Emax

Version 5.50c

User Guide

If you use Emax with Maxwell
Maxwell version 6.x or later supports this version of Emax.
Earlier versions of Maxwell may also work, but this is not guaranteed nor supported.

"Infinitem" (dual-Tx-loop) surveys
Emax can process this data when running in stand-alone mode,
but at present Emax *cannot* process it via Maxwell.

Fullagar Geophysics Pty Ltd

Fullagar Geophysics Pty Ltd, 45 Tahune Crescent, Blackmans Bay, Tasmania, 7052, Australia.

www.fullagargeophysics.com

Contents

Licence

Emax is a licenced software product to be used in accordance with the terms and conditions of your Licence Agreement with Fullagar Geophysics Pty Ltd. The Licence Agreement is displayed by the setup during the software installation process.

Running Emax

Emax runs on IBM compatible machines. A Pentium processor is recommended as the minimum.

Two modes of operation are possible. The basic one is a command line *stand-alone* mode. For this mode the input data needs to be prepared in a specific format which requires the user to expend some effort preparing field data for input. This mode is more convenient if the user wishes to test different parameter settings or output a variety of different CDI data formats.

The second mode is to run Emax through the *Maxwell*™ e/m modelling software interface developed by ElectroMagnetic Imaging Technology (EMIT) in Perth, Western Australia. Maxwell reads a wide variety of data formats, runs Emax from within the Maxwell GUI interface, and provides a graphical display of the conductivity-depth output data. Optionally the input data can be exported into a new file in the format required by the stand-alone mode of operation.

For users working in stand-alone mode, a typical procedure is to first run Emax through Maxwell and choose to export the data to a stand-alone input file format. That input file can then easily be edited, parameters can be changed in the file's header, and stand-alone re-runs done from the command line.

System Requirements

Windows 7 or later.

(Windows 2000, XP, Vista : may run, but no longer supported)

The program is a 32-bit executable
which will run on 32-bit or 64-bit machines.

See also Maxwell™ system requirements.

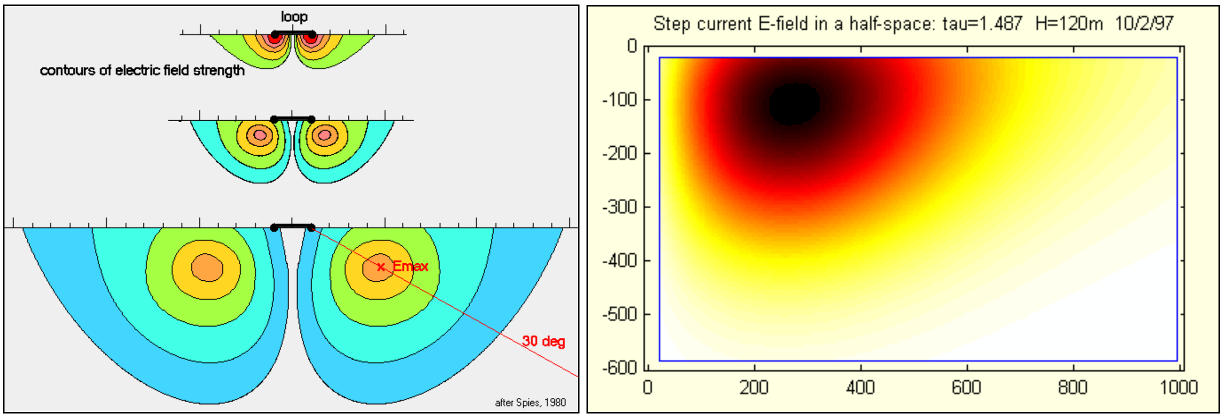
1. Introduction

1.1. Description

Emax calculates conductivity versus depth pseudosections from the transient electromagnetic (TEM) dB/dt or B-field decays recorded with various Tx/Rx loop geometries. The algorithm is described in publications by Fullagar (1989), Fullagar and Reid (1992), Reid and Fullagar (1998), and Schaa et al (2006).

A conductivity and depth are assigned to each TEM channel. The assigned conductivity is the conventional apparent conductivity $\boldsymbol{\sigma}_a$. The assigned depth is the depth to the current maximum (for dB/dt data) or vertical B-field maximum (for B-field data) at the delay time in question, for a half-space of conductivity $\boldsymbol{\sigma}_a$. This transformation from voltage versus time or B-field versus time to conductivity versus depth is computationally efficient.

In the context of depth conversion methods it is easy to confuse *physical* currents and *image* currents. A physical current ("smoke ring") is the real flow of charge carriers in the ground; an image current ("current filament") is a mathematical abstraction which replicates the magnetic field on the surface. The physical current maximum, $|\mathbf{E}|_{max}$, travels down into a half-space along a straight line path at an angle of approximately 30^o, whereas the image current filament travels in a similar manner but more steeply at about 47^o. This is so because the "equivalent current filament" which has an *infinite current density* must always be deeper than the maximum of the actual *distributed current* system. The consequence of this is that depth conversion methods based on image currents will inherently overestimate penetration depths. The depth conversion method used in Emax pertains to physical currents.



(a) evolution with time (b) numerical example

Figure 1- Secondary physical currents.

The maximum secondary Bz is located beneath the centre of the loop, somewhat deeper than the maximum current.

The methods used in Emax have been applied to various theoretical data and in each case the apparent conductivity provides a good qualitative indication of the true variation of conductivity with depth. This statement even applies in cases where a number of channels are rejected because of "depth reversal" (decreasing apparent depth with time); such channels are easily identified and removed automatically during processing.

The purpose of Emax's CDI processing is to quickly and reliably transform raw data into a useful form for presentation of conductivity-depth sections, and to allow for a fast initial interpretation of the data. Emax can be run in stand-alone mode, or via Maxwell.

1.2. Derived Quantities

Emax is does not always process the data in its original, "as measured" form.

If only windowed dB/dt data are available, it can be advantageous to process quasi-B, either alone or in combination with dB/dt. Quasi-B, denoted qB, is an approximation to B-field, defined by

$$qB_n = \sum_{k=n}^{K} \frac{dB_k}{dt} t_k$$

In fixed loop surveys, a cross-over anomaly is the z-component signature across compact conductor. After CDI processing, a cross-over is expressed as a pair of conductors, one of either side of the actual conductor. *Such artifacts can be avoided if two or more components have been measured*. Emax can process the total field amplitude, defined by

$$|D| = \sqrt{D_x^2 + D_z^2}$$

in the 2-component case or

$$|D| = \sqrt{D_x^2 + D_y^2 + D_z^2}$$

in the 3-component case, where D denotes either dB/dt or B.

If only the z-component has been measured, the horizontal component (along-line, across-strike) can be estimated from the vertical component via Hilbert transform if the geology is essentially two-dimensional (Asten, 1992). It can be advantageous to process the horizontal along-line component because the peak responses occur above the conductors. Emax includes an option for Hilbert transformation of vertical component data.

1.3. Survey Geometry

Emax is able to process data from 4 loop geometries:

Coincident Loop – Rx and Tx at same position (dB/dt only)

In-Loop – Rx at centre of Tx loop.

Fixed Loop – Rx moves (inside/outside of a fixed Tx loop)

Slingram – Rx at a constant offset outside Tx loop.

{"*Dual Loop*" – special case - see Figure 14}

The following assumptions are made:

Tx loops are square or rectangular.

Rx is a small coil or magnetometer (except for coincident loop dB/dt, when Rx is a loop with same size and position as Tx).

Only the vertical component of dB/dt or B-field is processed for coincident loop surveys. For fixed loop, in-loop, and slingram surveys the options are z-component alone, z-component and the along-line horizontal component (as total field), or all three components (as total field).

A repetitive bipolar square wave waveform is assumed, with linear turn-off ramp.

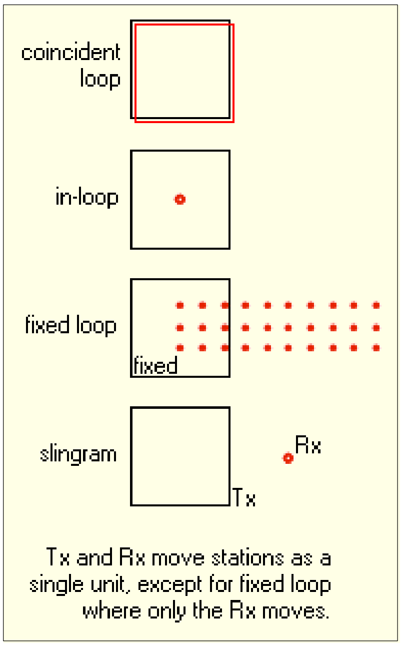


Figure 2 - Loop geometries.

1.4. References

Asten, M.W., 1992.
Interpretation of ground TEM data from conductive terrains.
Exploration Geophysics, **23**, 9-16.

Christensen, N.B., 2002.
A generic 1-D imaging method for transient electromagnetic data.
Geophysics 67, 438–447.

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Fullagar, P.K., 1989.
Generation of conductivity-depth pseudo-sections from coincident loop and in-loop TEM data.
Exploration Geophysics, **20**, 43-45.

Fullagar, P.K., and Reid, J.E., 1992.
Conductivity-depth transformation of fixed loop TEM data.
Exploration Geophysics, **23**, 515-519.

Fullagar, P.K., and Pears, G., 2010.
High Resolution Conductivity Depth Transformation of TEM Data.
ASEG Extended Abstracts, 2010:1, 1-4.

Reid J.E. and Fullagar, P.K., 1998.
Conductivity-depth transformation of Slingram transient electromagnetic data.
Exploration Geophysics, **29**, 570-576.

Schaa R., Reid, J.E., and Fullagar, P.K., 2006.
Unambiguous apparent conductivity for fixed loop transient electromagnetic data.
Exploration Geophysics, **37**, 348-354.

2. Installation

2.1. Software

There are two licence types available.

- A ***registry-key*** licence. These licences are locked to a single computer and can be issued immediately through an exchange of e-mails. To enable a licence key to be generated you will need to send us your computer's *MAC address* (also known as the *physical address*). This can be found by running the command "ipconfig/all" in a Command Window and noting the physical address of the *Ethernet adapter Local Area Connection*. Often multiple physical addresses will be listed; if unsure which one to send, you can download the licence utilities tool "GET_Ethernet_Physical_Address.zip" from www.fullagargeophysics.com and send us the output file it produces.

- A ***dongle*** licence. We have to ship you the dongle before you can start to use Emax. These licences are more convenient if you want to install Emax on more than one computer. Emax will then only run on a computer with a dongle inserted.

Installation is via a *setup* executable file which can be downloaded from www.fullagargeophysics.com.

You will need to download the setup file that matches your licence type (registry or dongle).

When you run the Emax software setup file you will need to enter a *setup password*.
Please contact us to get the current setup password.

If you are installing the dongle version of Emax for the first time, before inserting the dongle: download and install the "run-time setup for dongles – zip" file.

