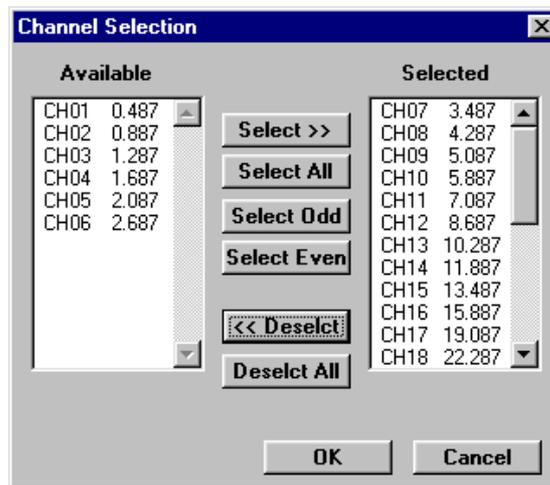
Select MARCO as the algorithm to use for modelling. When initially selected (from the **Modelling>Algorithm** option), MARCO displays a window to define the precision of computation (Quick, Normal or High precision). Initially, select the Normal setting.

There is a compromise between EM response accuracy and computation time.

Step 10 - Controlling Which Channels to Model

By default, MARCO models all data channels available. If early or late time noise is present in the data being modelled it is often a good idea not to model the noisy channels. Using the **Modelling>Set Active>Channels** option it is possible to ‘turn off’ certain channels which are not to be computed by MARCO. Alternatively, you can model all channels but only display those that are meaningful when comparing the model responses with the observed data.

When the option is selected, the standard channel selection dialog is presented.

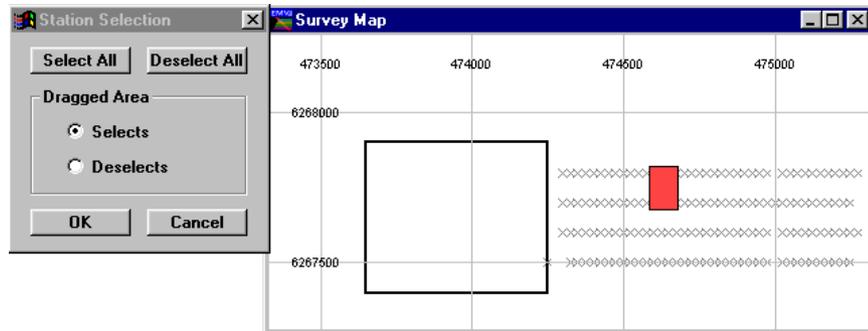


Channel selection dialog for channel activity

Refer to the section on *Standard Operations* for details on selecting and deselecting channels.

Step 11 - Controlling Which Stations to Model

The MARCO program models station responses individually. This means that you can control which stations you wish MARCO to calculate responses. This control is provided by the **Modelling>Set Active>Stations** option. When selected, the option presents a dialog accompanied by a survey map of the data. Individual or groups of stations can be selected as being ‘active’. Stations that are highlighted are deemed to be active.



Setting stations to be active for modelling

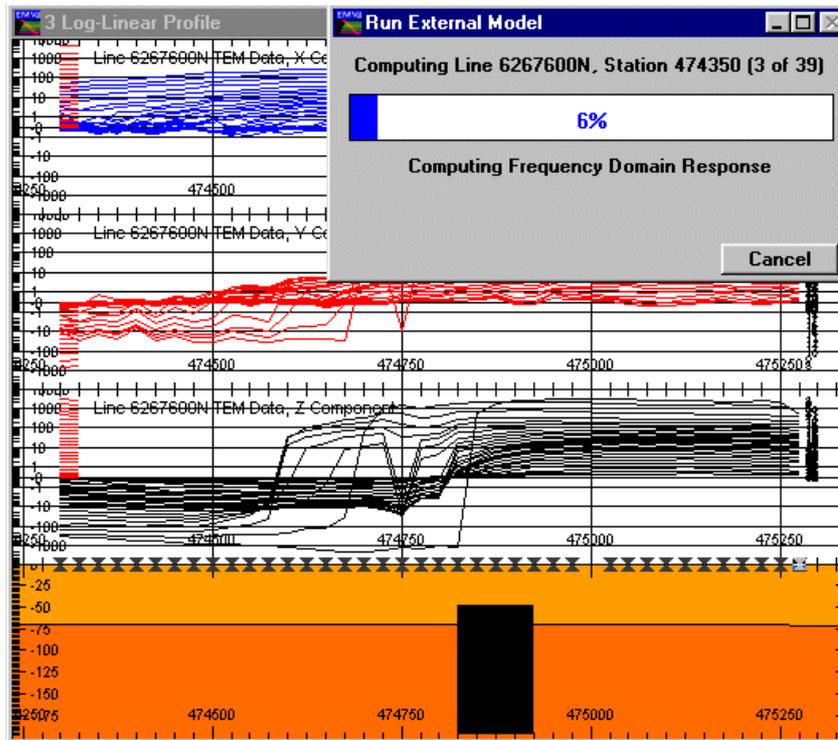
It is possible to drag a rectangle over one or more stations and select them as active or inactive, depending on the setting of the dialog. To do this, position the cursor where appropriate and then press the left mouse button while moving the mouse. A rectangle is created and all stations contained in this are selected.

For this example, only the stations for the appropriate line have been set to active (Line 6267600N).

After creating a model and setting the activity and algorithm appropriately, you can initiate MARCO. This can be done in one of two ways:

Press the **Compute** push button (or icon) on the toolbar or select the **Modelling>Compute Model** option from the menu.

When MARCO is initiated, a progress bar is displayed as the program computes the individual station responses. As responses are derived, the progress bar is updated but also the model response is displayed (assuming the Model Response option was enabled during the profile display).



Forward model with modelled and observed responses

The program continues executing until all stations and channels are completed. If required, you can terminate a program run early by selecting the **Cancel** button.

Step 12 – Adding Additional Block Conductors

Once a cross-section is presented beneath a profile (as in Step 7), Additional bodies can be added to the section in the normal fashion. The sections on *Create Body Option* and *Block Body Creation* provides information on conductor placement and editing.

After the conductors are in the positions required with appropriate properties, modelling can commence (Steps 9-11). Only MARCO can compute the multiple block response with the EM coupling between the block and layers being calculated. Initiate modelling by either the **Modelling>Compute** option or the



command icon. When the program is run, MARCO treats each target collectively after generating the frequency domain response (the slowest phase of the processing). Once computation is completed, a report of output is created

(that may be viewed), and the modelled data responses are displayed in the profile.

Step 13 - Saving (or Loading) a Computed Model

Prior to, or after running MARCO, 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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