User Guide

For

Stratagem EH-5Pro Software

P/N 770-00114-01

Version 1.00, Rev. B

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GEOMETRICS
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1.0 Introduction

The EH5Pro software is the data processing software for the Stratagem EH5 audio magnetotelluric instrument. This manual is a supplement to the "Stratagem EH5 Operator's Manual".
The first task is to install the EH5Pro software and licensing it for the computer to be used. This process is explained below.

2.0 Eh5Pro Installation and Registration

Eh5Pro is Window based MT/AMT data processing program for Geometrics Eh5 instrument. It is tested on Windows 7, Windows 10 and Windows 11. Eh5Pro is not compatible with Unicode. Data input and file path must be ASCII character. PC display resolution is recommended to set as 1920X1080.

2.1 Installation and Registration

Run "Eh5ProSetup.Exe" to install Eh5Pro program (Figure 1). You can specify where to install Eh5Pro. The default folder is "C:\ Eh5Pro".

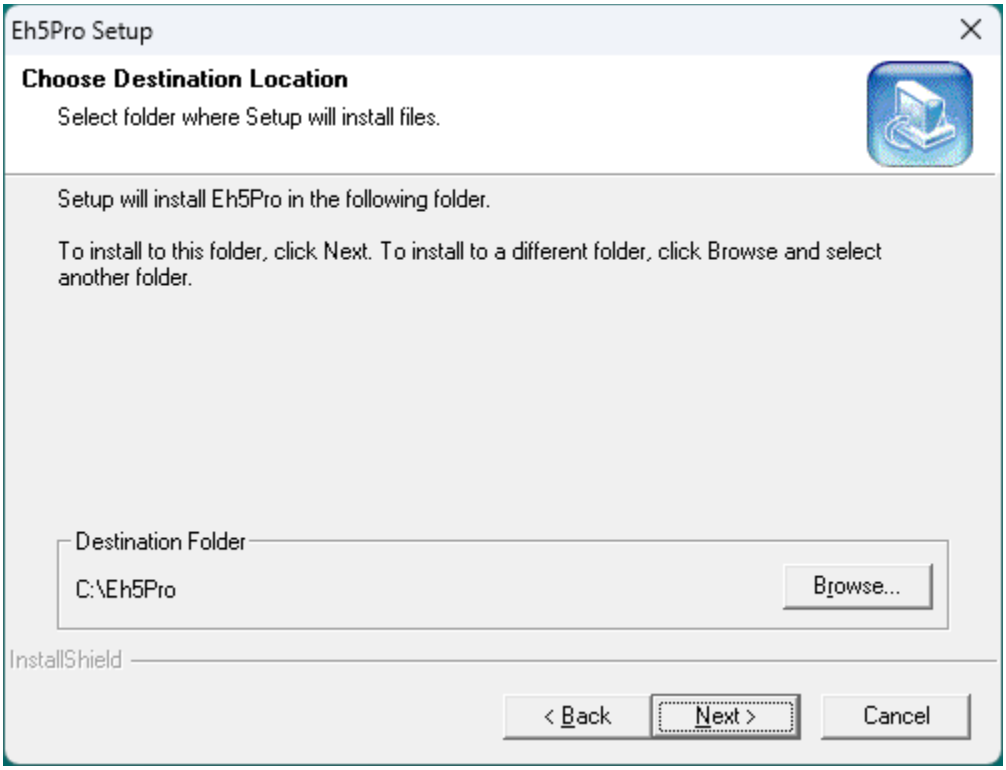


Figure 2-1 Install En5Pro

The first thing to do after installation is to register Eh5Pro for your PC. Each Eh5Pro order can be installed in maximum four computers. It is recommended to register 1-2 computers at very beginning, register more in future if needed.

On the top menu bar click on "Help\ About En5Pro" to pop up the register window (Figure 2) and fill "Client","Client Email" and "Box SN" and then click "Generate Eh5ID File" button to save Eh5ID file. Send the saved Eh5ID file to your representative or vendor by email. Your representative or vendor will

reply to your email with a license key. Copy and paste the key in License Key field, then click “Resister License” button to finish registration (Figure 1.3).

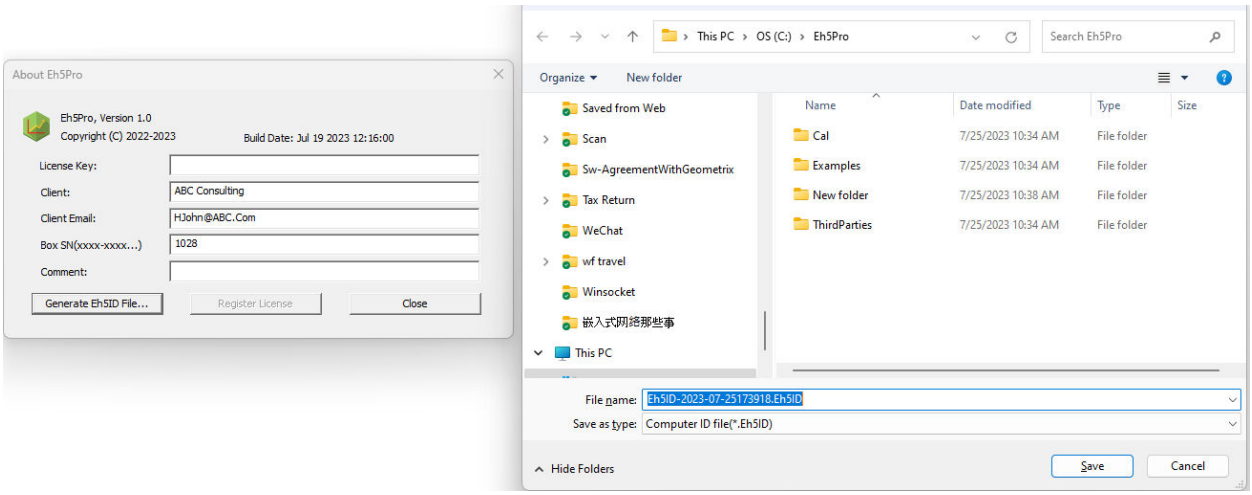


Figure 2-2 Generate Eh5ID File

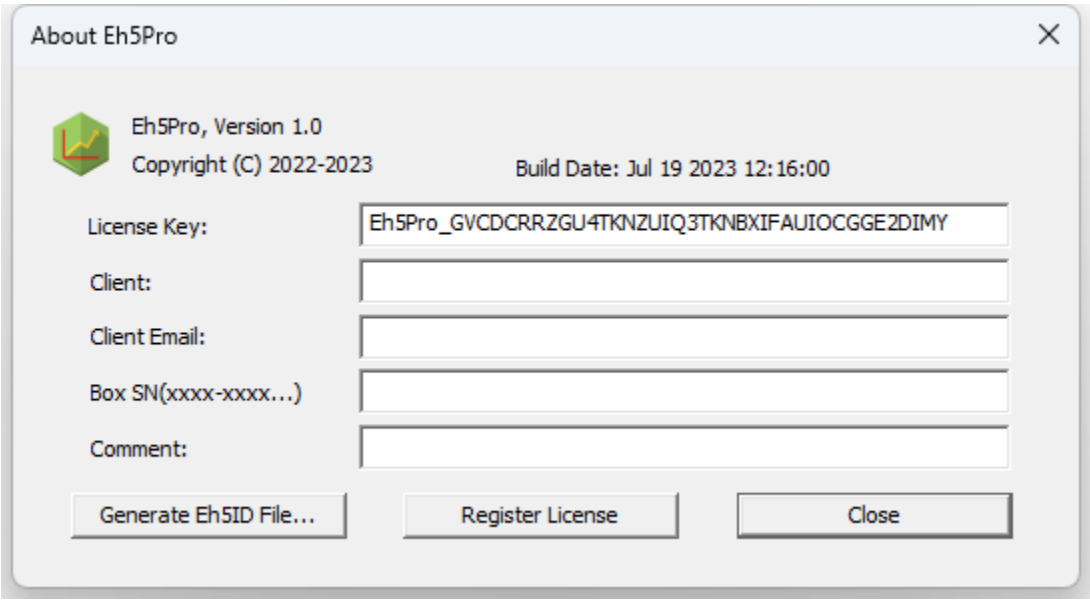


Figure 2-3 Register Eh5Pro

The detailed licensing procedure is as follows:

1. Run the EH5Pro installation program.
2. After successfully installing EH5Pro open it up and click on “Help\About EH5Pro”
3. Fill in the information for the window that pops up.
4. Click on the “Create EH5ID” button.
5. Email the EH5ID file to me.
6. We will send you back a license ID key code.
7. Copy the key code into the License Key field
8. Click on Register License

The procedure is the same for the Emage2D inversion software if that has been purchased.

2.2 Data File Format:

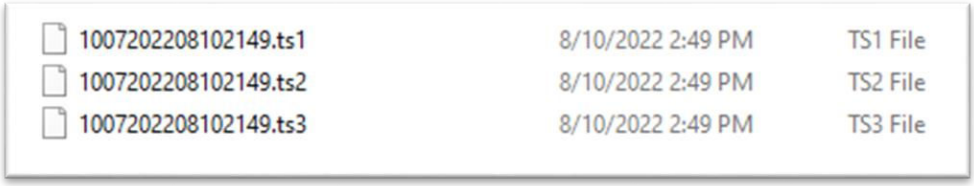
The data files acquired by the Stratagem EH5 are read into the EH5Pro for editing and data processing. The acquired data files have an extension of either **.ts1** or **.ts2** or **ts3**.
data.
Below is a sample of three .ts files.

1. The *.ts1 files contain the high-frequency band data from approximately 3,000 Hz to 90,000 Hz.

2. The *.ts2 files contain the mid-frequency band data from approximately 7 Hz to 3,000 Hz.

3. The Ts3 file is the data band from approximately 2 Hz to 20 Hz.

For example,



1007202208102149.ts1	8/10/2022 2:49 PM	TS1 File
1007202208102149.ts2	8/10/2022 2:49 PM	TS2 File
1007202208102149.ts3	8/10/2022 2:49 PM	TS3 File

Figure 2-4: Sample TS files

The naming convention includes information about the receiver serial number, time of acquisition, and frequency band. For file 1007202108252015.ts1, the file name means the following: receiver serial number = 1007, acquisition date = 2021-08-25 (August 25, 2021), UTC time in hours and minutes = 20:15 (8:15 pm GMT), ts1 = high-frequency data. The file 1007202108252015.ts2 was acquired at the same date and time but for low-frequency data.

Prelimary Notes: Before time series can be viewed and data processing can begin the EH5 data files must be downloaded from the EH5 receiver and stored on the data processing computer. This is explained in detail in the Stratagem EH5 User Guide, section 3.4. As a summary the following steps are necessary.

1. Confirm you are connected to the EH5 receiver WiFi with the data processing computer.

2. Remember that the EH5 WiFi address is **http://eh** and the password is 12345678.

3. Go to "File\Download EH5 Data Files". If you are connected to the EH5 receiver you will see a list of the EH5 data files.

4. You can either create a data folder on your processing computer by the current date or create a new data folder in Windows Explorer. Navigate to the chosen data folder by clicking the button.

5. Individual files can be selected and downloaded or all undownloaded files can be downloaded by clicking on download all. Choosing only todays data will download only those files acquired on the current date.

3.0 Time Series Viewing and Editing

3.1 View Time Series

To view the acquired time series you must first read in the **.ts** files. From the menu at the upper left of the screen shown in figure 1.

A. Click on **Time Series** from the menu bar as shown below.

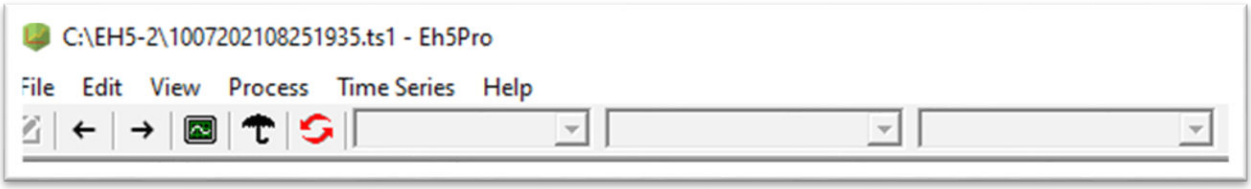


Figure 3-1 – Menu bar

B. Select **Open Time Series File**.

C. Navigate to the folder where your **.ts** files are located. Select the data files you want to view and edit. Only one time series file can be selected at one time.

D. Click **Open** and time series from the first acquisition segment will be displayed for all five channels as shown in Figure 3-2.

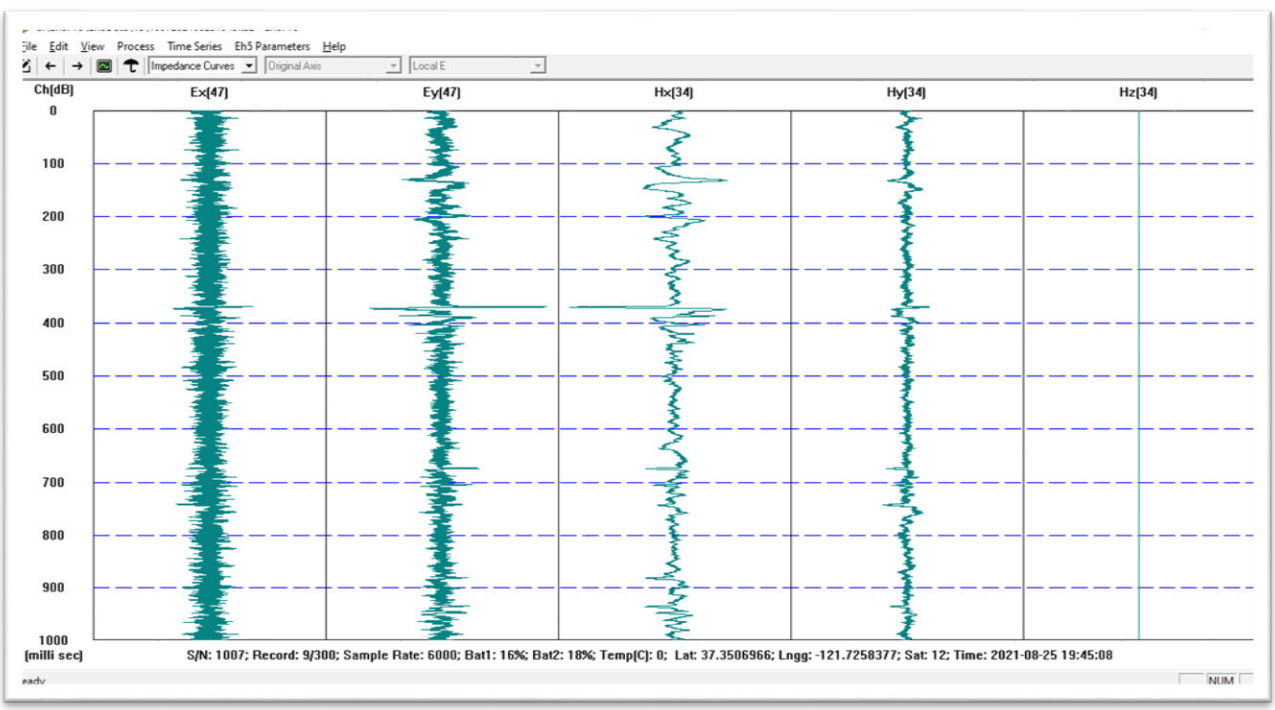


Figure 3-2 – Time series curves from all five channels

Information about the segment is displayed along the bottom edge of the screen.

3.2 Scrolling through the time series:

The time series will automatically scroll thought each record in the file. To stop the scrolling click on the **sine** icon, at the upper left of the screen. You can manually continue to scroll through the data by hitting **Enter** to scroll forward and hitting **Backspace** to scroll backwards. This record can also be scrolled or stopped by clicking in the screen.