A typical install commences like this;

Figure 3 - Installation of Emax software.

Files are installed into the following directory (which is created if necessary);
32-bit operating system `C:\Program Files\Fullagar\Emax`
64-bit operating system `C:\Program Files (x86)\Fullagar\Emax`

To uninstall, either run the executable (usually named *unins000.exe*) that is stored in the program directory, or use Windows Control Panel (under Programs and Features, or Add/Remove Programs on older systems).

2.2. Operating system environment

For convenient *stand-alone* operation a batch file (Emax.bat) is included in the program folder
32-bit operating system `C:\Program Files\Fullagar\Emax`
64-bit operating system `C:\Program Files (x86)\Fullagar\Emax`
and this program folder is automatically added to the operating environment PATH during installation.

To start Emax simply open a Command Window in your working folder and run the command **Emax** at the prompt. If the operating system environment has been set correctly then Emax should begin running.

2.3. Licence Key

Your licence is set up separately to the installation of Emax.

If you installed the version of Emax that uses a ***registry licence*** then we will email you a ".reg" licence file. This attachment will usually arrive with a different filename extension (.txt for example) to prevent internet security software from automatically quarantining the attachment. The attachment should be saved to a temporary folder on disk, unzipped if necessary, renamed to *.reg and double-clicked. This adds the licence information to your computer's registry; you will be prompted for permission to modify the registry.
You cannot move a registry licence to another computer; the licence remains locked to a specific computer.

If you have installed the version of Emax that uses a ***dongle*** then we will need to ship a dongle to you.
You can install Emax on multiple computers. The dongle can be moved between computers as required, however Emax will only run on the computer which has the dongle attached.

3. Running Emax under Maxwell

3.1. Processing your data

Load your data into Maxwell as you would normally do.
Display the Line Editor window by doing one of the following;
Either select **Edit and Process Lines** under the **Data/Preferences** pull-down menu (**Figure 4**),
or click the **Line Editing icon** on the toolbar.

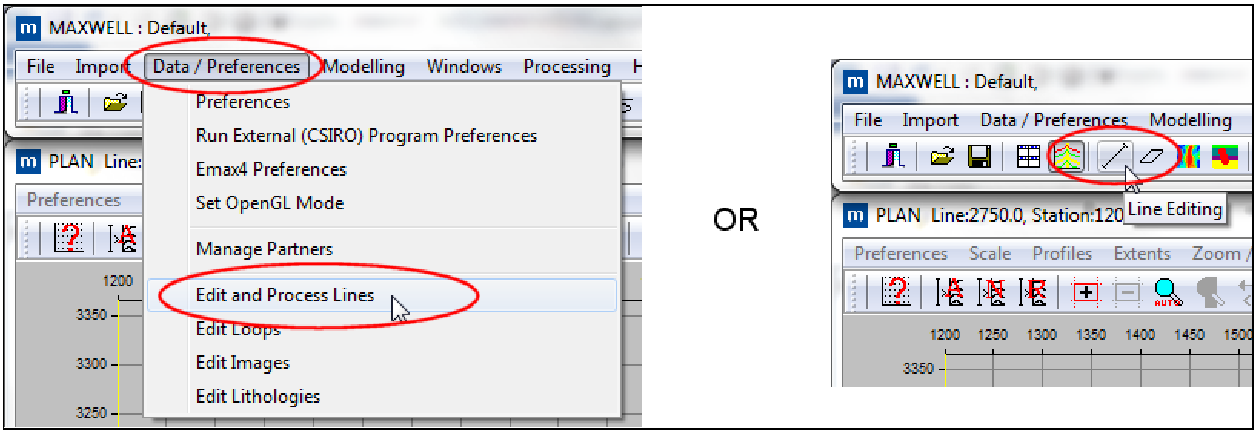

Figure 4 - Starting the Line Editor.

In the Line Editor window (**Figure 5**) select the line or lines you wish to process (yellow highlights).

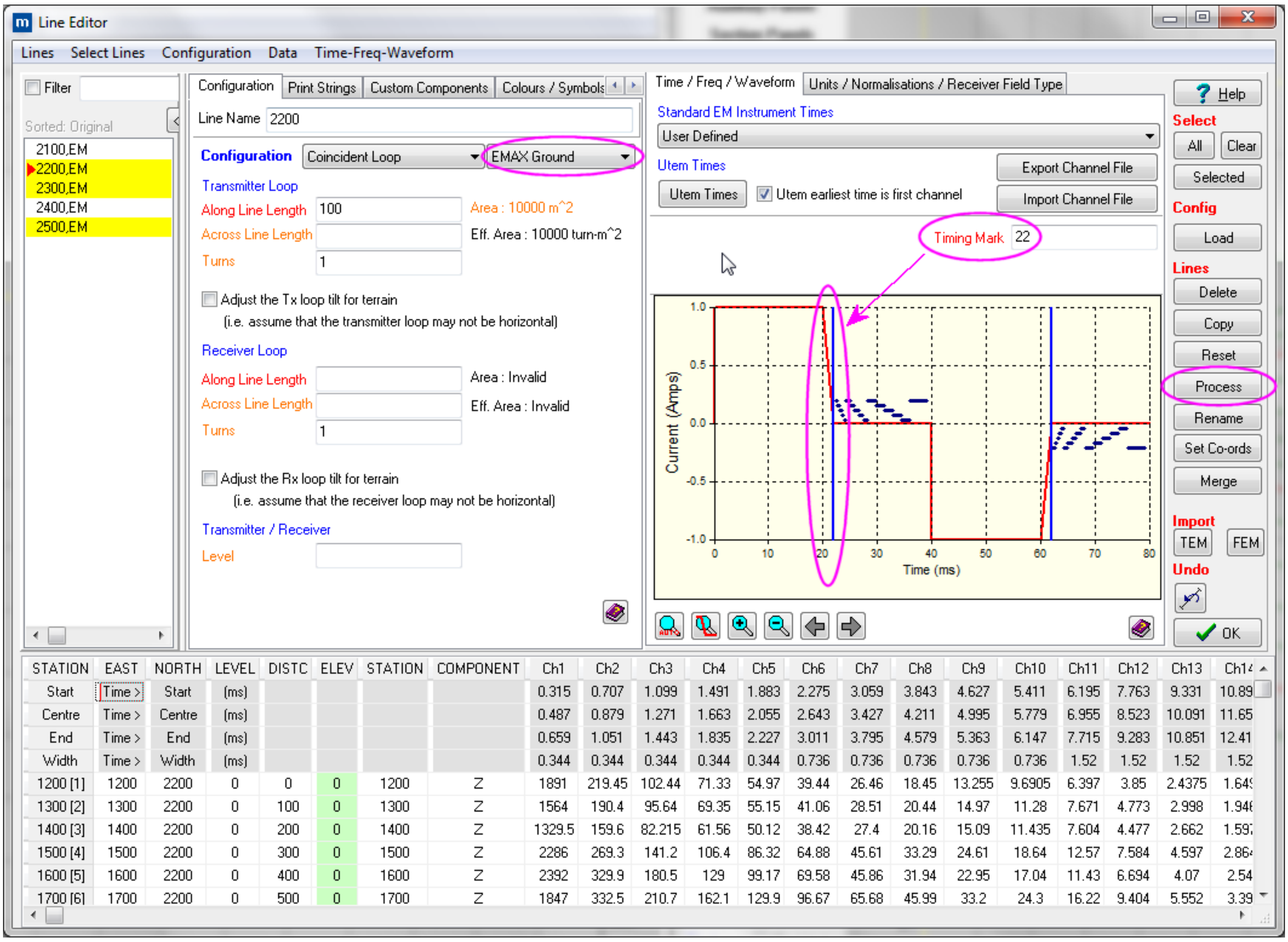

Figure 5 - Line Editor window.

Set the configuration to the correct survey type, and select "EMAX Ground".
Set values for the parameters: those with *red* titles are mandatory, while *orange* are optional and *black* are not relevant.

Set the Waveform parameters and Timing Mark.

- *If the Timing Mark is not located at the end of the Tx off-ramp then Maxwell will adjust the times it uses for Emax processing; in this case if the "Write Input File for Standalone Emax" option has been ticked then the channel times written to that file will be referenced to the end of the Tx off-ramp, not to Maxwell's Timing Mark.*
- *Any channel occurring earlier than the end of the Tx off-ramp will generate a warning because such channels cannot be processed by EMax. The cause might be a timing error in how Maxwell has been set up. However if the channel is a genuine on-time one then it must be deleted from Maxwell before Emax processing can proceed; in this event it is recommended that a working copy of the Maxwell PRJ be used for Emax processing so that the original PRJ retains the on-time channel.*

You should also check the parameters under the "**Units / Normalisations / Receiver Field Type"** tab.

Click the **Process** button when ready to continue.

A Line Processing window should now appear. In the left panel, open the Electromagnetics branch of the navigation tree structure and click on the **EMAX** option (**Figure 6**).

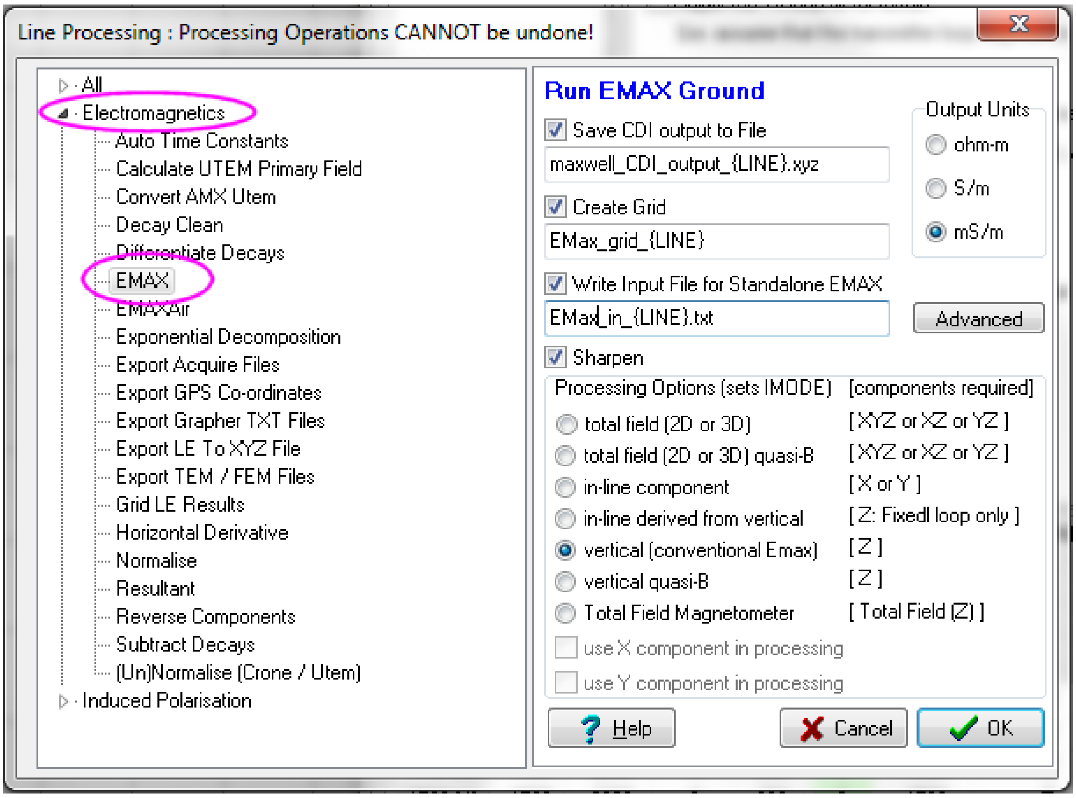

Figure 6 - Selecting basic options for Emax.

To create ASCII files containing the conductivity data generated by the Maxwell run tick the **Save CDI output to File** checkbox.

To create gridded images inside the Maxwell project tick the **Create Grid** checkbox. These grids can subsequently be displayed as images in Maxwell's Section Panels of the Profile Window.

If you want Maxwell to reformat and save files containing Emax input data for stand-alone runs in the future tick the **Write Input File for Stand-alone EMAX** checkbox. There will be one file saved for each survey line processed by Maxwell. The reformatted data will be ready for Emax stand-alone to read. See Section **4** for more information on Emax stand-alone.

The default filename specifications have the line coordinate {LINE} embedded in them. *If you are processing multiple lines but remove {LINE} from a filename specification then all lines will be given the same filename and thus each successive line processed will overwrite the data from the previously processed line. There are other "Character Conversion Strings" apart from {LINE} which can also be used. Click the Help button for more information.*

Choose the preferred **Output Units** for conductivity.

If the **Sharpen** checkbox is ticked then the calculated apparent conductivity curve for each station is internally reprocessed to enhance features prior to output. While sharpening will better define good quality anomalies, for poor or noisy data the sharpening process may accentuate unwanted features. Some trials with and without sharpening are advised before embarking on routine processing of data using this option.

If you want to inspect or change other Emax parameters then click the **Advanced** button. Altering advanced parameters is not recommended for normal processing situations. The advanced parameter window (**Figure 7**) displays read-only parameters at the top; these are determined by Maxwell according to the survey setup and may vary from line to line. Parameters at the bottom can be modified by the user if necessary. *Note that the one set of values will be applied to all lines processed; the << and >> line buttons at the top of this window simply allow you to review which lines are selected for processing*.

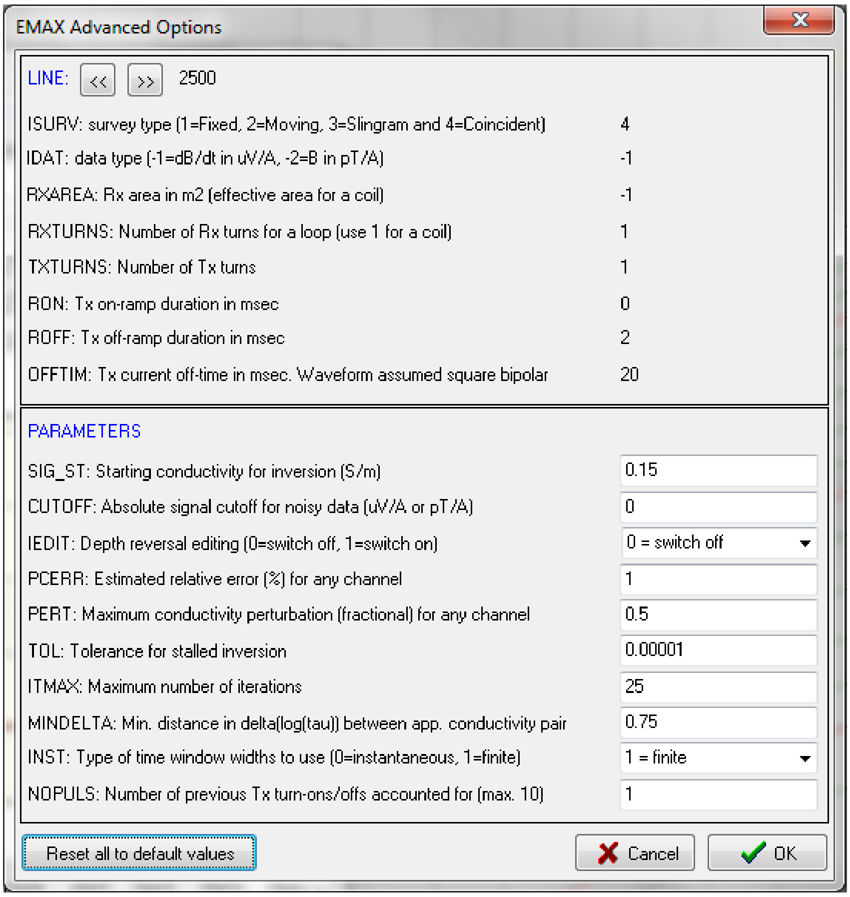

Figure 7 - Selecting advanced options for Emax.

If you have opened the Advanced Options window, click the **OK** button to close it.
Click the **OK** button on the Line Processing window (**Figure 6**) to begin processing the data.

If you ticked the "Create Grid" option in the Line Processing window (**Figure 6**) then a **Grid Setup window** (**Figure 8**) is now displayed.

Unless you need to change parameters, simply click the **OK** button as each line is processed.

If more than one Line is being processed you can change the gridding parameters for individual lines if required, prior to clicking the OK button in each case. The default gridding parameters for any given line will be the same as the values used for the previously processed line. However the coordinate and depth limits will be automatically re-calculated for each grid so setting these in the Grid Setup dialog will not alter the values used for subsequent grids. Typically you will just click OK on each Grid Setup window as it appears and accept the default gridding and coordinate parameters.

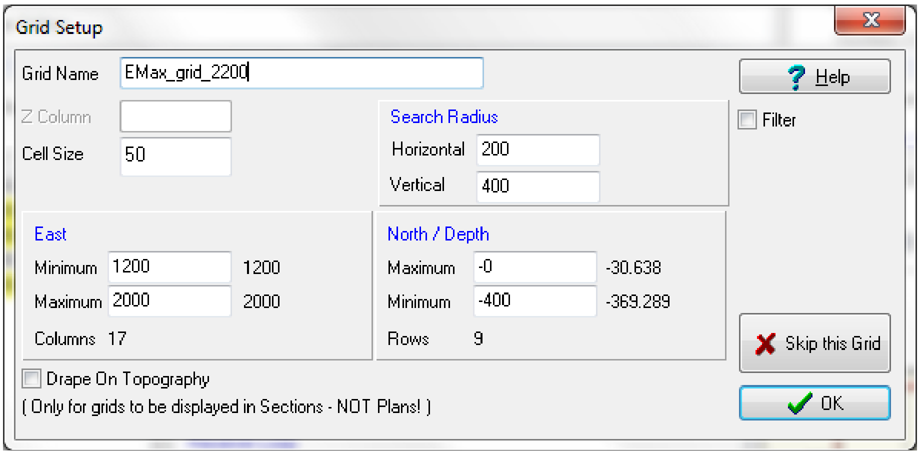

Figure 8 - Grid Setup window.

By default the sections are gridded using depth below surface, with ground surface being 0mRL. You can optionally tick the "Drape On Topography" box so that the defined elevation column is instead used for ground surface (for example if you have station DEM heights or GPS heights recorded in the defined elevation column). Refer to Maxwell Help for more information.

Once processing is completed the Line Editor window (**Figure 5**) is once again active. This Line Editor window can now be closed and the grid(s) displayed in Maxwell's Section Panels.

3.2. Displaying the Emax conductivity section

Near the top of the **Profile Window**'s scrollable Preferences area (if not visible, right-click over the window, and select Show Preferences) select **Section Panels** and tick the **Display This Panel** checkbox (**Figure 9**).

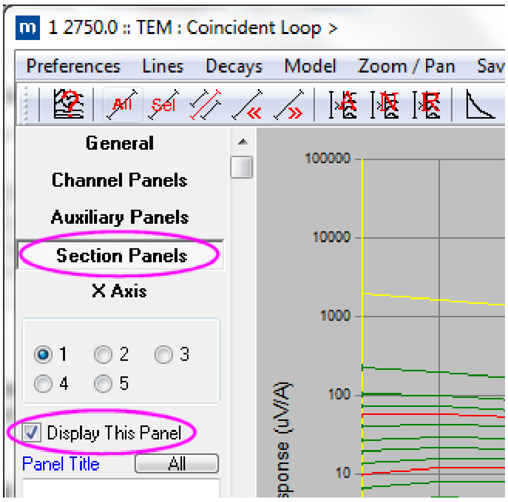

Figure 9 - Profile Window's Preferences area; display a section panel.

Then scroll to the bottom of the Preferences area (**Figure 10**) and click on the **Image** button. A new Profile Image Select window pops up. Select the image to display. Click **OK**.

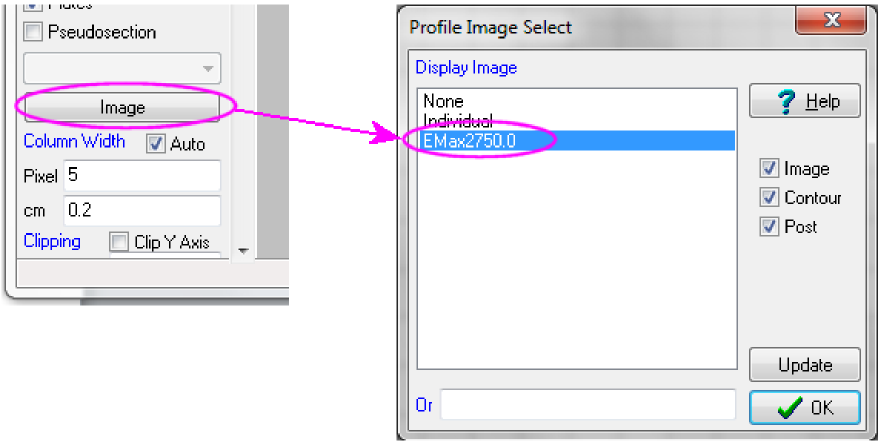

Figure 10 Select image to display in the section panel.

The displayed image (**Figure 11**) is *not necessarily* for the same line of data as the displayed profiles. You should check that the image which you selected for display corresponds to the line for which the profiles are displayed. The line identifier for *profiles* is shown at the top-left corner of the Profile Window. To change the profile line displayed use the **<<** or **>>** button at the top of the window.

Moving the mouse cursor over the image will display position, depth, and conductivity values in the bottom left corner of the Profile Window.