3.3 Masking out time series records:

To mask out a segment so it is not used in processing, click the umbrella icon or click the **Delete** key on the computer keyboard. The segment information at the bottom of the screen will turn red, meaning it will be masked and not used in data processing. To unmask the segment hit the umbrella icon again and the segment information will turn black again meaning it is active and will be used in data processing.

After you have edited your times series file you need to save it. Use a different file name. For example, if you edited file 1007201208252015.ts1 you could save it as 1007201208252015-edit1.ts1. From the menu bar at the top of the screen click on **Time Series \Save Time Series File.**

Navigate to the folder where you want to save the file and click **Save** at the bottom right of the screen.

3.4 Shift between time series and power spectrum

Clicking on the red icon shifts the display from the time series to a power spectrum display of that record. The vertical axis in the power spectrum is in frequency (Hz) as shown below. The display can also be changed from time series to power spectrum using the **esc** key.

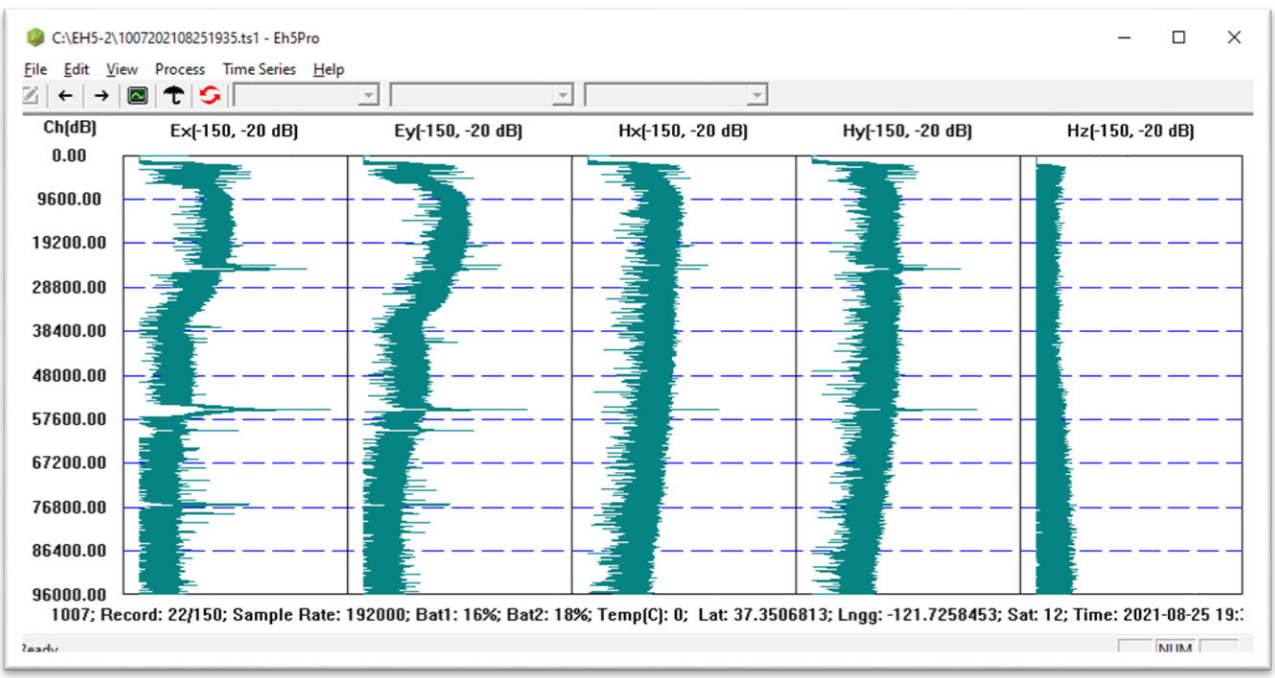


Figure 3-3 Power Spectrum for record 22 of 150.

Hitting "enter" will advance the display to the next record for both the power spectrum and time series. The backspace key will display the previous record.

E. Hitting the **Delete** key when the time series is displayed will also mask out that record so it is not used in processing the data. Hitting **Delete** again will reactivate the record so it is used in processing. When the record is masked the bottom of the display turns red as shown below.

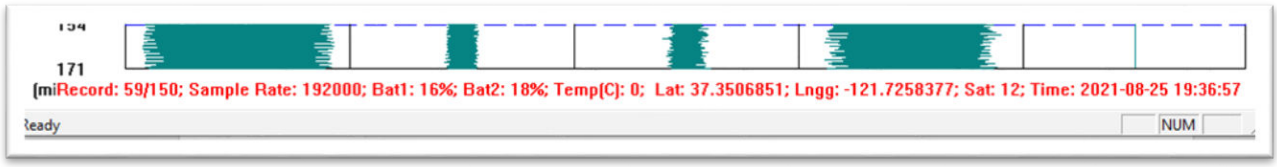


Figure 3-4 - Red letters show the record is **not** active and will not be used in data processing.

When viewing impedance curves, the icon will allow you to switch between the impedance curves and the site location map.

3.5 Time series header information

A. Click on **Time Series\TS File Head Information** to see the screen below:

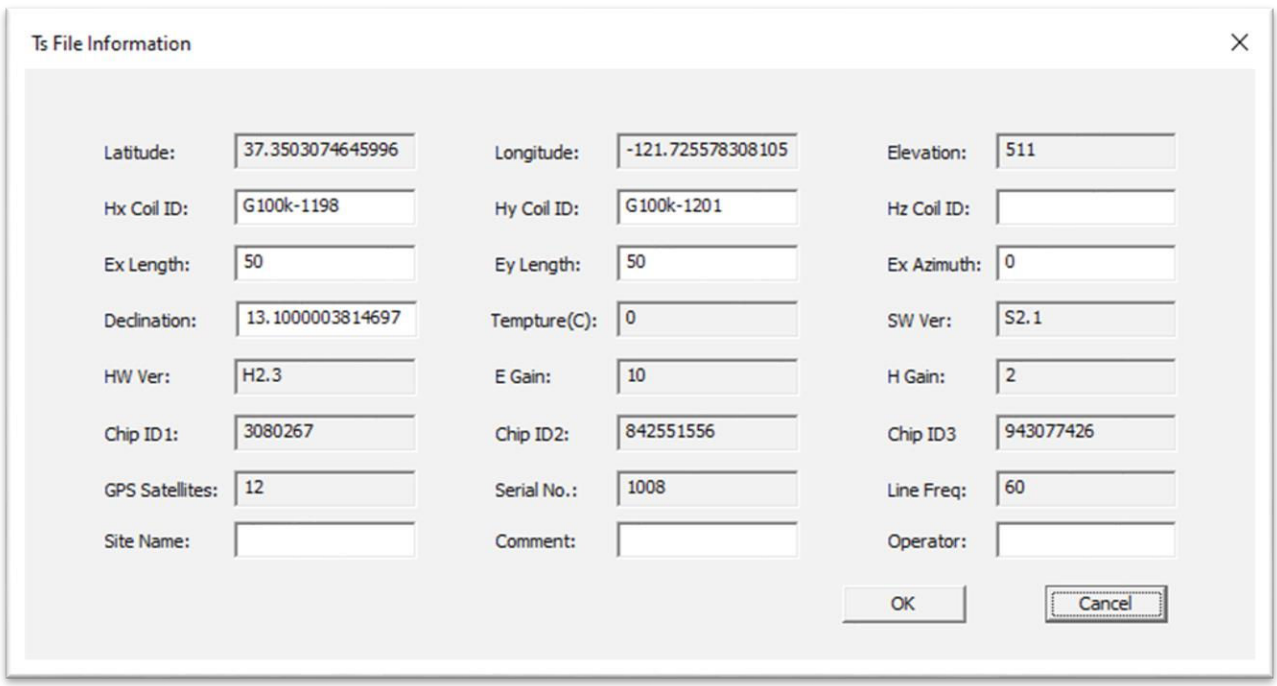
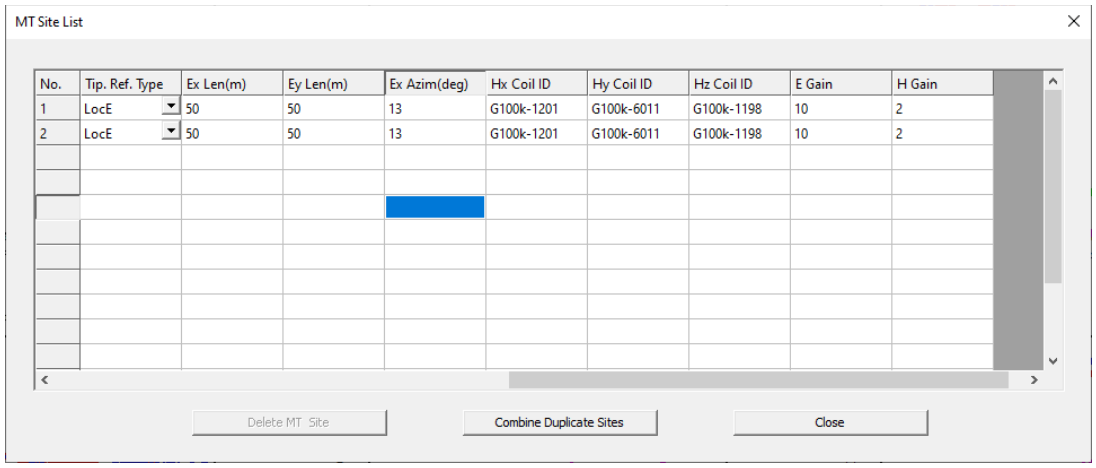


Figure 3-5 – TS file information

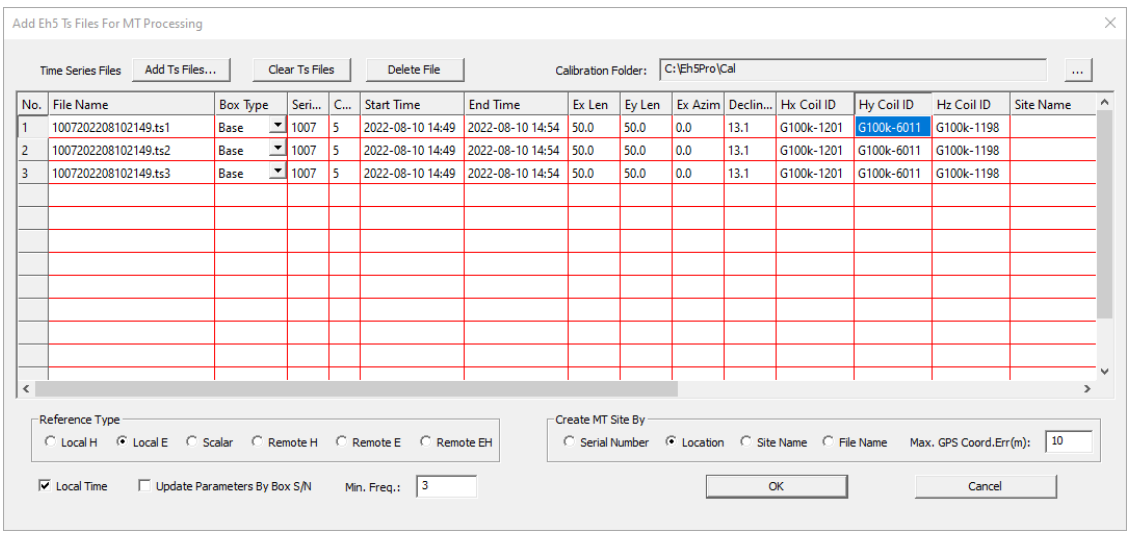
These fields can be edited for processing. For example, if the wrong calibration file had been entered it can be changed here. Note that the calibration file information can be viewed for each receiver by clicking on "**Edit\MT Site List**" as shown below.



No.	Tip. Ref. Type	Ex Len(m)	Ey Len(m)	Ex Azim(deg)	Hx Coil ID	Hy Coil ID	Hz Coil ID	E Gain	H Gain
1	LocE	50	50	13	G100k-1201	G100k-6011	G100k-1198	10	2
2	LocE	50	50	13	G100k-1201	G100k-6011	G100k-1198	10	2

Figure 3-6 – File calibration screen. Calibration information can be verified here.

However, the data cannot be edited in this screen. It must be edited in the screen when the TS files were brought into the software. This would be under "Process\MT Process\Add TS files\Open".



No.	File Name	Box Type	Seri...	C...	Start Time	End Time	Ex Len	Ey Len	Ex Azim	Declin...	Hx Coil ID	Hy Coil ID	Hz Coil ID	Site Name
1	1007202208102149.ts1	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	
2	1007202208102149.ts2	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	
3	1007202208102149.ts3	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	

4.0 "Process" - Data Processing and Re-Processing

4.1 MT Processing

4.1.1 Open and view TS file for data processing

A. Click on **Process\MT Processing** to see the menu **Add EH5 TS Files For MT Processing**

B. Click on **Add TS Files** and go to your data files folder.

C. Select a TS file or a range of TS files by highlighting the files you want to process.

D. Click **Open**. An example of both TS1 and TS2 files for a range of stations as in the example below (Figure 4-1) where you selected both the TS1 and TS2 files for the stations. Shown below:

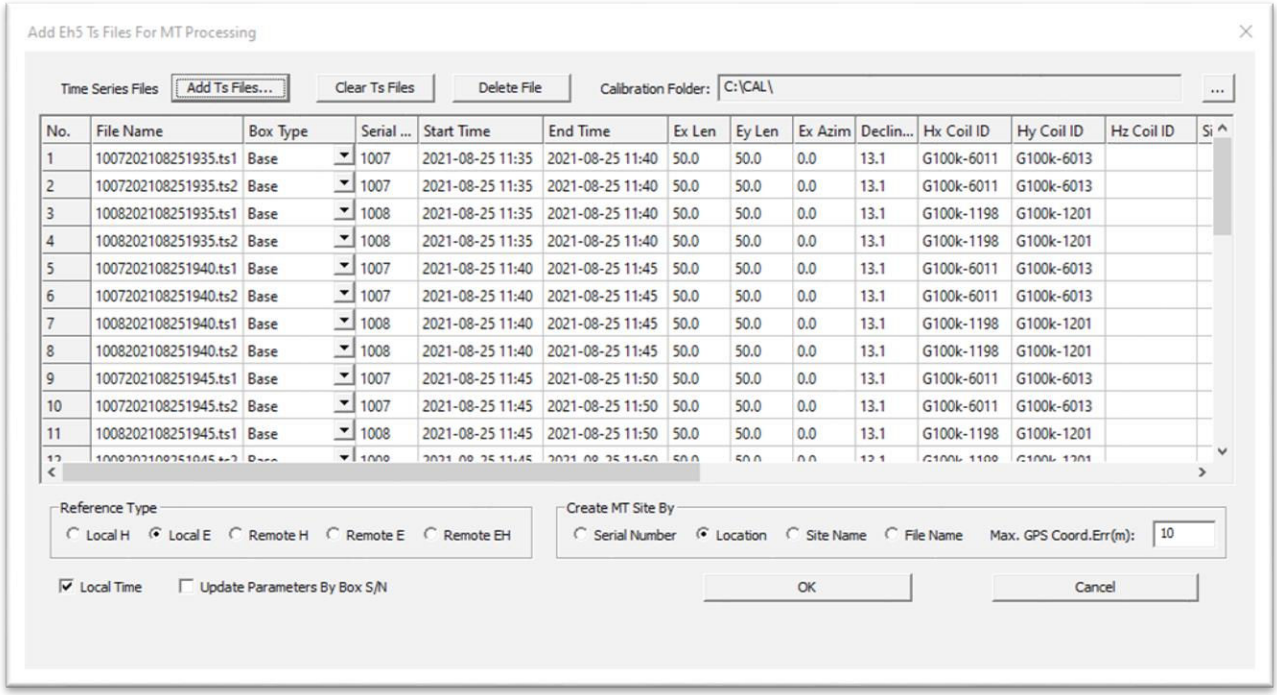


Figure 4-1 – This screen allows users to choose the TS files they want to process.