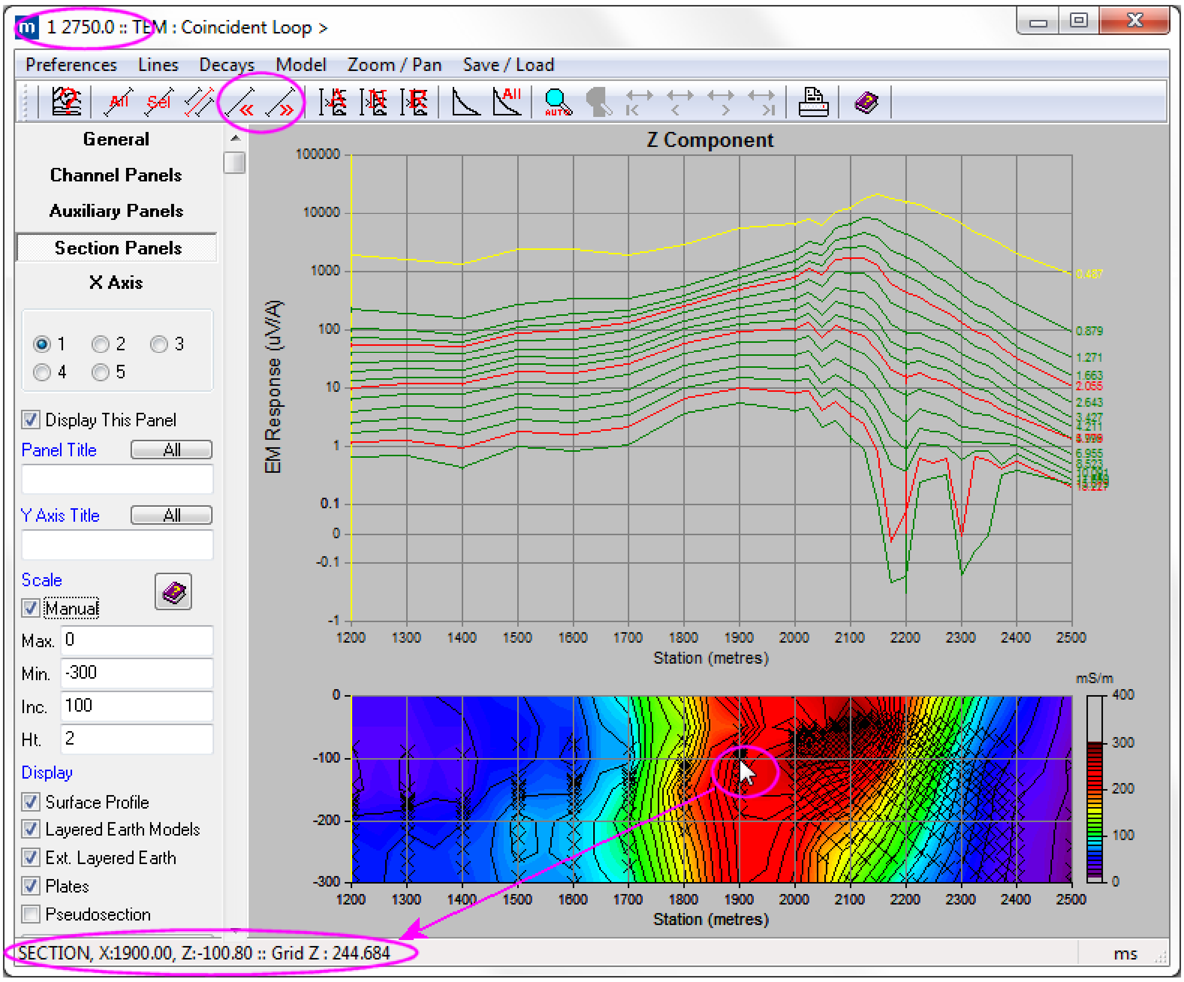

Figure 11 - Profile Window display of Emax conductivity data.

Consult the Maxwell Help and documentation for more information on displaying gridded images in section profiles, including how to use the Maxwell keyword {GRID} to, for example, automatically update the displayed image when changing the displayed line.

3.3. The conductivity output files

If the **Save CDI output to File** checkbox was ticked (**Figure 6**) then for each line processed (**Figure 5**) there will be a separate CDI output file written. An example of this Maxwell output format is shown in **Figure 12**.

East	North	Station	Depth (m)	Conduct or Resist	Time (ms)
1200.0000	2200.0000	1200.0000	-53.2809	254.1682	0.4870
1200.0000	2200.0000	1200.0000	-108.1482	78.1367	0.8790
1200.0000	2200.0000	1200.0000	-131.8097	24.9211	1.2710
1200.0000	2200.0000	1200.0000	-141.2440	85.1814	1.6630
1200.0000	2200.0000	1200.0000	-147.2196	115.6263	2.0550
1200.0000	2200.0000	1200.0000	-155.2302	121.5211	2.6430
1200.0000	2200.0000	1200.0000	-166.5219	111.8419	3.4270
1200.0000	2200.0000	1200.0000	-178.1071	98.7460	4.2110
1200.0000	2200.0000	1200.0000	-189.9486	86.3584	4.9950
1200.0000	2200.0000	1200.0000	-202.6431	75.0216	5.7790
1200.0000	2200.0000	1200.0000	-220.9897	63.7146	6.9550
1200.0000	2200.0000	1200.0000	-246.6216	53.4331	8.5230
1200.0000	2200.0000	1200.0000	-273.0527	44.3336	10.0910
1200.0000	2200.0000	1200.0000	-298.0131	35.9228	11.6590
1200.0000	2200.0000	1200.0000	-325.2747	25.4556	13.2270
1200.0000	2200.0000	1200.0000	-369.2894	12.7971	15.5790
1300.0000	2200.0000	1300.0000	-57.3955	219.4070	0.4870
1300.0000	2200.0000	1300.0000	-113.5411	73.3416	0.8790
1300.0000	2200.0000	1300.0000	-134.9684	40.8687	1.2710
1300.0000	2200.0000	1300.0000	-142.5881	112.2762	1.6630
1300.0000	2200.0000	1300.0000	-147.0576	151.6119	2.0550
1300.0000	2200.0000	1300.0000	-153.1079	158.0257	2.6430
1300.0000	2200.0000	1300.0000	-162.3030	141.6366	3.4270

Figure 12 - Maxwell's CDI conductivity output file *(column headers added for illustration only).*

3.4. Creating reformatted input data files for stand-alone processing

There are a wide variety of input formats which Maxwell will read and these data can be processed using Emax from within Maxwell. However when Emax is run as a stand-alone application (when it is run direct from the command line, outside of Maxwell) it has no ability to read anything except a standardised emax-specific format input file. There are two ways to convert TEM-format files and prepare input data files for Emax stand-alone processing;

(a) As a by-product of running Emax in Maxwell (described below).
(b) By running "TEM2Emax" which is included with the Emax installation (See section **4.6**)

Each time Maxwell processes data with Emax it will ***optionally*** export that data to Emax stand-alone input files, with one survey line per file. This means you are then able to re-run Emax as a stand-alone application without having to manually reformat your data. Note that data is only exported in this format for those lines which you selected to be processed by Emax (**Figure 5**), not the complete input data file which you loaded when you started Maxwell. To create these standardised format input files you need to tick the checkbox named "**Write Input File for Stand-alone Emax**" shown in **Figure 6**.

Processing data by running Emax stand-alone is useful if you want to generate different output formats (eg. formats more suited to using with software such as Geosoft to plot CDI sections). Also, if you want to test different processing parameters most output file formats from stand-alone runs include header records which contain the processing parameters used, program version, and run time for later reference.

See the comments in Section **4** (Running Emax stand-alone) for a description of the Emax stand-alone formats.

4. Running Emax in “stand-alone” mode

Emax can be run as a stand-alone application from the command line. The only limitation is that input data must be available in an Emax stand-alone input data format file. As described above, Maxwell can be used as an easy way to reformat a wide variety of raw TEM data formats into this stand-alone format.

- Emax version 4 saw the introduction of a completely new stand-alone input format. Earlier versions of Emax used a complex “v2” format that was difficult to edit in a text editor. The “v4” data format is similar in structure to the familiar TEM format used by Maxwell, and is easy to edit in a text editor that has column editing capability (for example TextPad from www.textpad.com and similar).

- For backward compatibility purposes the Emax setup includes a free program that will reformat the old “v2” Emax input files to the newer “v4” format.

4.1. Input data format

A sample of the Emax “v4” stand-alone input data format is shown in **Figure 13**.

For Total Field Magnetometer (“**Samson**”; IMODE=3) data there are three additional parameters required on record 3, plus *two additional data columns*.

For dual loop (“**Infinitem**”; IMODE=4) data there are two additional parameters required on record 3.

For **UTEM** (IMODE=5) data there are *two additional data columns*.

Record 1 : The first record is a comment of your choice.

Record 2 : This indicates the version of the input file format. It should always be “EMAXv4”.

Record 3 : Parameters used by Emax. Format is **keyword1:value1 keyword2:value2 …** . A colon separates the keyword and its value, with space separators between successive keywords. Keywords are not case sensitive and can be in any order. *Parameters are explained in Section **4.5** below.*

Record 4 : Channel times in milliseconds (measured from the *end* of the Tx off-ramp; i.e. from the cessation of current). The equals sign tells Emax where to start reading the times from on the record, thus any characters preceding the equals sign are ignored. This record can be copied without modification from a Maxwell TEM format file if desired.

Normally channel 1 is early time, however for **UTEM** channel 1 is **late time** not early time.

Record 5 : Channel widths in milliseconds. The equals sign tells Emax where to start reading the widths from on the record, thus any characters preceding the equals sign are ignored. This record can also be copied without modification from a Maxwell TEM format file if desired.