4.2 Viewing and editing site information

Special note: This is the place where you can edit the site information. For example, if you had entered the wrong Hy coil calibration file name for Hy on receiver serial number 1010 it can be corrected here. As shown below changing from Hy G100k-1528 to G100k-G1521. To do this the box **Update Parameters By Box S/N** must be check as show below. Click OK to process the data with the new calibration file.

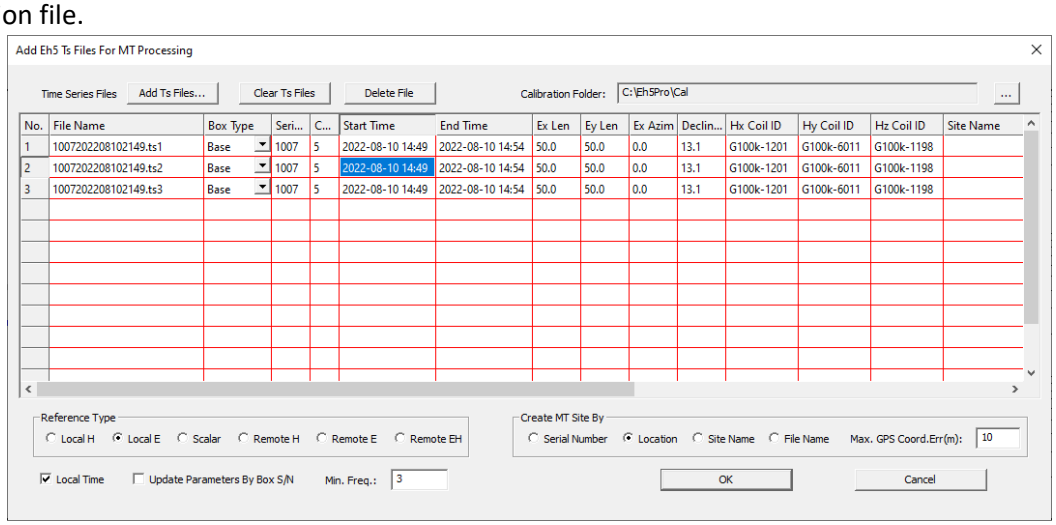


Figure 4-2 – Screen for adding TS files for MT Processing.

Note that the minimum frequency for data processing can be set in the "Min. Freq." box. The default is 3 Hz but it can be set to as low as 1 Hz.

4.3 Menu Items

A. **File Name**: Name of the .TS file

B. **Box Type:** This can either be Base which is the sounding station receiver. Or it can be Remote which is the remote reference station.

C. **Serial:** Is the serial number of the receiver box.

D. **Start Time** and **End Time:** Are the start and end times of the acquisition for that TS file.

E. **Ex Len:** Is the dipole length of the Ex dipole.

F. **Ey Len**: Is the dipole length of the Ey dipole.

G. **Ex Azim**: Is Azimuth of the Ex dipole.

H. **Declination**: Is the local magnetic declination of the site where the TS file was acquired.

I. **Hx, Hy,** and **Hz Coil ID**: Are the serial numbers of he magnetic coils and also the calibration file name of each coil.

J. **Site Name**: Is the user designated name of the location where the TS file was acquired.

K. **Sample Rate**: Is the acquisition sample rate of the file. TS1 files are for the high frequencies and are sample at 192 kHz and TS2 files are for the low frequencies and are sampled at 6 kHz.

L. **E gain** and **H gain**: Are the acquisition gains set in the field for that TS file.

M. **Latitude, Longitude**, and **Altitude**: Are the GPS lat, long, and elevation of that site, based on the internal GPS of the in the receiver box.

N. **Scans per record**: Is the number of samples in each record.

Selecting a file and clicking **Delete File** will remove only that file from the list. Click "Clear Ts Files" remove all the files from the list.

Note: The calibration file folder for the TS files must be entered into the **Calibration Folder** field in the processing menu screen. This is in the upper right of the menu screen as shown in in the green box in Figure 4-3 below.

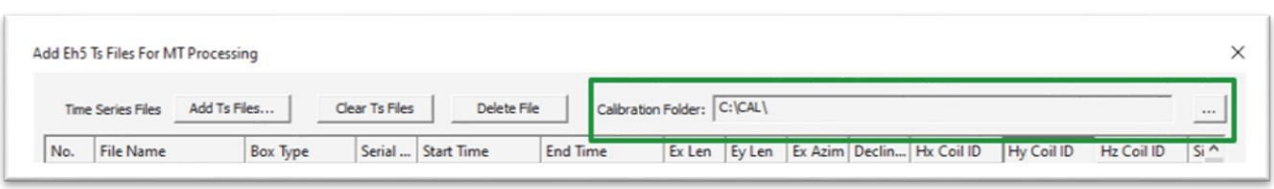


Figure 4-3

The menu bar at the bottom of the screen is as follow:

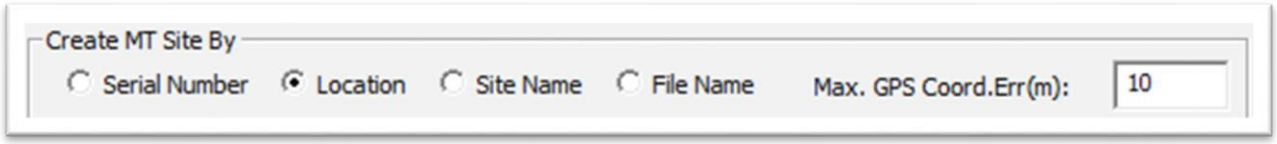


Figure 4-4

4.4 Viewing processed data

The menu name "Create MT Site By" is how the MT sites are determined. They can be defined by the serial number of the receiver box, the GPS location, the given site name, or the file name. The **Max. GPS Coord. Err(m**) is the GPS drift allowed before it is considered a different location.

Click **OK** and the program will begin to process the data for each station. This can take several minutes for large data sets. After processing a multi-curve screen is displayed, as shown in Figure 4-5.

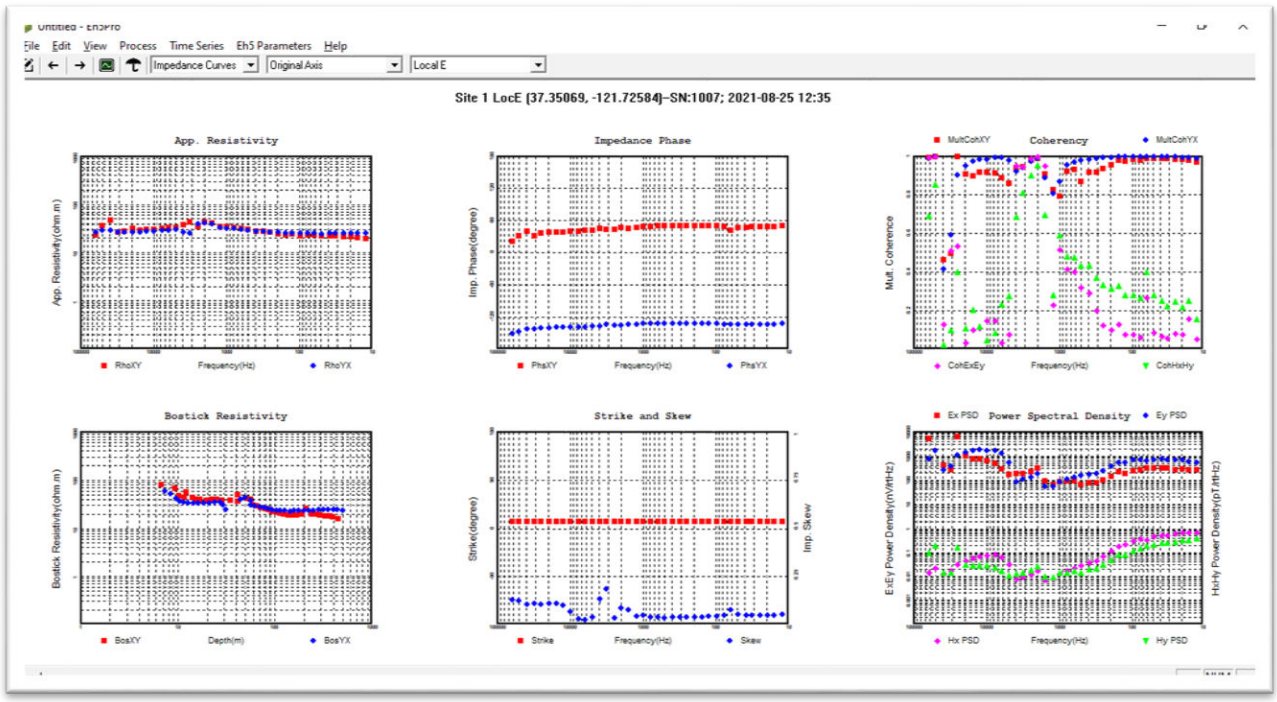


Figure 4-5 – Site 1 processed data

Click the right-left arrow keys to scroll through the sites selected.

The **Impedance Curves** screen shows apparent resistivity, impedance phase, coherency, Bostick resistivity, station strike and skew, and spectral density for the selected site. The individual plots can be view from the plot type menu. For example, resistivity plots can be selected to see a display such as seen in Figure 3-7 below.

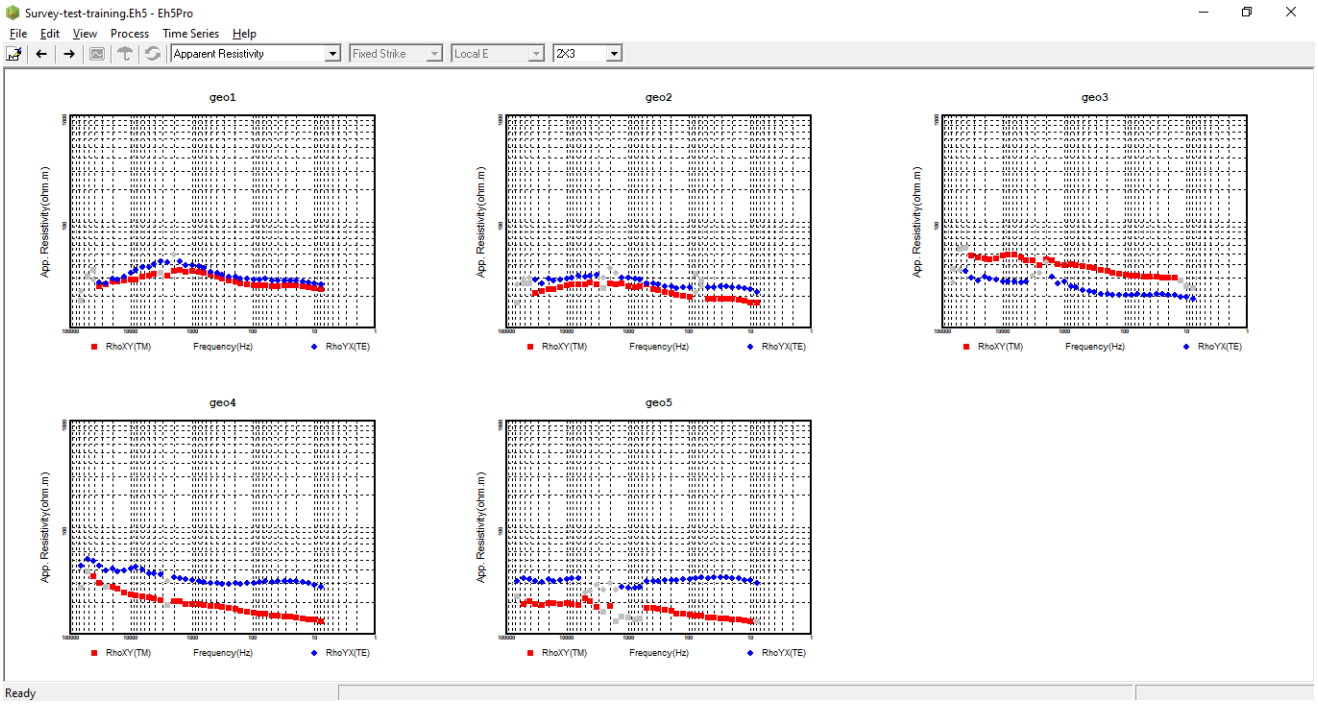
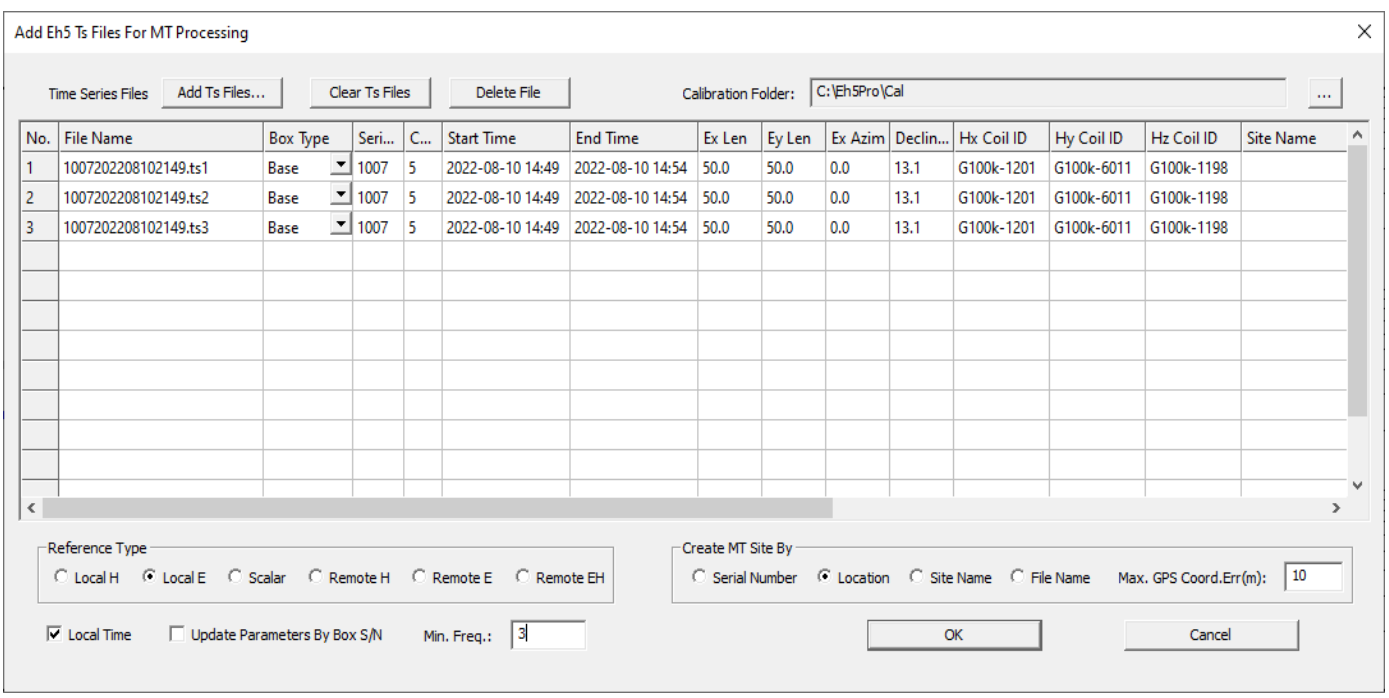


Figure 4-6

4.5 Re-Processing

Reprocessing data that was previously processed may improve data quality. You may re-process the data after reviewing the time series and making any necessary deletions to either the time series or records. After the time series edits are finished, you should reprocess the data to see the new results as shown in Figure 4-7. Note that you can set the minimum frequency for the processing. The default minimum is 3 Hz but it can be set as low as 1 Hz.



No.	File Name	Box Type	Seri...	C...	Start Time	End Time	Ex Len	Ey Len	Ex Azim	Declin...	Hx Coil ID	Hy Coil ID	Hz Coil ID	Site Name
1	1007202208102149.ts1	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	
2	1007202208102149.ts2	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	
3	1007202208102149.ts3	Base	1007	5	2022-08-10 14:49	2022-08-10 14:54	50.0	50.0	0.0	13.1	G100k-1201	G100k-6011	G100k-1198	

Figure 4-7 – Screen that appears after clicking Reprocessing.

Note the following when re-processing data:

A. You may change the reference type and MT site type.

   a. If the GPS locations of two soundings are greater than the **Max. GPS Coord. Err (m)** the two soundings will be treated as two separate sites. If the distance is less than the Coord. Err the two soundings will be combined as one site.

   b. If **local time** is checked, the local computer time is used. If it is unchecked, GMT time is used.

B. The correct calibration folder must be indicated in the **Calibration Folder** field.

C. **Parallel Noise Processing**: This allows the operator to set up the two H coils parallel to one another, and the two electrodes parallel to one another but perpendicular to the two H coils. The parallel data is then used to display the noise level on the sensors and display parallel apparent resistivity and phase.

D. **Re-processing** allows the user to view the file parameter menu shown in Figure 4-7 and make changes to the parameters, then process the files again.

E. **Undo Processing**

   a. Undo processing will revert the re-processed data back to its original processed state.

4.6 Viewing the station survey positions:

Note that clicking on the  icon from the impedance curves screen will show the site location map of the data. Right clicking on the site location map will switch to the impedance curves display. If the **edit** icon has been activated right click the impedance curves will not switch to the location map. Instead, it will swap the position of the Zxy and Zyx impedances.

The display scales can be changed by going to **View/Display Settings**. The parameters can be edited in the following menu:

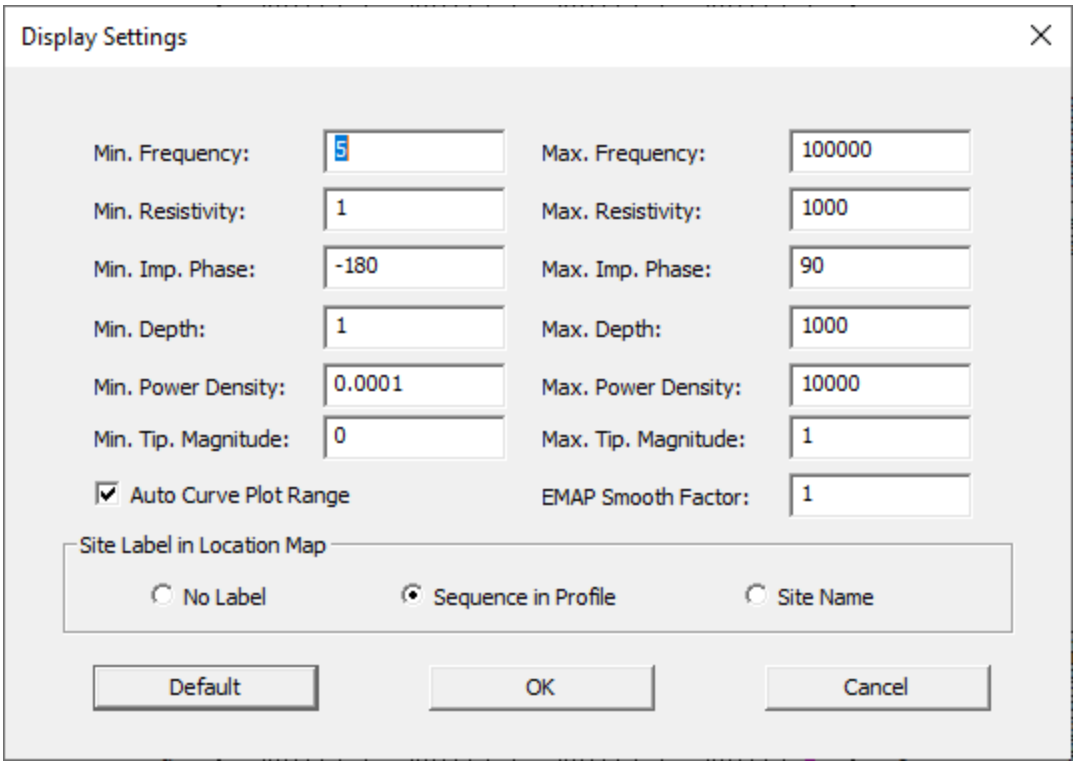
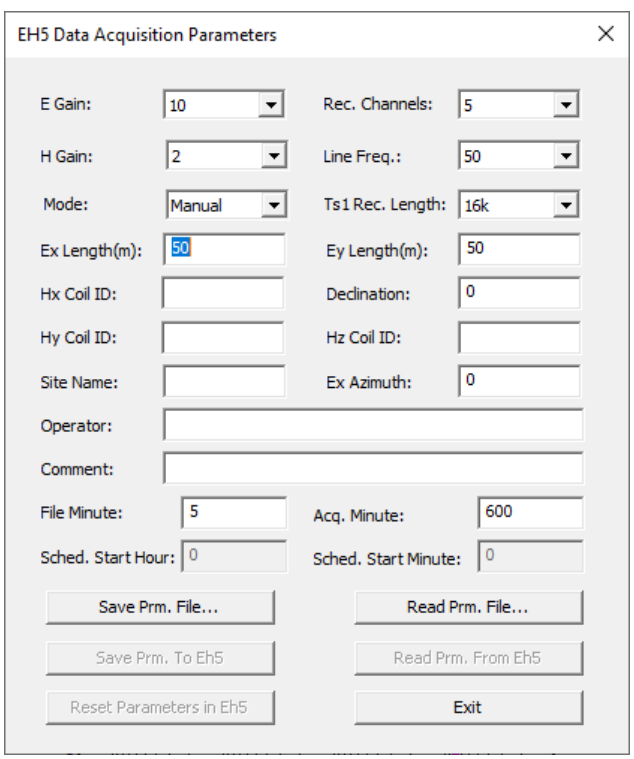
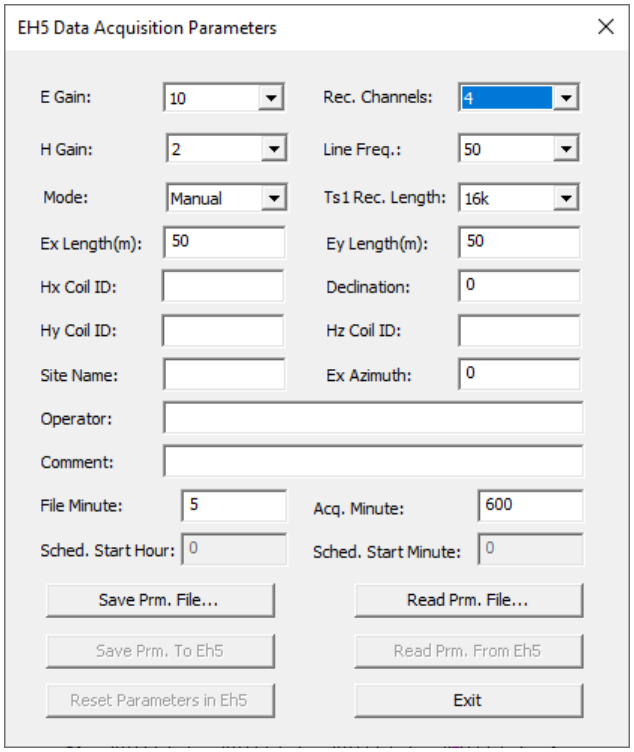


Figure 4-8

Clicking on **Auto Curve Plot Range** will automatically scale the plot axes to the range of the data. Stratagem EH5 acquistion paramaeters can be set by clicking "File\EH5 Acquistion Parameters". See below:



If you are not recording vertical field magnetic data (Hz) is is advisable to change the “Rec. Channels” from 5 to 4. If you are not using channel 5 it is a waste of data memory and acquisition time to not fill up the memory with data from channel 5, whick would only be noise without a mag sensor connected. See the menu below.



4.7 Parallel noise processing

Parallel Noise Processing: The parallel nose test is a quality control tool that can help determine if the instrument and sensors are working properly. Parallel Noise Processing allows the operator to set up the two H coils parallel to one another, and the two electrodes parallel to one another but perpendicular to the two H coils. The parallel data is then used to display the noise level on the sensors and display parallel apparent resistivity and phase.

Parallel noise test field operation*:* In order to do the scalar parallel noise test the system must be set up in a parallel mode in the field and data acquired. Parallel mode means that both E-field measurements are parallel to one another and both H-field measurements are in parallel to one another but perpendicular to the E dipoles. For example, if both E dipoles are oriented to 0 degrees then both magnetic coils should be oriented to 90 degrees. Data is then acquired in the parallel mode.

4.7.1 Parallel noise test processing: Do the following

A. Click on Process/Parallel Noise Test

B. Choose Add TS File and select the file or files that were acquired in the parallel mode. Click Open.

C. You will see the following screen:

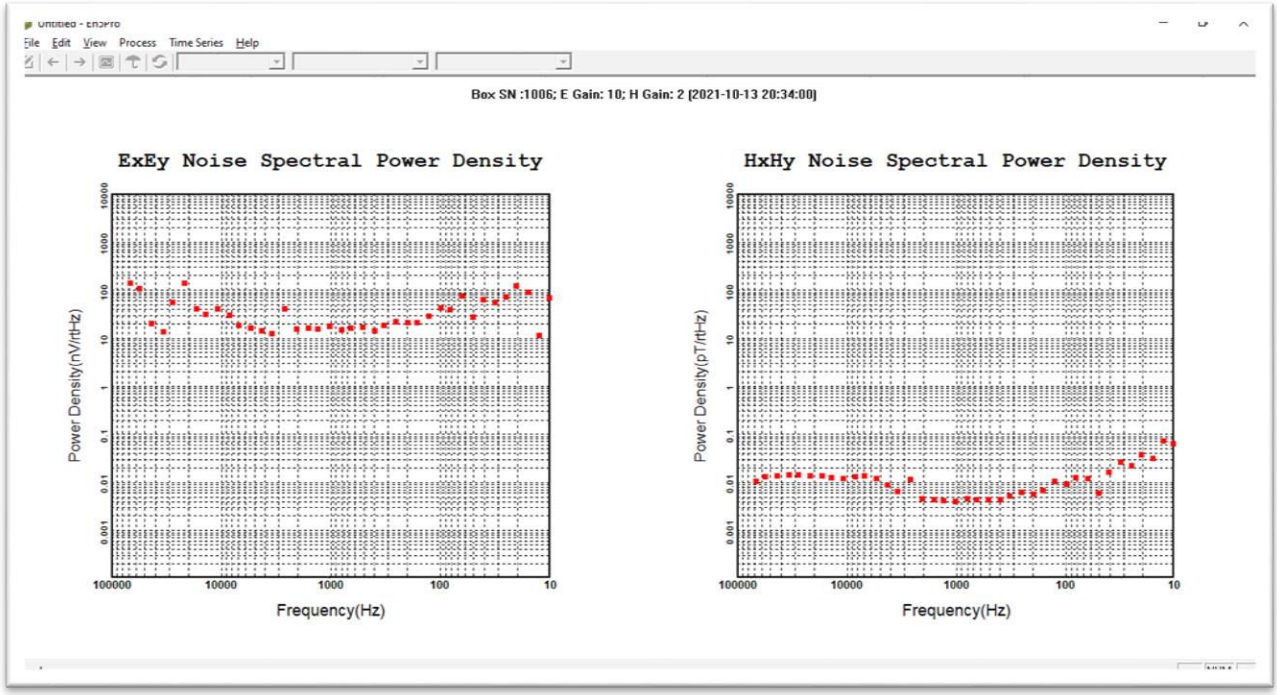


Figure 4-9 – Screen showing parallel noise spectral power density.

Note that the top of the screen shows the receiver box serial number, the E and H gain levels, and the date and time of acquisition as shown below:

Box SN :1006; E Gain: 10; H Gain: 2 (2021-10-13 20:34:00)

4.7.2 Parallel noise test interpretation

The noise spectra is an indication of instrument noise. Be aware that there are few limits when interpreting the noise spectra. The E power density is normally less than 200 nV/rtHz. Power density higher than that may indicate an instrument problem. H power density less than 0.1 pT\rtHz is good and above that might indicate an instrument problem.

A smooth curve is good, but don't be overly concerned about a few random spiked data points in the noise spectrum. Perform this test in a low-noise zone, as these spikes might be the result of environmental noise. The examples above were selected to show random spikes on the noise spectra. Or random noise in the instrument operation.

Short-Circuit Noise Processing: You may perform a Short-Circuit Noise test to confirm the noise level on the sensors. To do this, you must short circuit the channels prior to starting the test using a set of short circuit test cables. After short-circuiting the channels, you may now perfor the test by doing the following:

A. Click on Process and select Short Circuit Noise Process

B. Click Add TS Files and select the TS files that you created during the by short-circuit noise test.

C. Click OK to see the following noise test screen.

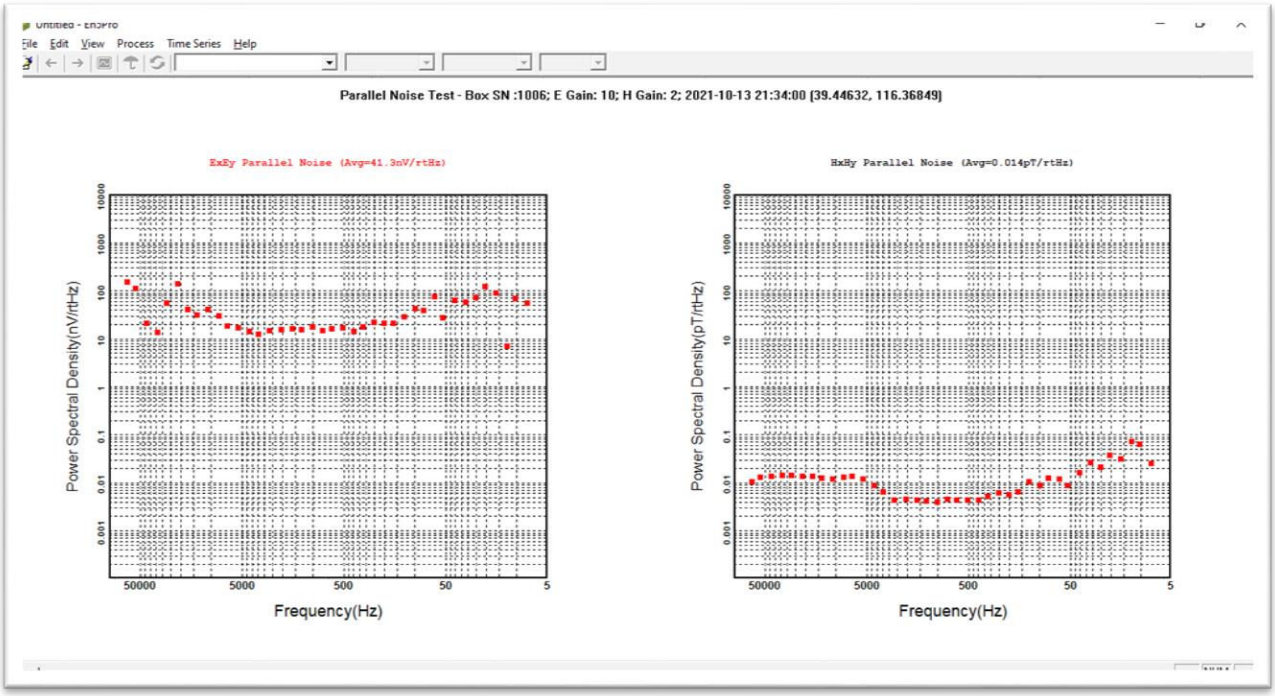


Figure 4-10 – Screen showing the data collected during a Short-Circuit Noise Test.