Record 6 : Data column names.
The Tx loop must have 4 vertices defined, no more and no less.
Approximate the actual loop shape if necessary.
Loops must be square or rectangular.
These names must be in upper case and in a *fixed order* as follows;

```
LV1X      X-coordinate for Tx loop vertex 1
LV2X      X-coordinate for Tx loop vertex 2
LV3X      X-coordinate for Tx loop vertex 3
LV4X      X-coordinate for Tx loop vertex 4
LV1Y      Y-coordinate for Tx loop vertex 1
LV2Y      Y-coordinate for Tx loop vertex 2
LV3Y      Y-coordinate for Tx loop vertex 3
LV4Y      Y-coordinate for Tx loop vertex 4
LV1Z      Z-coordinate for Tx loop vertex 1
```

```
LV2Z        Z-coordinate for Tx loop vertex 2
LV3Z        Z-coordinate for Tx loop vertex 3
LV4Z        Z-coordinate for Tx loop vertex 4
RXX        X-coordinate for Rx
RXY        Y-coordinate for Rx
RXZ        Z-coordinate for Rx
CMP         Component ("X" or "Y" or "Z")
NCH         Number of channels on record
TXI        for IMODE=3 only (Samson): Tx current (amps).
V_P        for IMODE=3 only (Samson): not used at present; set to 1.
HTOTAL       for IMODE=5 only (UTEM): total B-field magnitude (nT/A)
HSENSOR      for IMODE=5 only (UTEM): not used at present; set to 1.
CH1         Channel 1 signal
CH2         Channel 2 signal
CH3         Channel 3 signal
...etc...
```

Record 7+ : Data records in units of uV/A or pT/A. Columns must be in the fixed order listed above.
At present, data records must be sorted on;
either COMPONENT then RX COORDINATE
or RX COORDINATE then COMPONENT

```
Converted from Emax v2 input data file : samp_c_v2_in.dat
EMAXv4
OutputFmt:7 MaxArrayChan:0 ncx:1 ncy:1 ron:0.00 roff:0.0 txturns:1 rxturns:1 ntimmax:16 isurv:4 rxarea:10000.00000 pce
/TIMES(ms)=0.48700 0.87900 1.27100 1.66300 2.05500 2.64300 3.42700 4.21100 4.99500 5.77900 6.95500 8.52300 10.09100 11
/TIMESWIDTH(ms)=0.34400 0.34400 0.34400 0.34400 0.34400 0.73600 0.73600 0.73600 0.73600 0.73600 1.52000 1.52000 1.5200
LV1X   LV2X   LV3X   LV4X   LV1Y   LV2Y   LV3Y   LV4Y   LV1Z   LV2Z   LV3Z   LV4Z   RXX   RXY   RXZ   CMP   NCH   CH1   CH2   CH3   CH4   C
1150.00 1250.00 1250.00 1150.00 2800.00 2800.00 2700.00 2700.00 0.00 0.00 0.00 0.00 1200.000 2750.000 0.00 Z 16 1891 2
1250.00 1250.00 1350.00 1350.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1300.000 2750.000 0.00 Z 16 1564 1
1350.00 1350.00 1450.00 1450.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1400.000 2750.000 0.00 Z 16 1329.5
1450.00 1450.00 1550.00 1550.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1500.000 2750.000 0.00 Z 16 2286 2
1550.00 1550.00 1650.00 1650.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1600.000 2750.000 0.00 Z 16 2392 3
1650.00 1650.00 1750.00 1750.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1700.000 2750.000 0.00 Z 16 1847 3
1750.00 1750.00 1850.00 1850.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1800.000 2750.000 0.00 Z 16 2852 5
1850.00 1850.00 1950.00 1950.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 1900.000 2750.000 0.00 Z 16 5362.5
1950.00 1950.00 2050.00 2050.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2000.000 2750.000 0.00 Z 16 6363 2
1975.00 1975.00 2075.00 2075.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2025.000 2750.000 0.00 Z 16 7757 3
2000.00 2000.00 2100.00 2100.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2050.000 2750.000 0.00 Z 16 6011 2
2025.00 2025.00 2125.00 2125.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2075.000 2750.000 0.00 Z 16 10410
2050.00 2050.00 2150.00 2150.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2100.000 2750.000 0.00 Z 16 12410
2075.00 2075.00 2175.00 2175.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2125.000 2750.000 0.00 Z 16 17980
2100.00 2100.00 2200.00 2200.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2150.000 2750.000 0.00 Z 16 20380
2125.00 2125.00 2225.00 2225.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2175.000 2750.000 0.00 Z 16 17090
2150.00 2150.00 2250.00 2250.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2200.000 2750.000 0.00 Z 16 15385
2175.00 2175.00 2275.00 2275.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2225.000 2750.000 0.00 Z 16 13660
2200.00 2200.00 2300.00 2300.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2250.000 2750.000 0.00 Z 16 10730
2225.00 2225.00 2325.00 2325.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2275.000 2750.000 0.00 Z 16 8743 1
2250.00 2250.00 2350.00 2350.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2300.000 2750.000 0.00 Z 16 6323 1
2275.00 2275.00 2375.00 2375.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2325.000 2750.000 0.00 Z 16 4458 6
2300.00 2300.00 2400.00 2400.00 2700.00 2800.00 2800.00 2700.00 0.00 0.00 0.00 0.00 2350.000 2750.000 0.00 Z 16 3858 5
```

Figure 13 - Emax version 4 Stand-alone input format.

Emax stand-alone is designed to process one survey line per input file. Lines are assumed to be straight but can be at any bearing. ***You must not have more than one survey line per input file.***

- If you need to convert an old Emax input format data file to the new version 4 format you can run **Emax_convert_data_v2_v4.exe** found in the Emax program files folder.

4.2. Repeat stations and NULL readings

Repeats : Emax generally assumes that the data in the input file is free of repeat stations. It is recommended that the user inspect and prepare data prior to processing. This may entail deleting bad data (either single channels or whole stations) and averaging any remaining repeats. Much of this preparation and averaging may be done with software like Maxwell.

If the data to be processed is only a *single-component* (eg. coincident loop Z-component data) then Emax will still be able to process repeat stations correctly but there will be a corresponding number of repeat stations output on the CDI data file.

However if the data to be processed is *multi-component* (eg. total field) then Emax requires the data to be properly prepared. *No repeat stations allowed*. Each station must have one of each of the required components.

Nulls : You may delete individual channel(s) from a station due to noisy data or some other reason. A deleted channel value should be replaced by a NULL value that Emax recognizes. There are two options for setting NULL values and these can be used interchangeably or mixed; either –9 999 999 (integer) or any large negative value less than or equal to –1.0e+30 (scientific notation is accepted by Emax). The latter value is used to trap Maxwell-generated null values that are usually "-99999999999999994560000000000000".

4.3. Fixed Loop Input Data for Multiple Tx Loops

For fixed loop data, any single Emax input file can only contain data for ***one* Tx loop**.
If you mix data from different Tx loops, Emax will detect this as an error and stop.

Where multiple fixed Tx loops are used along a single survey line, and the requirement is to produce a single conductivity-depth section for the whole line, the data for individual fixed loops should be processed in separate Emax runs. The output files can then be concatenated into a single file which is edited and sorted on Rx coordinate in preparation for plotting.

4.4. Dual loop ("Infinitem") parameters

In dual loop mode, two identical transmitter loops are laid out, separated by some offset. Current flows anti-clockwise in one loop (the positive loop) and clockwise in the other loop (the negative loop). *The Tx coordinates in the data file refer to the positive loop*.

XOFF is the offset between the loop centres in the local X direction; YOFF is the offset between the loop centres in the local Y direction. If XOFF > 0 then YOFF = 0, and vice versa; ie. the "negative loop" can only be offset in the local X or the local Y direction, not in both directions simultaneously.

The local X direction is the direction from the 1st Tx loop vertex to the 2nd Tx loop vertex, as defined in the data file. When looking in the local X direction, the local Y direction is to the left.

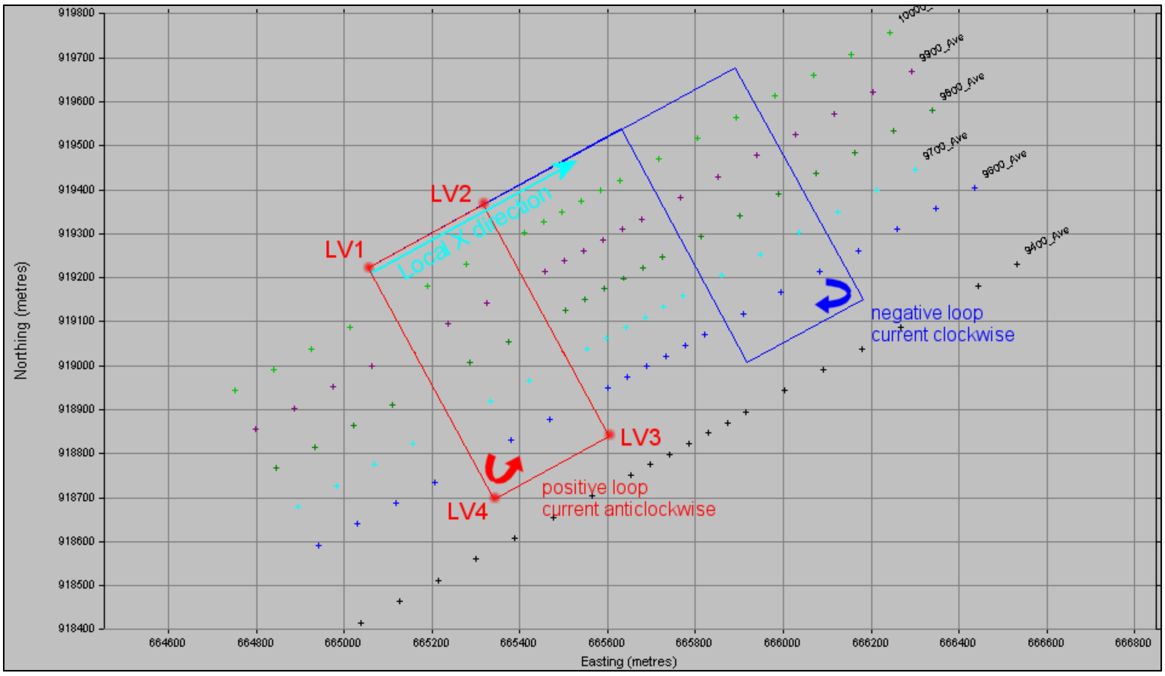

Figure 14 - Dual loop ("Infinitem") TEM example survey layout.

4.5. Input parameters

The following **Table 1** briefly explains the input parameters contained on Record 3 of the input data file (refer to **Figure 13**).

Valid combinations of IMODE and IDAT parameters are shown in **Table 2**.

Keyword	***Description*** Any new functionality since the previous documentation is highlighted in green
OutputFmt	Used to control which set of output formats are created. Set the value of the OutputFmt flag as follows; option A, flag = 1 : Geosoft Line XYZ format – with line headers for each new station option B, flag = 2 : Flat ASCII format – automatic output filename extension "**.FLA**" option C, flag = 4 : Geosoft Array format – automatic output filename extension "**.ARR**" Set OutputFmt equal to the *sum of the flags* that correspond to the output formats required. For example, to output two files in formats **A** and **C** set OutputFmt to a value of 1 + 4 = **5** In addition to the above 3 formats, a "**.CDI**" format is always output. To output *only* the **".CDI"** format file, not any of the other formats, set OutputFmt = 0.
MaxArrayChan	Maximum number of channels output to Geosoft Array format files (OutputFmt option C). Normally set this to 0 which outputs the same number of channels as read from input. In some situations you may want to concatenate output files from different runs of Emax. If you concatenate array format files having differing array sizes then the new file will be unusable. Setting this parameter to a positive value will force all stations to write the same number of values to the output array file and thus concatenating several files will produce a valid new file. For stations with more channels than MaxArrayChan the excess channels' output values are lost. For stations with less channels than MaxArrayChan the remaining missing channels are filled with dummies (asterisks).
ncx ncy	Some processing options (see IMODE & IDAT) can utilize X and/or Y component data. Set NCX to 1 if the X-component data is to be used in these options, else set NCX to 0. Set NCY to 1 if the Y-component data is to be used in these options, else set NCY to 0. For Infinitem processing (IMODE=4): if NCX = -1 or if NCY = -1 then the z-component is ignored; if NCX = -1 then NCY can be zero and |Bx| is inverted, likewise if NCY = -1 then NCX can be zero and |By| is inverted.
Ron	Tx turn-on ramp duration (milliseconds). *At present this parameter is not used by Emax so can always be set to 0.*
Roff	Tx turn-off ramp duration (milliseconds).
Txturns	Number of turns in Tx loop.
Rxturns	Number of turns in Rx loop. Ignored for B-field data (IDAT = -2)
ntimmax	Maximum number of channel delay times for any station in the input data.