The **black** letters at the top of each channel test indicate a pass. **Red** letters at the top of the screen indicate higher than acceptable noise levels for that channel. The measured noise levels are shown in each channel's heading.

5.0 Site Location Map

5.1 Site location map display

The locations are of sounding sites are determined by the internal GPS in the receiver box. An example is shown below:

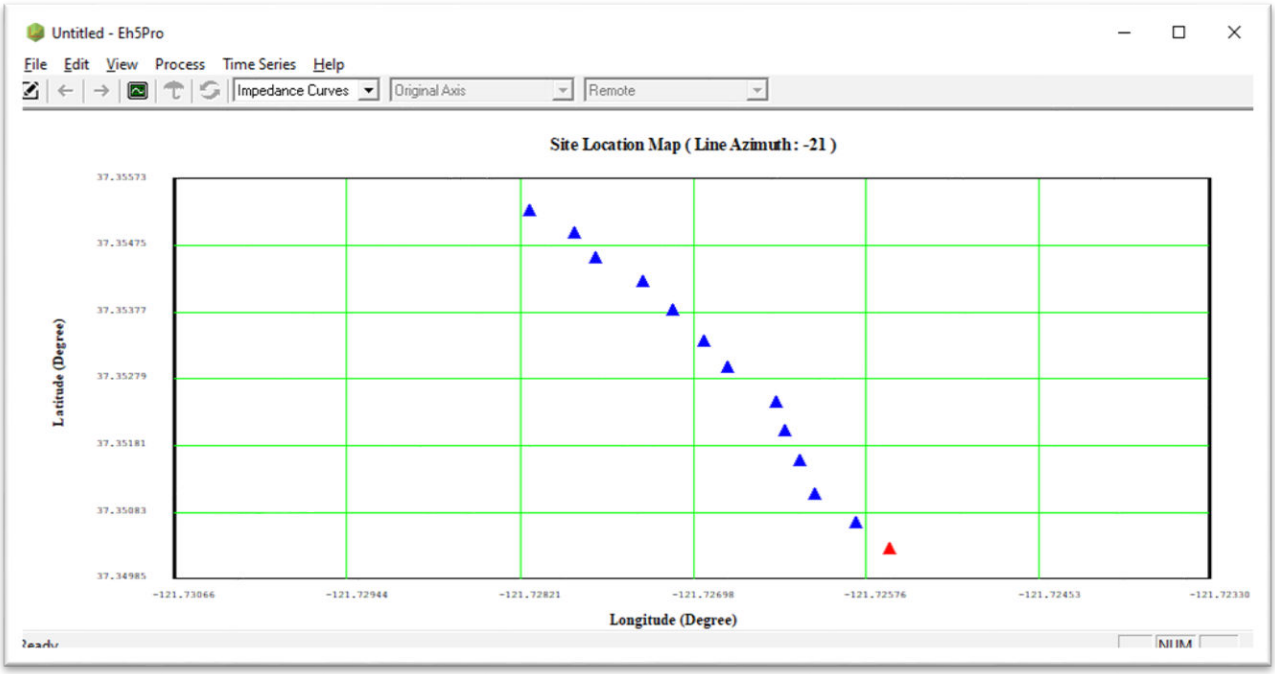


Figure 5-1 – Site location display map.

Coordinates are given in latitude and longitude. The **red** triangle is the active station.

The 2-D projection of the profile line can be displayed by clicking "Set Default Profile" in the "Edit" menu. An example is below. The 2-D projection can also be set manually by enabling the edit icon then holding down the Ctrl button and dragging the mouse. See the example below.

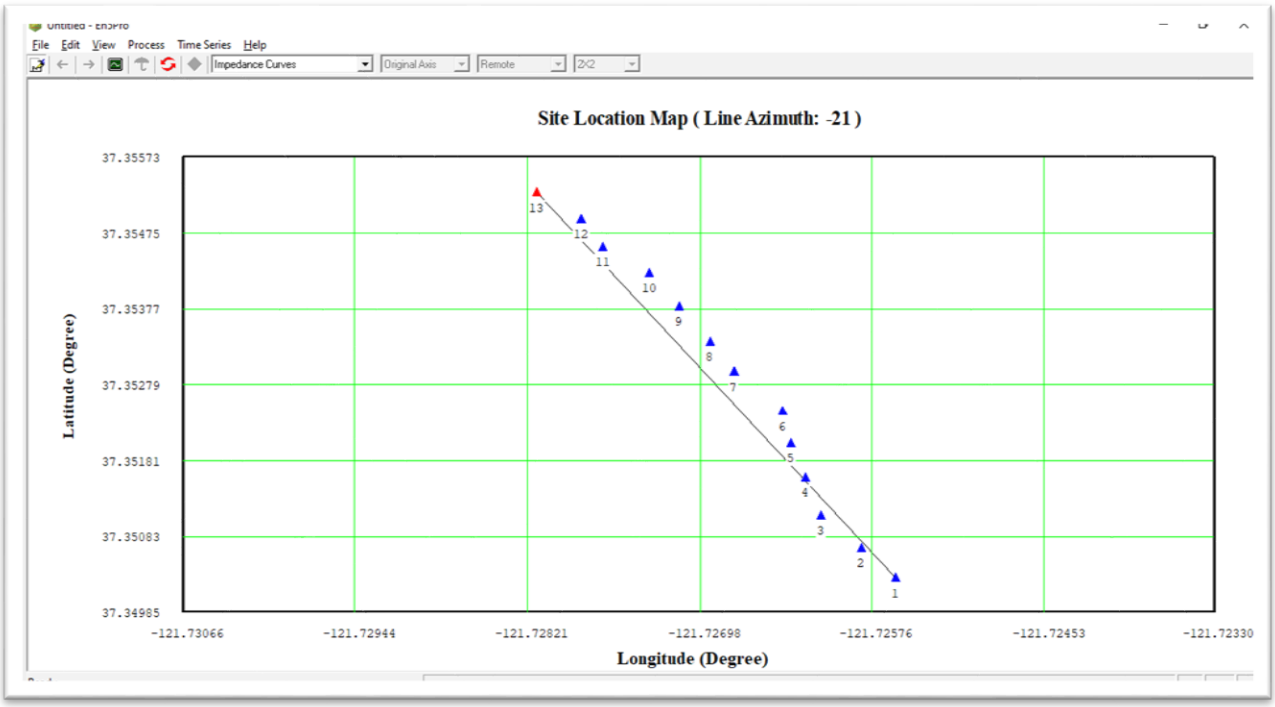


Figure 5-2 – Set default profile

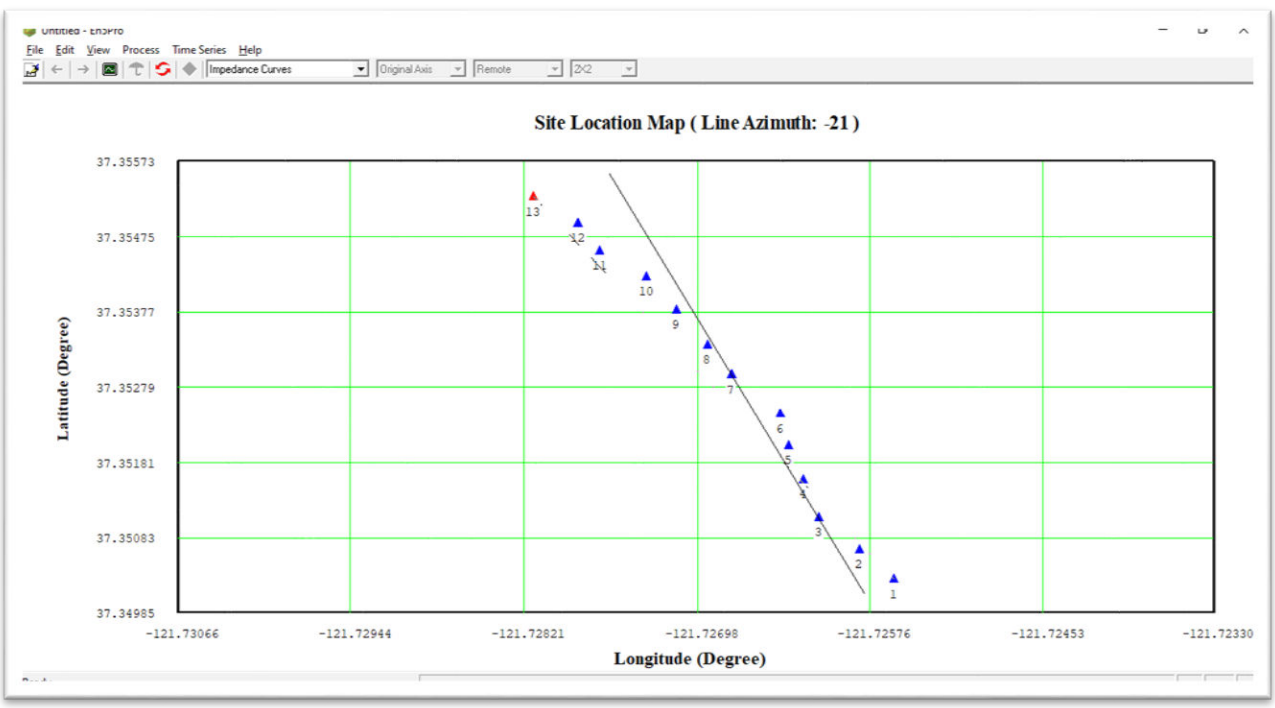


Figure 5-3 – Profile projection after manually setting the profile

CAUTION: The station can be disabled on the site location map if you are in the **Edit** mode by pressing the icon and then left clicking on a site position. Left clicking the disabled station again will enable it. If you are not in the Edit mode then right clicking the position has no effect. Right clicking the site location will take you to the impedance curve screen. If the site has been disabled you will see the screen below. The top header will be red with the label **disabled** displayed.

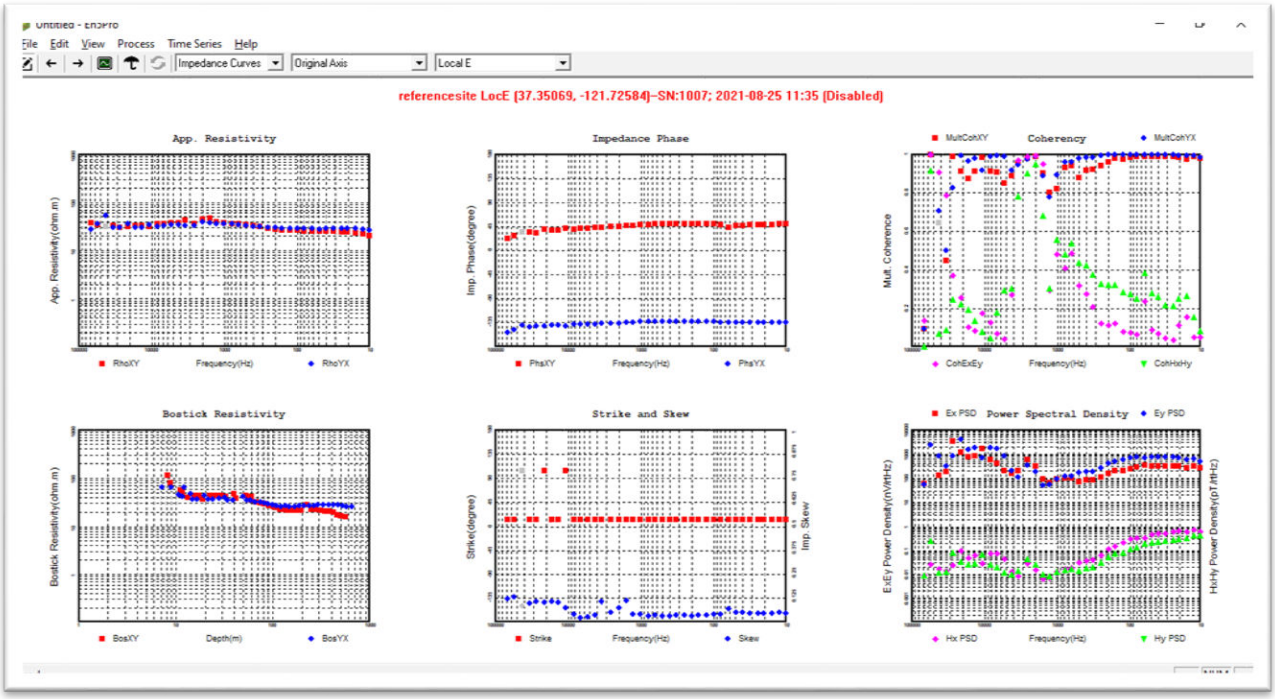


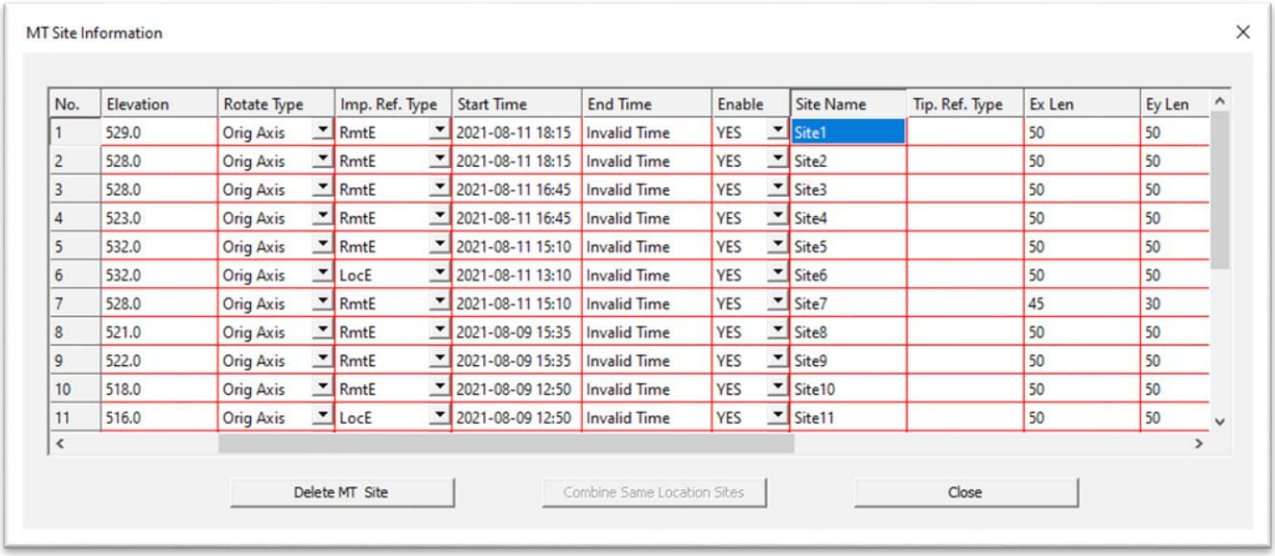
Figure 5-4

When the **edit** icon is clicked, you may swap the XY and YX positions by placing the cursor on a phase or impedance and left clicking.

5.2 Creating and viewing site names:

5.2.1 Site name

To name the site locations go to **Edit>>MT Site List** as shown below:



No.	Elevation	Rotate Type	Imp. Ref. Type	Start Time	End Time	Enable	Site Name	Tip. Ref. Type	Ex Len	Ey Len
1	529.0	Orig Axis	RmtE	2021-08-11 18:15	Invalid Time	YES	Site1		50	50
2	528.0	Orig Axis	RmtE	2021-08-11 18:15	Invalid Time	YES	Site2		50	50
3	528.0	Orig Axis	RmtE	2021-08-11 16:45	Invalid Time	YES	Site3		50	50
4	523.0	Orig Axis	RmtE	2021-08-11 16:45	Invalid Time	YES	Site4		50	50
5	532.0	Orig Axis	RmtE	2021-08-11 15:10	Invalid Time	YES	Site5		50	50
6	532.0	Orig Axis	LocE	2021-08-11 13:10	Invalid Time	YES	Site6		50	50
7	528.0	Orig Axis	RmtE	2021-08-11 15:10	Invalid Time	YES	Site7		45	30
8	521.0	Orig Axis	RmtE	2021-08-09 15:35	Invalid Time	YES	Site8		50	50
9	522.0	Orig Axis	RmtE	2021-08-09 15:35	Invalid Time	YES	Site9		50	50
10	518.0	Orig Axis	RmtE	2021-08-09 12:50	Invalid Time	YES	Site10		50	50
11	516.0	Orig Axis	LocE	2021-08-09 12:50	Invalid Time	YES	Site11		50	50

Figure 5-5 – Site Information screen

To display the site names on the site location map go to **View/Display Settings** to see the following menu:

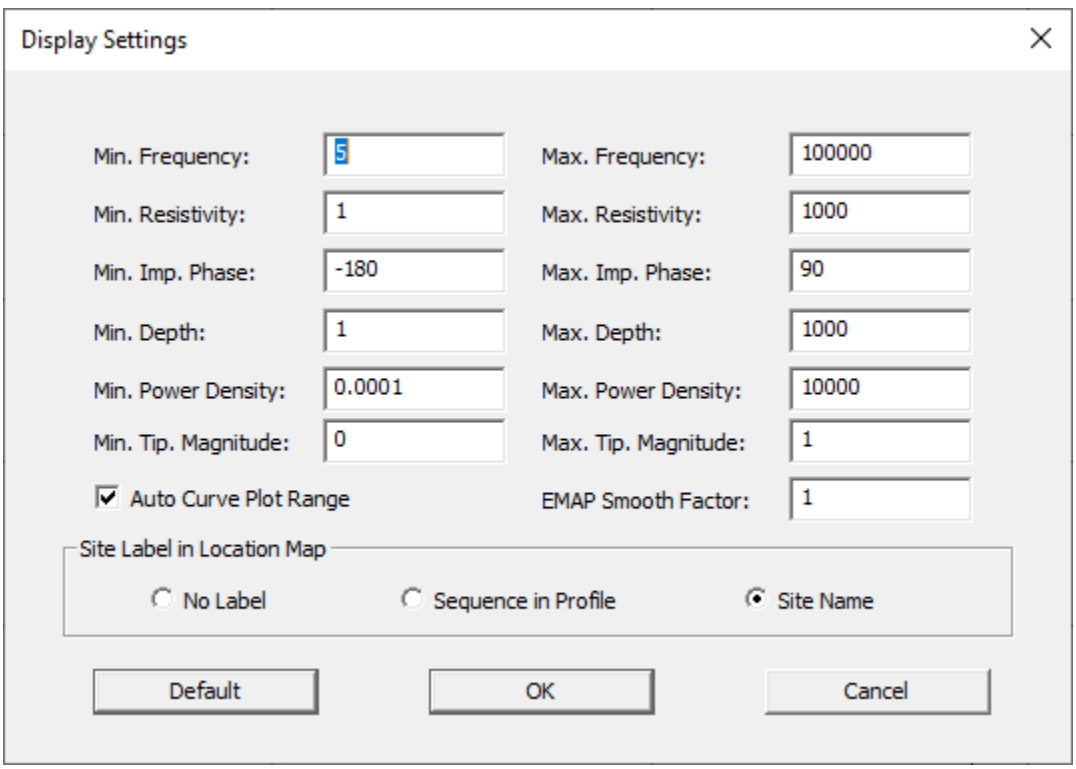


Figure 5-6 – View, display, and edit display parameters here.

Click **Site Name** and **OK** to see the site names displayed as follows:

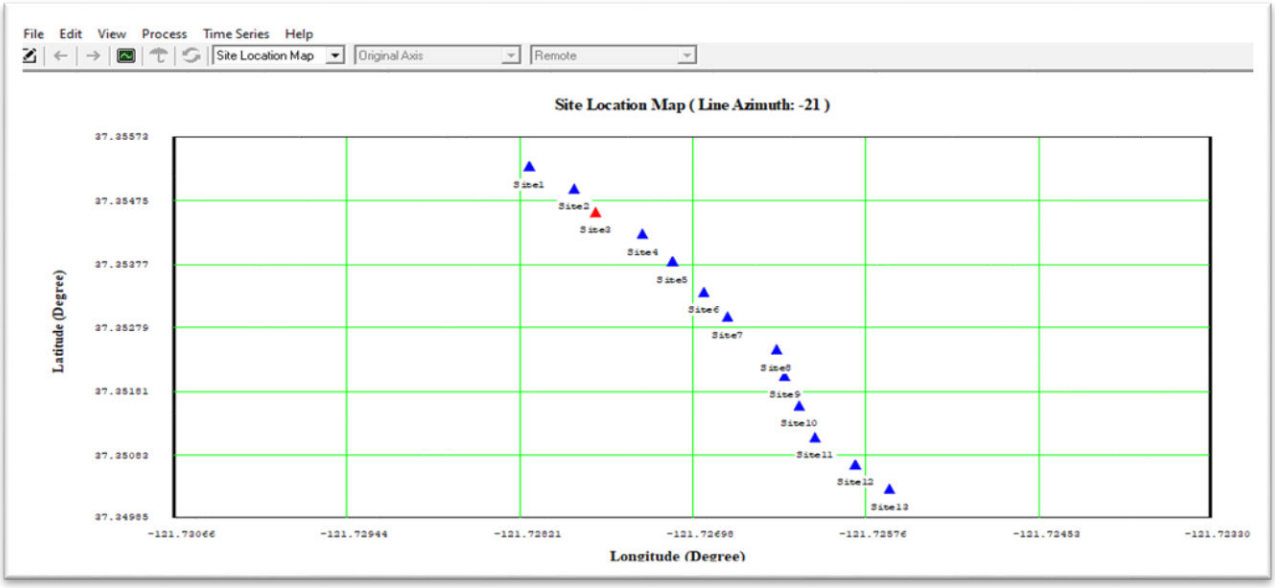


Figure 5-7 – Plot showing the data labeled during the previous step.

6.0 Top Menu Bar Options

6.1 Opening and exporting file type:

6.1.1 File

A. **Open**: This allows you to open a *.EH5 file that was previously saved from **Save** or **Save As**.

B. **Save** and **Save As**: Allows you to save processed and edited TS files as a .EH5 file to save all the edits and processing.

C. **Close**: Closes the currently open file in EH5Pro.

D. **Export EDI** File: Export data in a .EDI format.

E. **Export EMAP to XYZ File**: Creates a standard ASCII file with EMAP data with **Offsetv**(line position), **Depth**, and **Resistivity**.

F. **Export KMZ File**: Exports GPS station locations as Google Earth .KMZ files. For example the follow KMZ files can be opened in Google Earth:

Name	Date modified	Type	Size
Site1.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site2.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site3.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site4.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site5.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site6.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site7.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site8.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site9.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site10.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site11.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site12.kmz	9/10/2021 2:39 PM	KMZ	1 KB
Site13.kmz	9/10/2021 2:39 PM	KMZ	1 KB

Figure 6-1 – Data saved as kmz files

To show the following map.

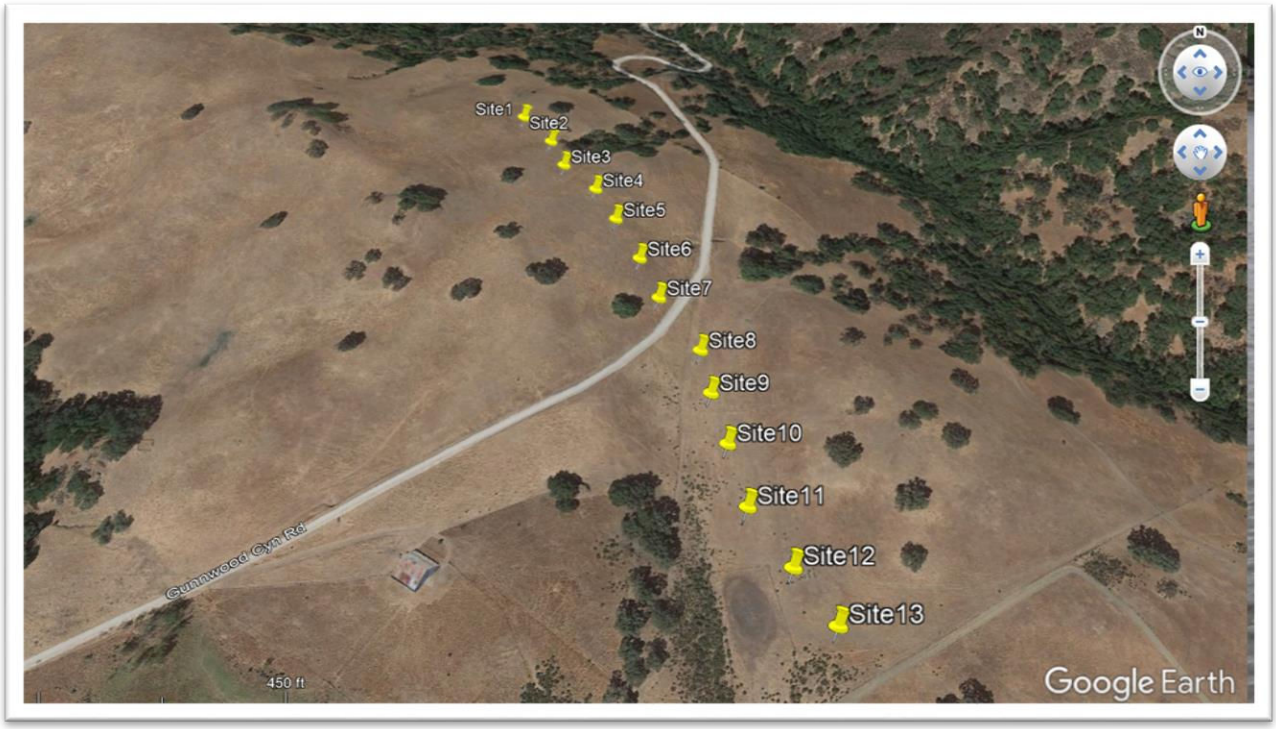


Figure 6-2 – Data from previous figure displayed on Google Earth.

G. **Download EH5 data files**: This allows you to download EH5 TS files directly from the EH5 receiver. The receiver must be turned on and the Windows device must be connected to the receiver's WiFi. The EH5 network is EH5****, where **** is the serial number of the receiver box. For example the WiFi name EH51007 is generated by receiver serial number 1007.

H. Click on **File\Download EH4 Data File** to see the following menu which will show the TS files that are in the EH5 receiver – in this case for receiver number 1007.

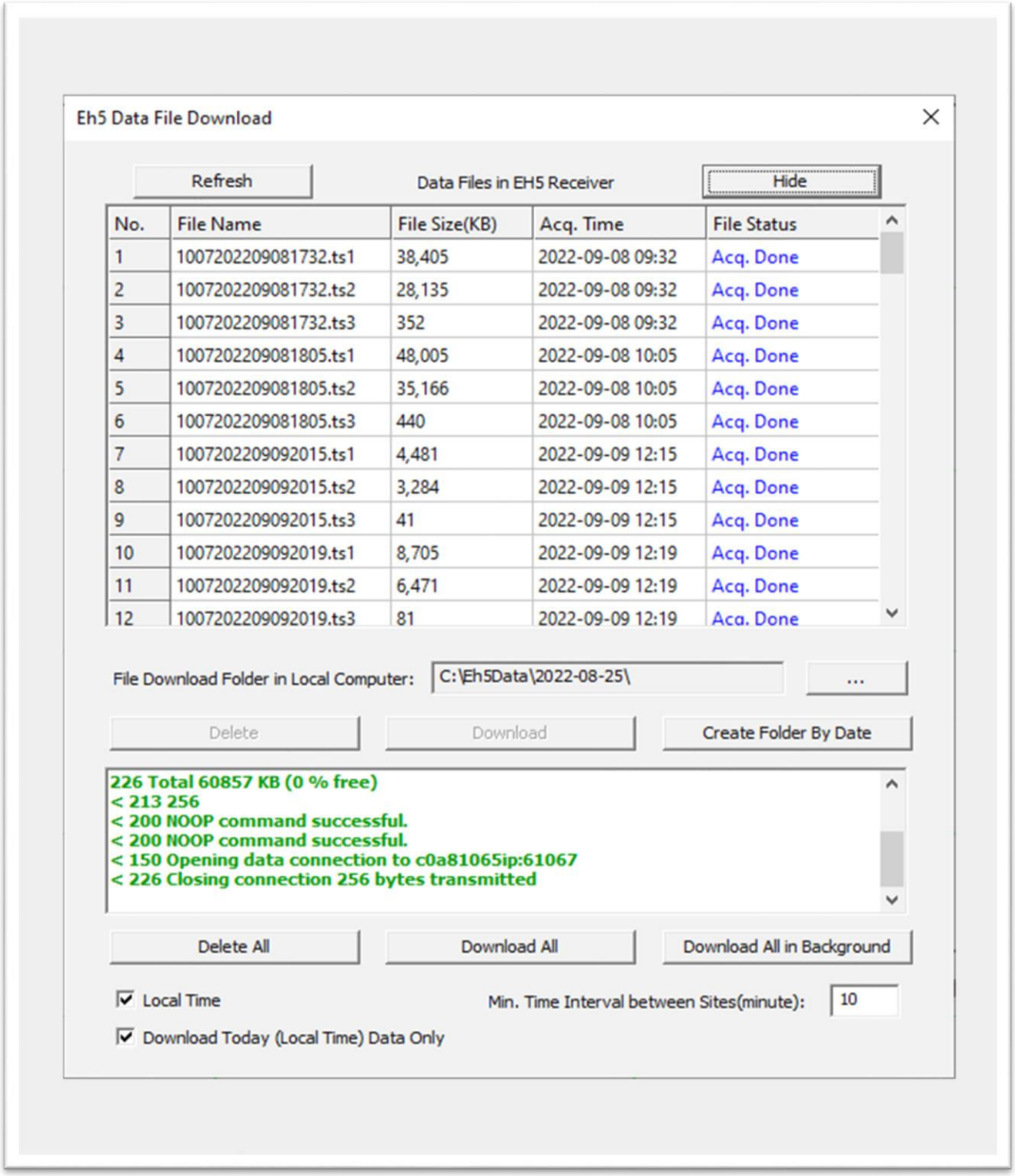
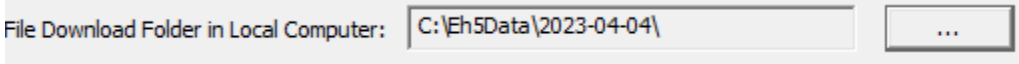


Figure 6-3 – TS files stored in the EH5 Receiver.

I. The menu will allow you to delete TS files or to download them to the Windows device for data processing. Selecting a TS file will activate the “Delete” button which can be clicked to delete the selected file(s). Clicking on “Delete All” will delete all the data files in the receiver’s memory.

J. When downloading the files, a folder is automatically created on the Windows tablet or PC. The folder name and location is displayed as the data is downloading. You can manually create the data folder by clicking the three periods on the right side of the screen as seen below:



K. **EH5 Acquisition Parameters**: Allows you to view and edit the EH5 acquisition parameters as shown in the image below:

L. **Upgrade EH5 web based GUI**. This requires a connection to the EH5 receiver and will allow for sending upgrades to the EH5 receiver.