Isurv	Survey type 1 = fixed loop 2 = moving in-loop 3 = Slingram [coil Rx] 4 = coincident loop
rxarea	Rx area (m^2). For a loop this is the actual area (length x width) (set rxturns to the actual number of turns). For a coil this is the effective area (actual area x turns) (set rxturns = 1).
pcerr	Maximum error (%) for any channel.
pert	Maximum conductivity perturbation (%) for any channel.
tol	Tolerance for stalled inversion.
cutoff	Absolute voltage cutoff (uV/A or pT/A) for noisy data.
itmax	Maximum number of iterations for any channel.
sig_st	Starting conductivity for inversion for any channel.
mindelta	cutoff value of *delta[log(tau)]* used to reject “unreliable” apparent conductivities.
inst	Finite window widths or instantaneous. 1 = finite Rx widths 0 = instantaneous data
nopuls	Number of previous Tx turn-on/off’s accounted for when calculating voltage response. Set to 1 for single step turn-off. Maximum is 10. *Use 1 unless you need a higher value.*
offtim	Tx current offtime (ms). This is the time between the end Tx off ramp until the beginning of the next on ramp. Waveform is assumed to be square bipolar.
sharpen	Apply sharpening enhancement. 0 = no 1 = yes, standard sharpening original apparent conductivities are treated like conductances, and are differentiated to produce a final "sharpened" apparent conductivity section. 11 = yes, alternative sharpening A modified version of standard sharpening. This is similar to the "normal" sharpening option, isharp=1, but it is often able to better handle some of the nearer-surface artefacts that can sometimes occur when Emax cannot find solutions for some of the earliest channels. 2 = yes, C-sharpening (required keyword “num_split”) original apparent conductivities are treated like inner products of the true conductivity with the linear sensitivity functions of Christensen (2002). A simple inversion yields a "C-sharpened" estimate of true conductivity vs. depth. *See section 5.3 for more information on sharpening.*

num_split	The number of extra layers to be inserted between the ground surface and the depth assigned to the earliest processed channel. Normally a maximum value of 10 is allowed, however on rare occasions if there is a special reason to use a value greater than 10 then specify it as negative rather than positive. Required when using C-sharpening (sharpen=2).
idat	Input data type. -1 = dB/dt (uV/A) -2 = Bfield (pT/A) *See also the table below explaining valid IMODE and IDAT combinations.*
imode	Defines quantities to be processed. 0 = total field 1 = measured along-line component 12 = along-line component estimated from vertical component via Hilbert transform 2 = measured vertical component 20 = quasi-Bz (derived from dBz/dt) 22 = simultaneous processing of dBz/dt and quasi-Bz 3 = total field magnetometer ("Samson") data 4 = dual loop ("Infinitem") data 5 = UTEM data *See also the table below explaining valid IMODE and IDAT combinations.*
ledit	Control editing of depth reversals in the output data. 0 = no editing 1 = depth reversals are removed
dec	geomagnetic declination (degrees clockwise from grid north) [**Samson** data only: imode=3]
inc	geomagnetic inclination (degrees; negative in S hemisphere) [**Samson** data only: imode=3]
amb	geomagnetic ambient field intensity (nT) [**Samson** data only: imode=3]
xoff	Distance between Tx loop centres (m) in local X direction [**Infinitem** data only: imode=4]
yoff	Distance between Tx loop centres (m) in local Y direction [**Infinitem** data only: imode=4]
depthrl	0 = output CDI depths as depth-below-surface. 1 = output CDI depths as RL (relative level). *To output depths as RL values you will need to have topographic heights in the RXZ data column (Z-coordinate for Rx).*

Table 1 – input file header record parameters.

The following table lists the valid combinations of IMODE and IDAT parameters.
Some are only valid for particular survey types (ISURV).
“Bi” or “dBi/dt” denotes the in-line component

IMODE	IDAT	Description	Input	ISURV
0	-1	Total dB/dt	(dBi/dt,dBz/dt) or (dBx/dt,dBy/dt,dBz/dt)	1, 2, 3
0	-2	Total B-field	(Bi,Bz) or (Bx,By,Bz)	1, 2, 3
0	-3	Total quasi-B	(dBi/dt,dBz/dt) or (dBx/dt,dBy/dt,dBz/dt)	1, 2, 3
1	-1	In-line dB/dt only	dBx/dt or dBy/dt	1
1	-2	In-line B-field only	Bx or By	1
12	-1	In-line dB/dt derived from dBz/dt (fixed loop)	dBz/dt	1
2	-1	Vertical component dB/dt only	dBz/dt	1, 2, 3, 4
2	-2	Vertical component B only	Bz	1, 2, 3
20	-3	Vertical component quasi-B only	dBz/dt	1, 2, 3, 4
22	-1	Vertical dB/dt and quasi-B together	dBz/dt	1, 2, 3, 4
3	-2	total field magnetometer (“**Samson**”) data	nominally Bz (Maxwell convention)	1, 2, 3
4	-2	“**Infinitem**”	Bi or (Bi, Bz) or (Bx, By, Bz)	1
5	2	**UTEM**	Bz (%)	1

Table 2 – input file header record parameters.

4.6. Preparing Emax input files *without* using Maxwell

Two tools are provided to help prepare and process TEM-format input files without the need to pre-process them through Maxwell first in order to create Emax input files for stand-alone runs of EMax.

EMax itself will only process Single-Line TEM files.
You can use these tools to reformat MULTI-Line TEM files into Single-Line TEM files, and as part of that processing it will create BAT files which will run all of the Single-Line TEM files through Emax automatically.

TEM_multi.exe

command line usage: TEM_multi MyData_multi_line.tem

This tool will split a multi-line TEM file into multiple single-line TEM files.
It also creates 3 sets of BAT files that can then be used to process all lines at once;

- _GO_run1_TEM2Emax*.BAT - converts all single-line TEM files into Emax input files.
- _GO_run2_Emax*.BAT - runs Emax for all the newly created Emax input files.
- _GO_run3_TEM2Mom*.BAT - [***see note***] runs TEM2Mom for all the newly created single-line TEM files.

There are two variants of each BAT file, one that pauses after each single-line file is processed to allow you to review output messages before continuing, and another that processes all single line files without pausing.

Note that there are a huge number of TEM file format variants possible and these tools are intended to handle the more common of those variants. Some less common TEM format variants may not process, so if you encounter any problems please let us know and we will try to find a solution or a workaround.

TEM2Emax.exe

command line usage: TEM2Emax MyData_single_line.tem

This converts a single-line TEM file into an Emax input file format.
It is recommended that you check the keyword parameters in the header line of the Emax input files created. In some cases you may need to add or change some parameters to produce the type of Emax processing you want. Generally the keyword parameters header line will be the same in all output files, so once you have edited one file you can copy & paste that line into all of the other output files.

The sample files provided

After running "TEM_multi.exe", the subsequent processing can all be done in the same folder by simply running the appropriate BAT files in sequence. The result of doing this is shown in the Emax Program Files folder "example_run__all_in_one_folder".

For clarity, the supplied example runs using these tools have also been provided in three separate folders;

(a) "example_run__TEM_multi" - the initial processing run of the multi-line TEM file by "TEM_multi.exe"
(b) "example_run__TEM2Emax" - the TEM2Emax reformatting run, after copying the BAT and TEM files into here from (a).
(c) "example_run__TEM2mom" - [***see note***] the TEM2Mom processing after copying the BAT and TEM files from (a).

note
TEM2Mom.exe is part of the VPem3D inversion application and is licensed separately to Emax.
You will not have access to TEM2Mom unless you have VPem3D installed.

4.7. Starting Emax

From a command window run the **Emax** executable (**Figure 15**).

Give the name of your input data file. A default name is shown in square brackets and can be accepted by just hitting the enter key.

Give your desired output file name. A default is again provided. If the file chosen already exists then you will be prompted to either confirm replacement of the old file, or asked for a different filename instead.

Figure 15 - Emax run as stand-alone.

4.8. The conductivity output files

Emax has three *optional* output formats. The setting of parameter OutputFmt determines which of these are actually written. Any combination of these three can be written simultaneously. OutputFmt is set to the ***sum of the flags*** corresponding to the output format(s) required. Each file contains data for only the one survey line being processed. In addition to the above 3 formats, a *.**CDI**" format is always output.

The three *optional* output formats (A, B, C) are:

(a) **Output option A, flag = 1 : Geosoft Line XYZ format**

This format is consistent with a Geosoft XYZ format containing "Line header" records.

Data for each station comprises a "Line" record and numerous data records containing the conductivity and depth data for that station. An example is illustrated in **Figure 16**. The **Table 3** following describes the items in these records. The output filename is specified by the user when Emax is started.

Each "Line header" marks the start of a set of conductivity-depth solutions at a *single station*. The Line headers facilitate the use of spline-gridding whereby the series of TEM channels at a station can be processed as a "line" of data for gridding purposes. These line headers *do not represent survey lines on the ground*.

In the output file the "*position*" column is the default surface position for plotting data. This gives the most active Rx ordinate thus allowing the user to cross-reference it against Rx coordinates on the input file. One disadvantage of using this column for plotting the CDI data is that surface distances are not necessarily true (eg. if lines are not oriented EW or NS). As an alternative the "*distance*" column can be used; this gives the true distance of each Rx from the start of its survey line. In addition the Tx-Rx "*midpoint*" (E,N coordinate) is also included as this may be used instead of the Rx position for separated loop geometries; this is likely to be the case with Slingram data.

```
/ EMax v5.10a (Jul 2015)
/ Run date and time : 20160506 162122.477
/ COMMENT: Converted from Emax v2 input data file : samp_c_v2_in.dat
/ Processing parameters used;
/ ISURV                 4
/ RXAREA       10000.0000
/ PCERR            1.0000
/ PERT             0.2000
/ TOL        0.0000100000
/ CUTOFF     0.0000000000
/ ITMAX              1000
/ SIG_ST     0.1500000060
/ MINDELTA         0.7500
/ INST                  0
/ NOPULS                1
/ OFFTIM          20.0000
/ Sharpen               0
/ IDAT                 -1
/ IMODE                 2
/ IEDIT                 0
/ RON              0.0000
/ ROFF             0.0000
/ TXTURNS               1
/ RXTURNS               1
/ NTIMMAX              16
/ MAXARRAYCHAN          0
/ OUTPUTFMT             7
/ NCX                   1
/ NCY                   1
/ DEPTHRL               0
/ -------------------------------------------------
/ This file format is consistent with Geosoft XYZ.
/ "Line" headers refer to STATIONS on the current survey line, NOT actual survey lines.
/ There should be NSTN Line headers in this file.
/ There are "count" records per station.
/ Data columns are ;
/ Position  Depth   Conduct_mS_per_m  Time_ms  East  North  count  midpoint_E  midpoint_N  Distance_from_start  uV_pe
/ X          Y      Conduct_mS_per_m  Time_ms  East  North  count  midpoint_E  midpoint_N  Distance_from_start  uV_pe
Line _samp_c_v4_in_00001
   1200.000     -81.30207       36.28514      0.4870000      1200.000       2750.000             16    1200.000
   1200.000     -140.5139       22.06356      0.8790000      1200.000       2750.000             16    1200.000
   1200.000     -160.5744       24.41273       1.271000      1200.000       2750.000             16    1200.000
   1200.000     -165.8037       29.98568       1.663000      1200.000       2750.000             16    1200.000
   1200.000     -168.6071       35.84605       2.055000      1200.000       2750.000             16    1200.000
```

Figure 16 - Emax (stand-alone) conductivity output file example - Geosoft Line XYZ format.

name	***record type***	***description***
Line *(_name_N)*	1	A Geosoft Line Header is used to mark the start of each new *station's* data: "*name*" is the main part of the input filename. "*N*" is a sequential number beginning at 1. Note that this "*Line*" is ***not*** an original field survey line on the surface but instead represents a single Rx station whose solutions form a vertical "line" on the CDI section; this facilitates spline gridding the CDI data with Geosoft "bigrid".
position	2 there are **COUNT** repeats of this record type for the station.	Position along the survey line; the most active Rx coordinate. (Geosoft uses this as "X"). Note: *not true* distance for angled lines.
depth		Depth attributed in section to the measurement point : negative is down. (Geosoft uses this as "Y").
conduct		Conductivity attributed to the measurement point (mS/m). (Geosoft uses this as "Z").
time		Delay time (ms).
east		Rx easting.
north		Rx northing.
COUNT		The number of type 2 records for this station.
midpoint E		Easting coordinate of Tx-Rx midpoint.
midpoint N		Northing coordinate of Tx-Rx midpoint.
distance		Distance along line from start of line.
original signal		uV/A or pT/A signal as on input data file.

Table 3 – Emax (stand-alone) conductivity output file structure OPTION A - Geosoft Line XYZ format.

(b) **Output option B, flag = 2 : Flat ASCII format**

This is a "flat" ASCII format comprising data columns
X, Y, Depth, Conductivity, Time, Midpoint E, Midpoint N.

The output filename is as specified by the user when Emax is started, but has a "**.FLA**" extension.

```
/ East         North          Depth     Conductivity     Time       midpoint_E  midpoint_N
   1200.000       2750.000       -81.30207      36.28514     0.4870000      1200.000      2750.000
   1200.000       2750.000       -140.5139      22.06356     0.8790000      1200.000      2750.000
   1200.000       2750.000       -160.5744      24.41273      1.271000      1200.000      2750.000
   1200.000       2750.000       -165.8037      29.98568      1.663000      1200.000      2750.000
   1200.000       2750.000       -168.6071      35.84605      2.055000      1200.000      2750.000
   1200.000       2750.000       -173.2927      43.65948      2.643000      1200.000      2750.000
   1200.000       2750.000       -181.6633      51.51482      3.427000      1200.000      2750.000
   1200.000       2750.000       -191.4040      57.02207      4.211000      1200.000      2750.000
   1200.000       2750.000       -202.1028      60.71737      4.995000      1200.000      2750.000
   1200.000       2750.000       -213.9489      62.75079      5.779000      1200.000      2750.000
   1200.000       2750.000       -231.1941      64.68532      6.955000      1200.000      2750.000
   1200.000       2750.000       -255.9038      64.60194      8.523000      1200.000      2750.000
   1200.000       2750.000       -281.9152      63.03596      10.09100      1200.000      2750.000
   1200.000       2750.000       -306.3614      61.74363      11.65900      1200.000      2750.000
   1200.000       2750.000       -333.1536      59.09005      13.22700      1200.000      2750.000
   1200.000       2750.000       -377.0169      54.21043      15.57900      1200.000      2750.000
   1300.000       2750.000       -87.01179      31.69564     0.4870000      1300.000      2750.000
   1300.000       2750.000       -147.3889      20.02703     0.8790000      1300.000      2750.000
   1300.000       2750.000       -164.4157      23.30082      1.271000      1300.000      2750.000
   1300.000       2750.000       -167.4138      29.41872      1.663000      1300.000      2750.000
   1300.000       2750.000       -168.4184      35.92558      2.055000      1300.000      2750.000
   1300.000       2750.000       -170.9343      44.86633      2.643000      1300.000      2750.000
```

Figure 17 - Emax (stand-alone) conductivity output file example – Flat ASCII format.

(c) **Output option C, flag = 4 : Geosoft Array format**

This format is consistent with Geosoft Array format.

Data columns comprise

X, Y, Distance from start of survey line, Midpoint E, Midpoint N

followed by three grouped values for

Depth, then Conductivity, and then Delay Time.

Each of the three groups contains the same number of array elements, with missing values represented by dummies (asterisks). Each group can be loaded into a Geosoft database as an array channel.

```
/ --------------------------------------------
/ The format of this file is consistent with Geosoft ASCII import of ARRAY CHANNELs.
/ Data columns are;
/          1            2            3            4            5           6           7           8           9          10
        EAST        NORTH     DISTANCE   midpoint_E   midpoint_N      Depth1      Depth2      Depth3      Depth4      Depth5
     1200.00      2750.00         0.00      1200.00      2750.00      -81.30     -140.51     -160.57     -165.80     -168.61
     1300.00      2750.00       100.00      1300.00      2750.00      -87.01     -147.39     -164.42     -167.41     -168.42
     1400.00      2750.00       200.00      1400.00      2750.00      -92.10     -156.51     -173.15     -174.36     -174.00
     1500.00      2750.00       300.00      1500.00      2750.00      -75.80     -131.02     -143.97     -144.65     -144.53
     1600.00      2750.00       400.00      1600.00      2750.00      -74.54     -122.05           *           *           *
     1700.00      2750.00       500.00      1700.00      2750.00      -82.00     -121.71           *           *           *
     1800.00      2750.00       600.00      1800.00      2750.00      -69.89           *           *           *           *
     1900.00      2750.00       700.00      1900.00      2750.00      -54.85      -80.44      -80.06      -79.64      -80.18
     2000.00      2750.00       800.00      2000.00      2750.00      -51.27      -61.83      -62.44      -63.95      -66.13
     2025.00      2750.00       825.00      2025.00      2750.00      -47.32      -53.43      -54.13      -55.80      -58.04
     2050.00      2750.00       850.00      2050.00      2750.00      -52.44      -55.72      -57.33      -60.09      -63.56
     2075.00      2750.00       875.00      2075.00      2750.00      -41.68      -43.02      -44.51      -47.17      -50.41
     2100.00      2750.00       900.00      2100.00      2750.00      -38.44      -39.76      -42.28           *           *
     2125.00      2750.00       925.00      2125.00      2750.00      -31.92      -35.03      -39.30      -44.23      -49.38
     2150.00      2750.00       950.00      2150.00      2750.00      -29.86      -36.01      -42.58      -49.32      -56.13
     2175.00      2750.00       975.00      2175.00      2750.00      -32.77      -42.83      -52.63      -62.74      -73.10
```

Figure 18 - Emax (stand-alone) conductivity output file example – Geosoft Array format.

(d) **The *.CDI format**

This format is always output.
Most columns are self-explanatory.
The "ITERCS" values are only relevant for C-sharpened output (sharpen=2).

/LINE	X	Y	DIST	DEPTH	CONDUCT	RL	TIME	ALT	DTM(RxZ)	ITERCS
0	1200.00	2750.00	0.00	-10.16	100.79	-10.16	0.487	0.00	0.00	6
0	1200.00	2750.00	0.00	-30.49	0.00	-30.49	0.487	0.00	0.00	6
0	1200.00	2750.00	0.00	-50.81	0.00	-50.81	0.487	0.00	0.00	6
0	1200.00	2750.00	0.00	-71.14	0.00	-71.14	0.487	0.00	0.00	6
0	1200.00	2750.00	0.00	-91.46	0.00	-91.46	0.487	0.00	0.00	6
0	1200.00	2750.00	0.00	-124.28	0.00	-124.28	0.879	0.00	0.00	6
0	1200.00	2750.00	0.00	-163.81	97.15	-163.81	1.271	0.00	0.00	6
0	1200.00	2750.00	0.00	-193.76	285.15	-193.76	1.663	0.00	0.00	6
0	1200.00	2750.00	0.00	-230.25	188.86	-230.25	2.643	0.00	0.00	6
0	1200.00	2750.00	0.00	-279.22	73.40	-279.22	4.211	0.00	0.00	6
0	1200.00	2750.00	0.00	-337.40	0.00	-337.40	6.955	0.00	0.00	6
0	1200.00	2750.00	0.00	-399.68	0.00	-399.68	10.091	0.00	0.00	6
0	1200.00	2750.00	0.00	-473.49	0.00	-473.49	15.579	0.00	0.00	6
0	1300.00	2750.00	100.00	-10.88	76.82	-10.88	0.487	0.00	0.00	7
0	1300.00	2750.00	100.00	-32.63	10.31	-32.63	0.487	0.00	0.00	7
0	1300.00	2750.00	100.00	-54.38	0.00	-54.38	0.487	0.00	0.00	7
0	1300.00	2750.00	100.00	-76.14	0.00	-76.14	0.487	0.00	0.00	7

Figure 19 – Emax (stand-alone) conductivity output file example – the CDI format.

5. Sample Data

5.1. Input Data Formats

When running Emax via the **Maxwell** interface, any input data originating from bipolar square-wave systems and supported by Maxwell can be imported and then processed with Emax. Instruments supported by Maxwell include Smartem, Sirotem, Zonge GDP, Crone, EM37, Protem, …and more. See Maxwell documentation for a complete list of supported instruments and formats.

Maxwell can save an Emax version of the input data if you select the Emax processing option "*Write input file for stand-alone Emax*" file. This is an easy way to prepare your data if you should wish to run Emax stand-alone at a later date.

When running **Emax stand-alone** the data must be in Emax stand-alone input data format. This format is described above in Section **4**.