M. **Upgrade EH5 firmware**: This requires a connection to the EH5 receiver and will allow for sending firmware upgrades to the EH5 receiver. If you are only using Ex, Ey, Hx, and Hy change the "Rec. Channels" to 4. This allows for faster data download times since it is not downloading data that is only noise on channel 5.

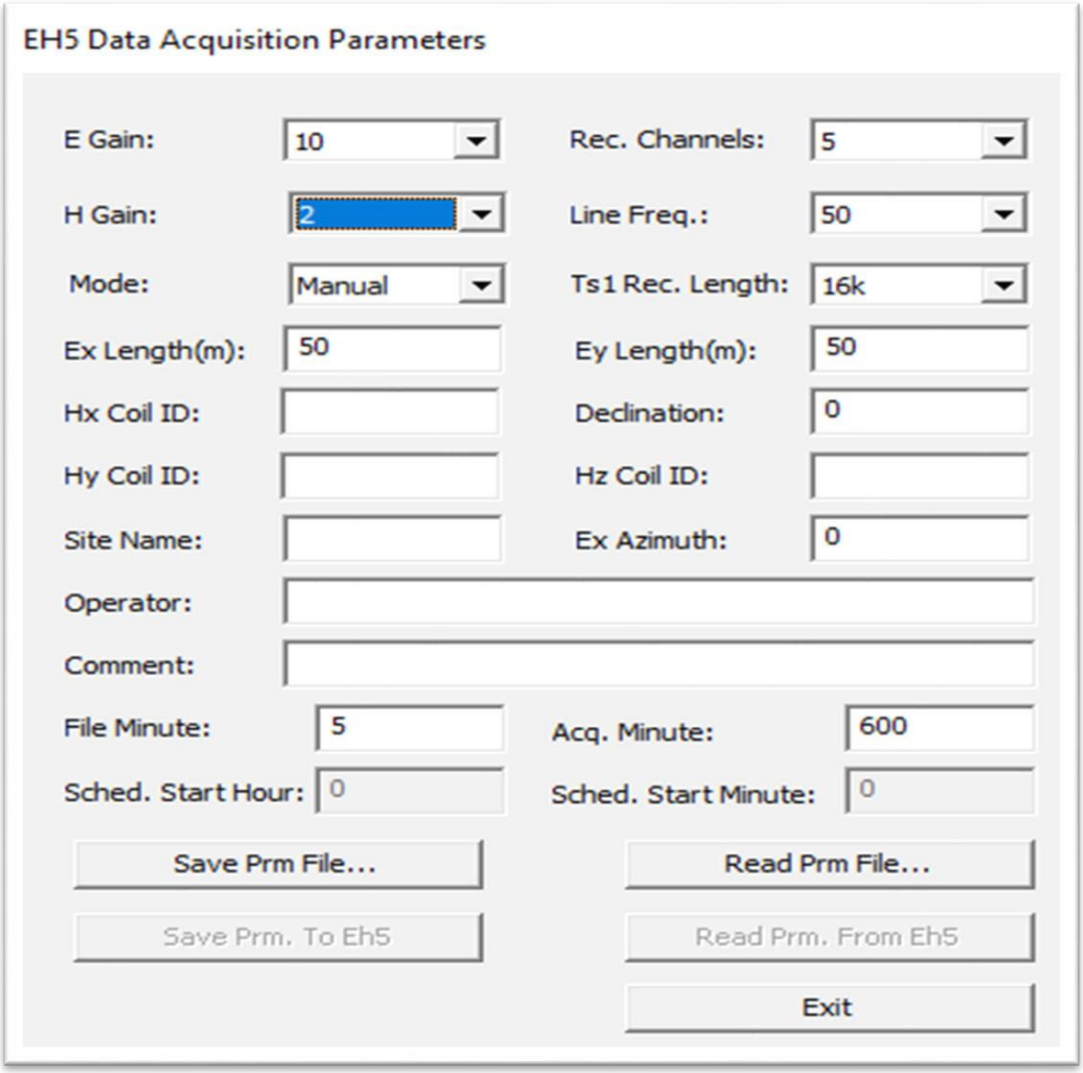
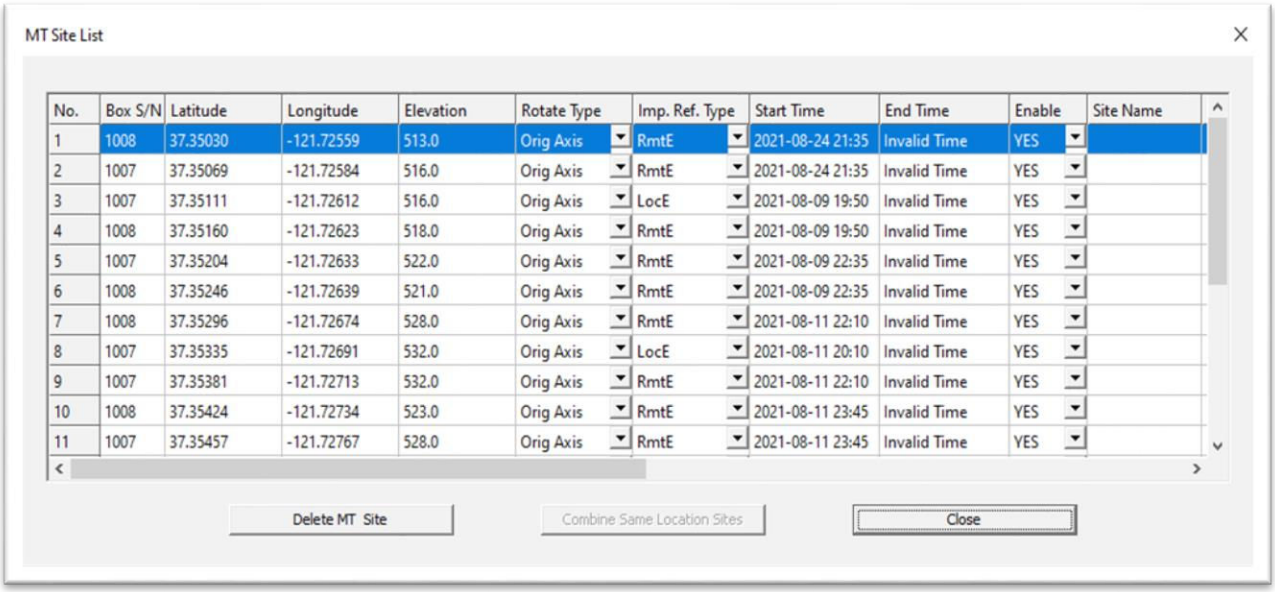


Figure 6-4 – Screen for reviewing or editing EH5 Acquisition Parameters

Editing

MT Site List: Provides information about each station such as serial number of the receiver, GPS position, etc. **Enable** allows the user to choose to use or not use that station in the processing. Clicking the site information will display the screen below. Site names can be changed in this menu.



MT Site List

No.	Box S/N	Latitude	Longitude	Elevation	Rotate Type	Imp. Ref. Type	Start Time	End Time	Enable	Site Name
1	1008	37.35030	-121.72559	513.0	Orig Axis	RmtE	2021-08-24 21:35	Invalid Time	YES	
2	1007	37.35069	-121.72584	516.0	Orig Axis	RmtE	2021-08-24 21:35	Invalid Time	YES	
3	1007	37.35111	-121.72612	516.0	Orig Axis	LocE	2021-08-09 19:50	Invalid Time	YES	
4	1008	37.35160	-121.72623	518.0	Orig Axis	RmtE	2021-08-09 19:50	Invalid Time	YES	
5	1007	37.35204	-121.72633	522.0	Orig Axis	RmtE	2021-08-09 22:35	Invalid Time	YES	
6	1008	37.35246	-121.72639	521.0	Orig Axis	RmtE	2021-08-09 22:35	Invalid Time	YES	
7	1008	37.35296	-121.72674	528.0	Orig Axis	RmtE	2021-08-11 22:10	Invalid Time	YES	
8	1007	37.35335	-121.72691	532.0	Orig Axis	LocE	2021-08-11 20:10	Invalid Time	YES	
9	1007	37.35381	-121.72713	532.0	Orig Axis	RmtE	2021-08-11 22:10	Invalid Time	YES	
10	1008	37.35424	-121.72734	523.0	Orig Axis	RmtE	2021-08-11 23:45	Invalid Time	YES	
11	1007	37.35457	-121.72767	528.0	Orig Axis	RmtE	2021-08-11 23:45	Invalid Time	YES	

Delete MT Site | Combine Same Location Sites | Close

Figure 6-5 – Screen for viewing or editing site locations.

Click on **No**. (Site Number) to highlight the site, then click **Delete MT Site** to remove the site. Click on **Combine Duplicate Sites** to combine sites with the same location.

Elevation information can be read from the receiver GPS or entered manually. Menu items include:

A. **Parallel Noise Test List**: Provides information about a parallel noise test that has been performed.

B. **Short Circuit Noise List**: Provides information about a short circuit test that has been performed.

C. **Rotate All Sites**: This mathematically rotates the orientation of the sensors for all sites.

   a. **Original Axis** is the original orientation in the field of the X-direction sensors

   b. **Max Zxy** rotates the impedances to maximize the amplitudes of the X-direction impedances.

   c. **Max Zyx** rotates the impedances to maximize the amplitudes of the Y-direction impedances.

d. **Fixed Strike** rotates the station to any orientation selected by the user.

D. **Set All Site Impedance Reference Type** and **Set All Site Tipper Reference Type**: These options allow you to select what type of referencing can be used.

a. **RMT** uses a remote site as the reference. This requires two receiver boxes.

b. **Loc H** uses the local magnetic data as the reference. This can be done with a single receiver box.

c. **Loc E** uses the local electric field measurements as the reference. This can be done using a single receiver box.

d. **Scalar** uses only scalar measurements. This is generally not recommended.

E. **Set Default Profile**: Shows a line that indicates the default profile azimuth.

F. **Reverse Profile Azimuth**: Changes the line azimuth by 180 degrees.

G. **Enable All Frequencies**: Re-enables any frequencies that have been previously masked out.

H. **Delete Frequencies**: Allows the user to delete all frequencies above or below set boundaries.

I. **Reverse Zxy Phase**: Reverses the X direction phase by 180 degrees

J. **Reverse Zyx Phase**: Reverses the y direction phase by 180 degrees

6.2 View

A. **Toolbar**: Turn on or off the tool bar at the top of the screen.

B. **Status Bar**: Turn of or off the tool bar at the bottom of the screen.

C. **Display Settings**: Allows user to set the plot scales, as in menu below. If the "Auto Curve Plot Range" is checked the resistivity scale will automatically ajust to the data resistivity range.

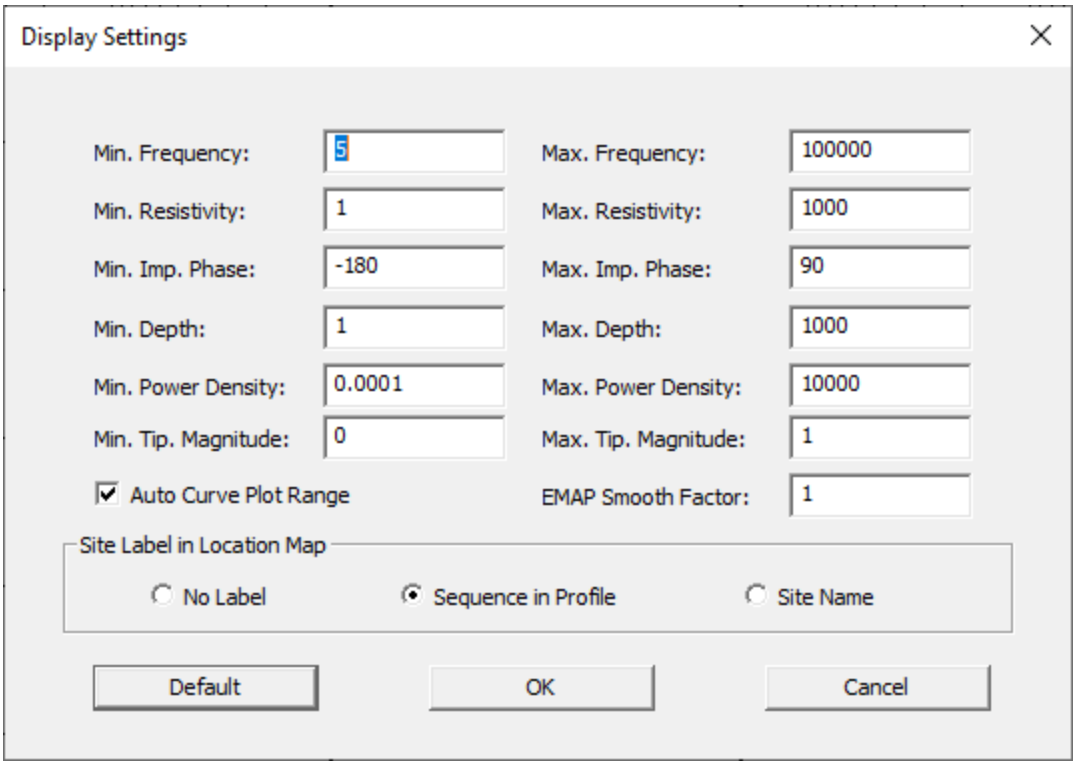
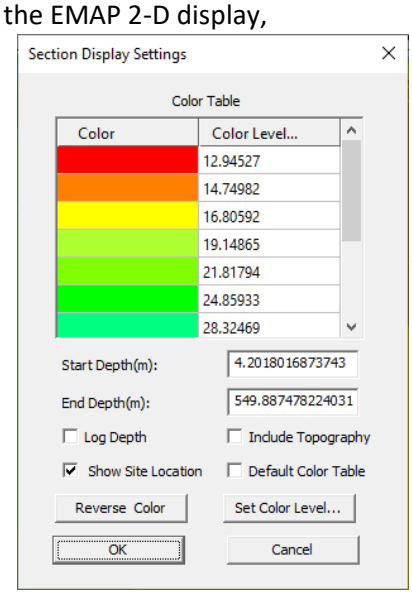


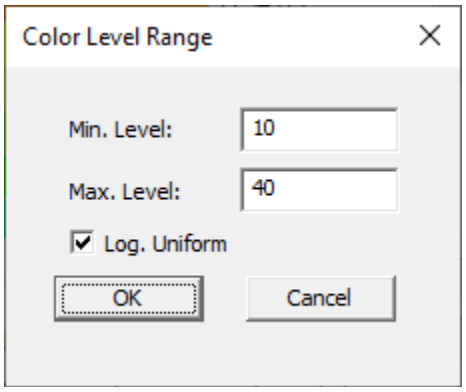
Figure 6-6 Display Parameters

The **Display Parameters** in the top box allows the user to set the screen display scale for the parameters shown in Figure 6-6 above.

EMAP Display Settings: This allows changing the EMAP display. This only is active when an EMAP 2-D section is created. The color settings are shown as below: The depth scale for start and stop of depth of the 2-D section can be set here. Clicking on "Set Color Level" will allow you to change the minimum and maximum color scale used for the EMAP 2-D display,



"Set Color Level" will display the following screen to set the color scale:



6.3 Processing and Reprocessing Data:

6.3.1 Data Processing

A. **MT Process**: This is explained in more detail above in section "3.0 Process – "Data Processing". It allows the user to add, clear (close), or delete TS files. It also tells the software where the coil calibration files are located.