5.2. Sample Data

Some sample data is provided in `C:\Program Files (x86)\Fullagar\Emax\Sample_Data` for checking and testing Emax operation and output results. These files are as follows;

file	*coincident loop*	*moving in-loop*	*UTEM*
Maxwell input file(s)	samp_coinc_amira.dat	samp_inloop_amira.dat samp_inloop_amira.chn	samp_utem.TEM
Maxwell project file(s)	samp_coinc_Maxwell.PRJ		samp_utem_Maxwell.PRJ
Emax input data file	samp_coinc_in.dat samp_coinc_sharp_in.dat samp_coinc_sharp2_Csharp_in.dat	samp_inloop_in.dat samp_inloop_RL_NO_in.dat samp_inloop_RL_YES_in.dat samp_inloop_sharp_in.dat samp_inloop_sharp2_Csharp_in.dat	samp_utem_in.dat
Emax output file	samp_coinc_out.xyz samp_coinc_out.xyz.ARR samp_coinc_out.xyz.CDI samp_coinc_out.xyz.FLA samp_coinc_sharp_out.xyz samp_coinc_sharp_out.xyz.ARR samp_coinc_sharp_out.xyz.CDI samp_coinc_sharp_out.xyz.FLA samp_coinc_sharp2_Csharp_out.xyz samp_coinc_sharp2_Csharp_out.xyz.ARR samp_coinc_sharp2_Csharp_out.xyz.CDI samp_coinc_sharp2_Csharp_out.xyz.FLA	samp_inloop_out.xyz samp_inloop_out.xyz.ARR samp_inloop_out.xyz.CDI samp_inloop_out.xyz.FLA samp_inloop_sharp_out.xyz samp_inloop_sharp_out.xyz.ARR samp_inloop_sharp_out.xyz.CDI samp_inloop_sharp_out.xyz.FLA samp_inloop_sharp2_Csharp_out.xyz samp_inloop_sharp2_Csharp_out.xyz.ARR samp_inloop_sharp2_Csharp_out.xyz.CDI samp_inloop_sharp2_Csharp_out.xyz.FLA	samp_utem_out.xyz samp_utem_out.xyz.ARR samp_utem_out.xyz.CDI samp_utem_out.xyz.FLA
CDI image	__image_coinc.png __image_coinc_sharp.png __image_coinc_sharp2_Csharp.png	__image_inloop.png __image_inloop_sharp.png __image_inloop_sharp2_Csharp.png	*[**]*

Table 4 – Emax (stand-alone) sample data filenames.

[**] sample UTEM data is very poor quality so plot files are not included.

5.3. Using the “sharp” options

The effect of applying the sharpening option is illustrated in **Figure 20**. The colour stretch is the same in sharpened and unsharpened images. This is the coincident loop sample data which is included with the software installation.

In the sharpened image the gently-west-dipping conductive feature has been better defined. Sharpening can often improve the resolution of conductors, especially their upper boundaries (as seen particularly in the left of **Figure 20**).

Sharpening also has the tendency to enhance noise where present, typically at late times where signal is poor. A small example of this effect can be seen below at 2325E and a depth of 400m. Users should be aware of these kinds of artefacts which may be produced by the sharpening process.

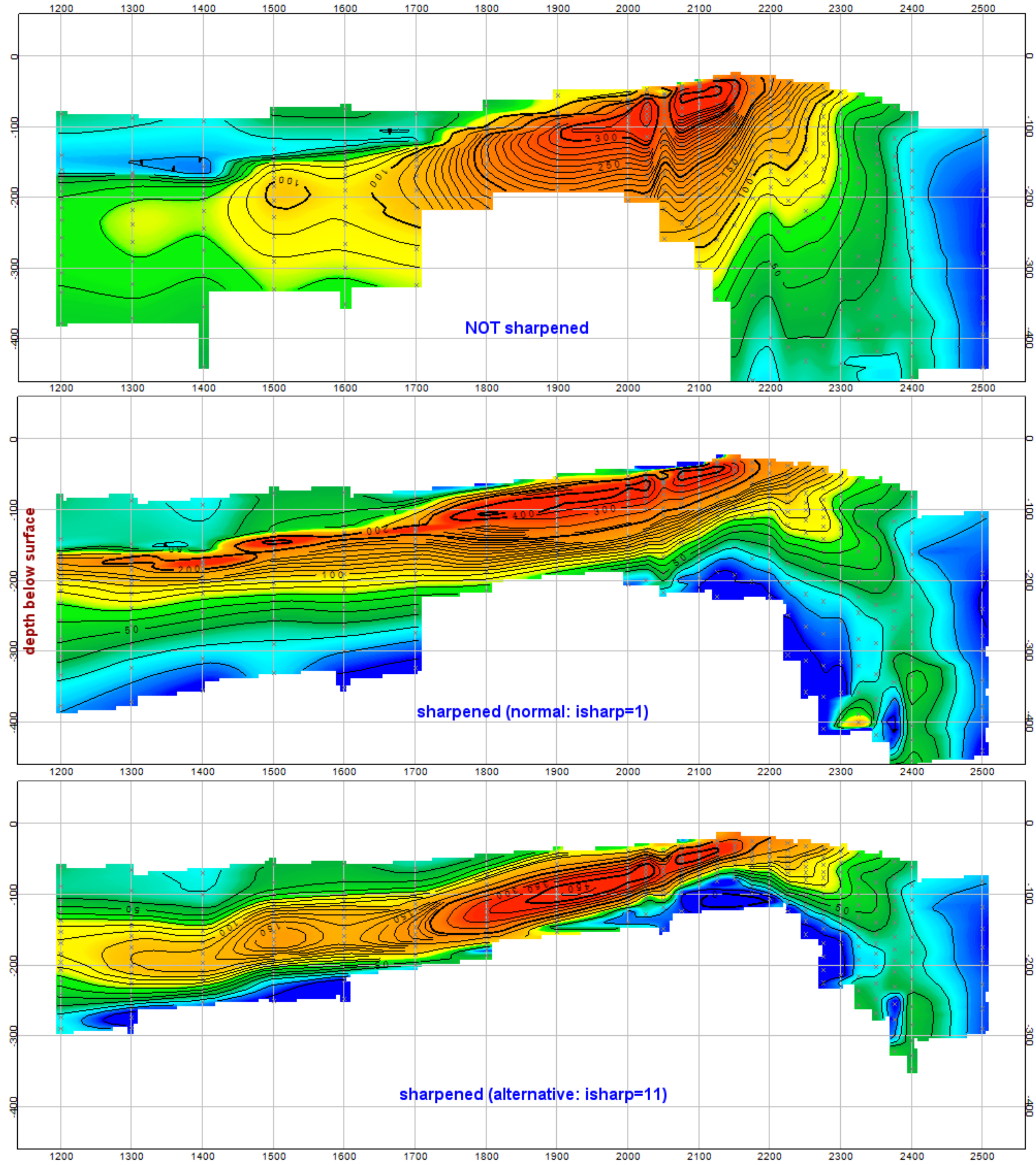

Figure 20 – Normal (top) and sharp (middle and bottom) processing.

5.4. C-sharpening (ISHARP=2) example and usage guidelines

C-sharpening creates a layered "model" extending up to the ground surface.

The input data for C-sharpening are the original apparent conductivities and depths computed by EmaxAIR. Depending on the ambient conductivity and the delay times, the first (shallowest) depth may be relatively large. In order to achieve the desired near-surface resolution, the user can insert additional layers between the first normal EmaxAIR depth, D1, and the ground surface; NUM_SPLIT is the number of extra layers to be inserted, and the interval between the first depth and the ground surface is divided into NUM_SPLIT+1 equal layers.

As NUM_SPLIT increases, convergence is usually achieved more quickly given the additional "unknowns" (degrees of freedom). Setting NUM_SPLIT is somewhat subjective, but there is a practical limit because the thickness of the extra layers becomes unreasonably small when NUM_SPLIT is large. The maximum permitted value of NUM_SPLIT is 10. If no acceptable solution is found after 19 iterations, the program terminates at the station in question and moves on to the next station.

NUM_SPLIT=0 is a valid choice, but the C-sharpening algorithm may have difficulty finding a satisfactory solution. The number of iterations required for convergence, ITERCS, is recorded in the output file. The assumed uncertainty of the apparent conductivity "data" submitted for C-sharpening is ~0.5*(1+ITERCS)%.

C-sharpening itself is formulated as an inverse problem, to derive estimates of the true conductivities from the EmaxAIR apparent conductivities. The greater ITERCS, the larger the final residuals between the EmaxAIR apparent conductivities (which can be regarded as "observed") and the apparent conductivities associated with the C-sharpened solution (which can be regarded as "calculated"). In other words, the larger the ITERCS value, the poorer the fit.

The result of C-sharpening on the example above (**Figure 20** Section **5.3**) is shown in **Figure 21**. The C-sharpening processing used NUM_SPLIT=8.

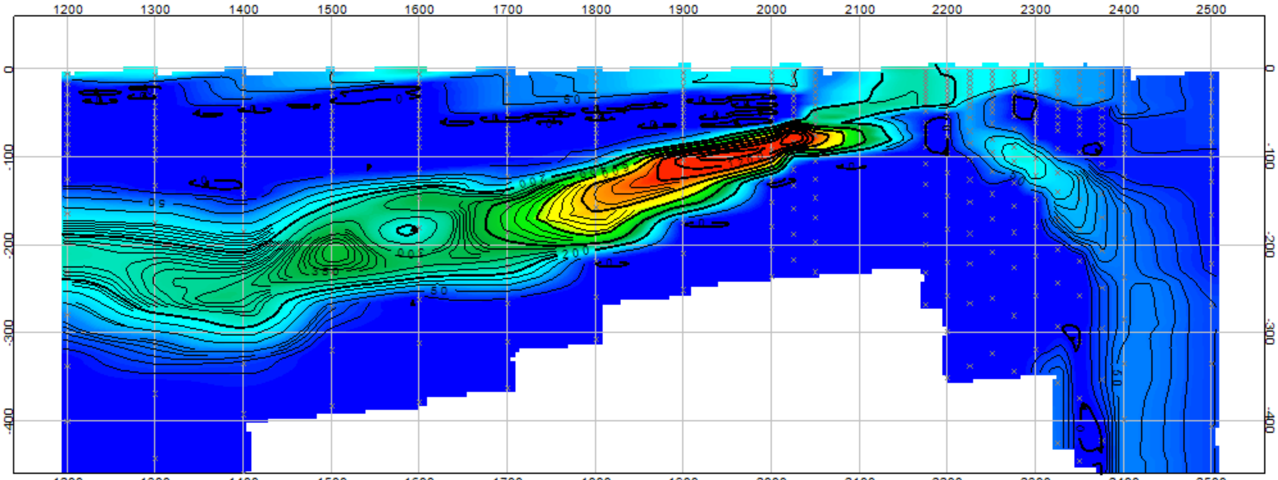

Figure 21 – C-sharpened version of the section seen in Figure 20.

Support

For support please contact

Phil Muir Southern Mineral Exploration Geophysics 45 Tahune Crescent Blackmans Bay Tasmania Australia. 7052 phil@fullagargeophysics.com or phil.muir@bigpond.com
Peter Fullagar Fullagar Geophysics Pty Ltd peter@fullagargeophysics.com or fullagargeophysics@yahoo.com phone: +61 (3) 6229 5631 cell: +61 (44) 751 1015