B. **Re-Processing**: Reprocessing of formerly processed data can sometimes be used to improve the quality of the data. When you choose **Re-Processing**, the menu in Figure 4-7 is displayed:

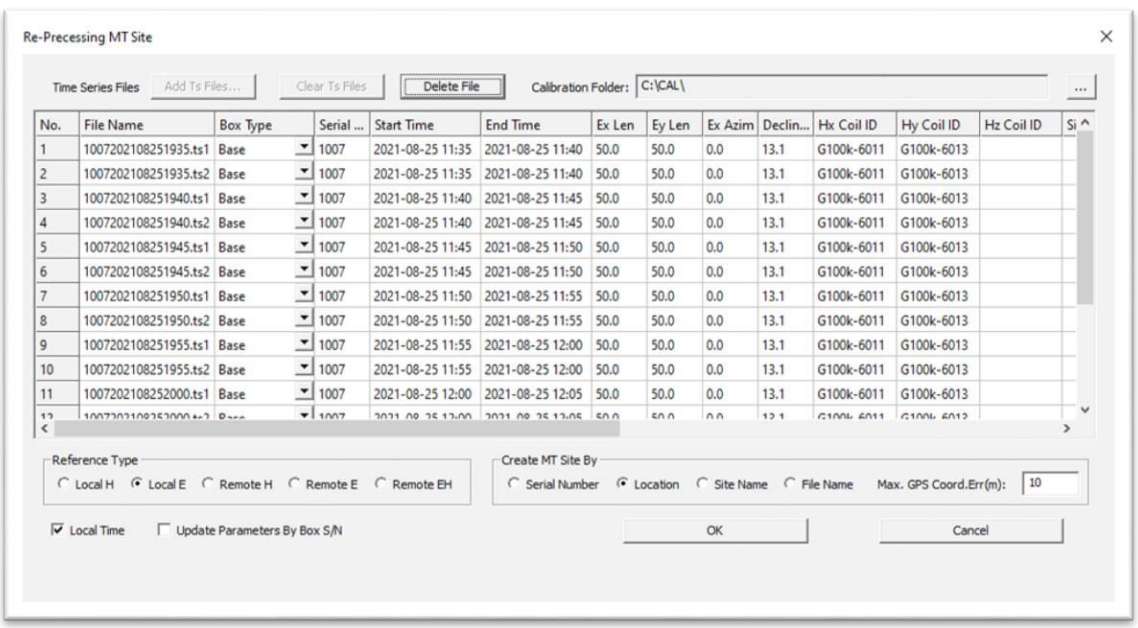


Figure 6-7

C. Note the following when re-processing data:

   a. The reference type and MT site type can be changed.

b. If the GPS locations of two soundings are greater than the Max. GPS Coord. Err (m) the two soundings will be treated as two separate sites. If the distance is less than the Coord. Err the two soundings will be combined as one site.

c. If local time is checked the local computer time is used. If it is unchecked GMT time is used.

d. The correct calibration folder must be indicated in the Calibration Folder field.

D. **Undo Processing**: Reverts the data to before the previous processing.

E. **Parallel Noise Processing**: This allows the operator to set up the two H coils parallel to one another, and the two electrodes parallel to one another but perpendicular to the two H coils. The parallel data is then used to display the noise level on the sensors and display parallel apparent resistivity and phase. The noise processing menu is as follows:

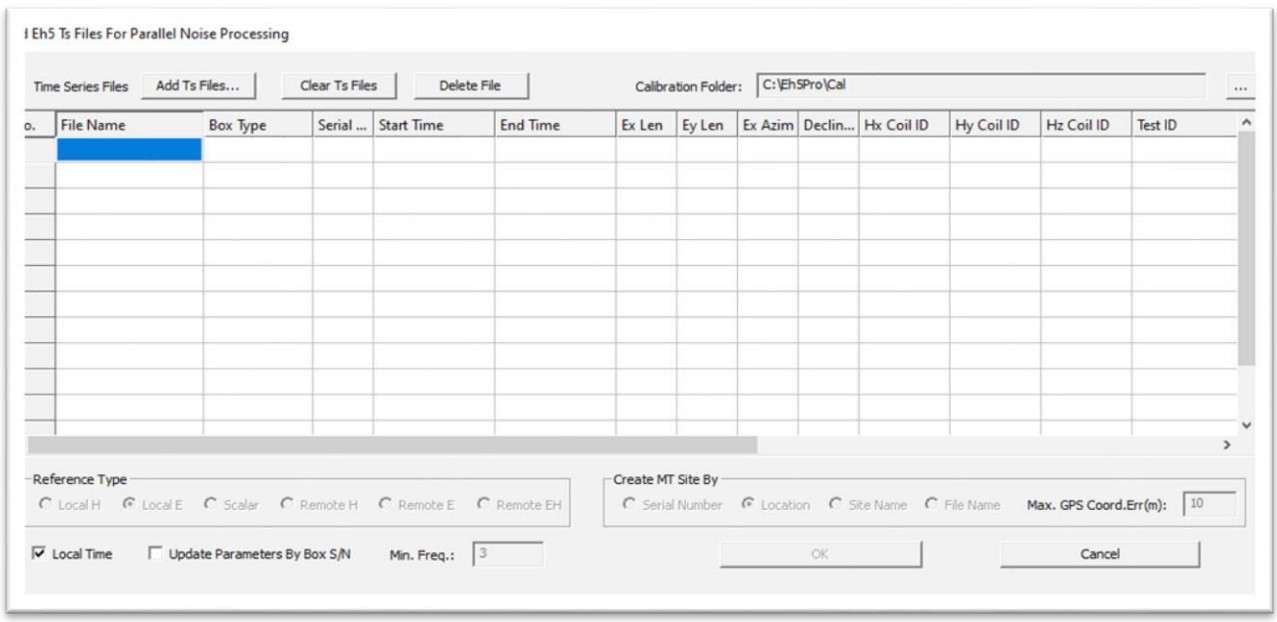


Figure 6-8

After acquiring the data in the parallel mode, click **Add TS Files** to read the TS files that were created during the parallel test. Read in the files and click **OK**. The noise test screen similar to the one below will be displayed showing system noise levels on the electric and magnetic channels.

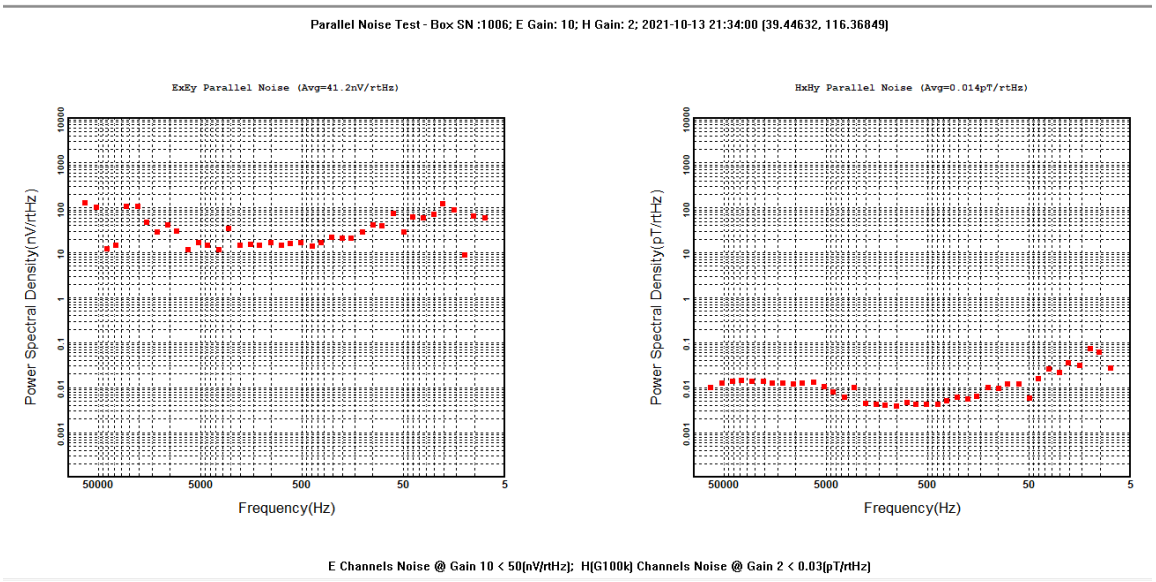


Figure 6-9

F. **Short Circuit Noise Process**: This test is done with all channel terminals shorted together. It is a quality control noise test that is done on all systems before shipment from the factory.

G. **Process All Files in Downloaded Folder** (also Recent Files and Last Site): This tells the software what files you want to process.

H. **Process Today (local time) Data**: This will process only data from the current date.

I. **Process Last MT Site:** This wil process only data from the most recent site.

6.4 Time Series:

A. **Set Time Series Display Gain**: This is screen gain only. It does not affect the acquisition gain.

   a. **Fix Gain**: allows the user to set a pre-determined display gain for the E and H channels. It does not automatically change based on the signal amplitude.

   b. **Auto Gain**: set each channel's display gain independently based on the signal amplitude and the width of the display channel.

   c. **Same Auto Gain for the Same Ch Type** will automatically set the gain for both E channels to the same gain setting and both H channels to the same setting. The gains for E and H can be different. This is generally the recommended setting for best in-field quality control.

B. **TS File Head Information**: This shows details of the displayed time series file.

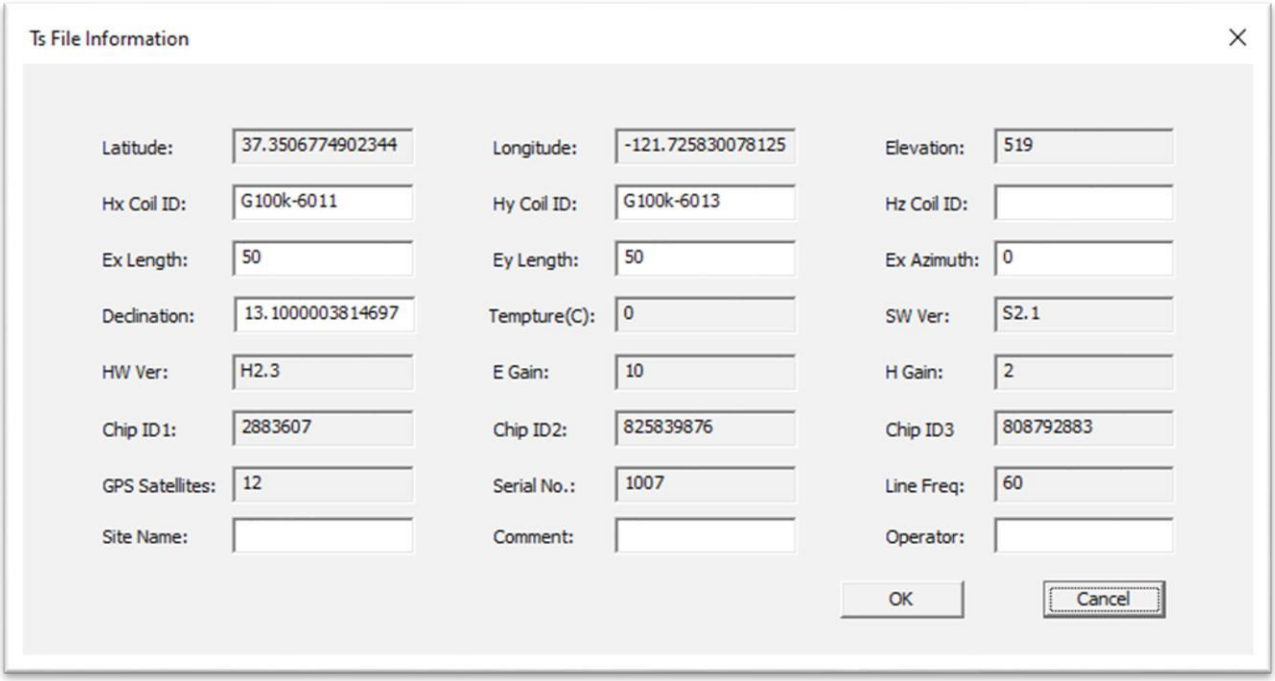


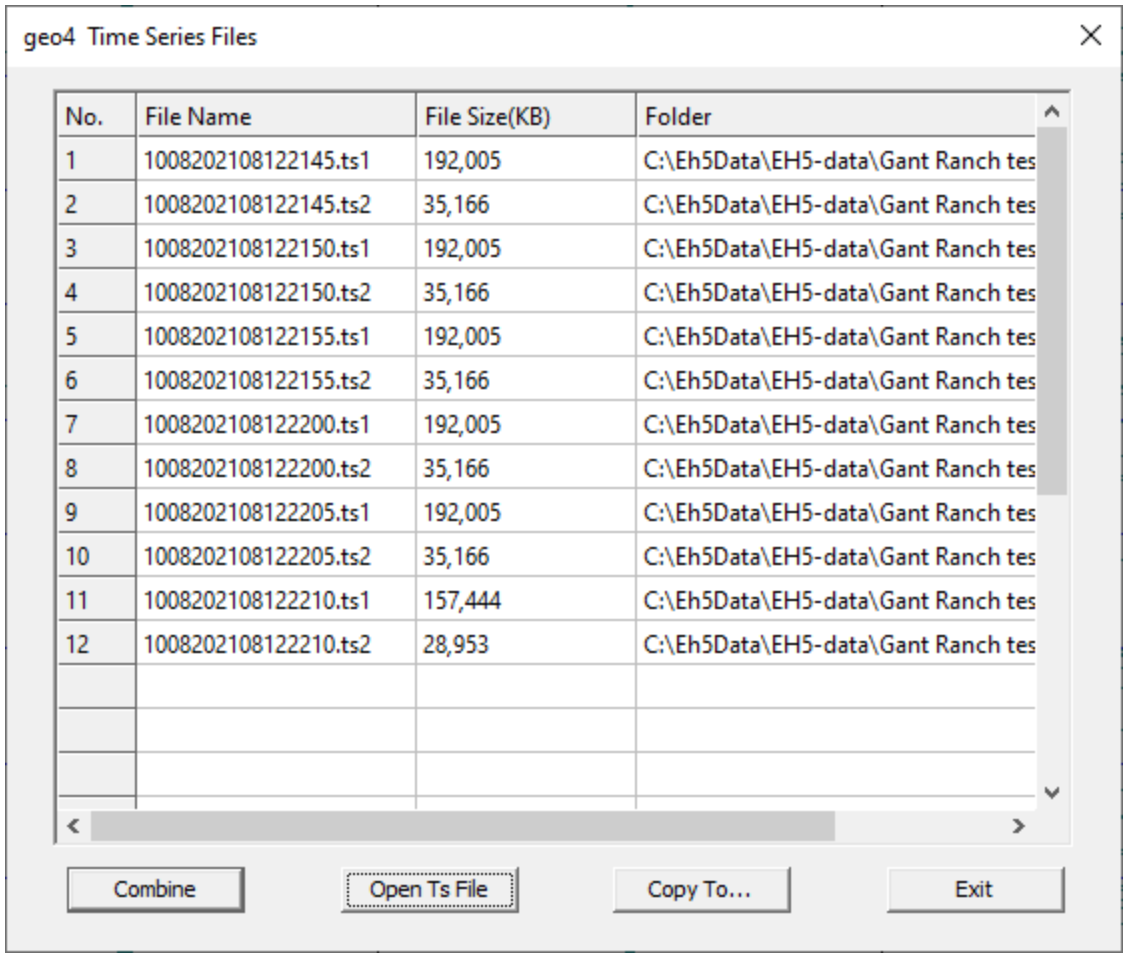
Figure 6-10 – Acquired time series information

C. **Open Time Series File**: This will allow you to navigate to the folder with your survey data an select the time series files you want to view.

D. **Save Time Series File**: After editing (masking out) individual time series records in the file they need to be saved to use the edits in data processing. It is recommended that the edited file be given a new name to show it has been edited.

E. **Go To Record**: Allows you to view a specific recorded in the selected TS file. For example, if there are 150 records in the selected TS file and you enter “132” it will show record number 132 in the file.

F. **Check Current Site Time Series**: This will show all the TS files available at the same site based on the GPS location of the site.



No.	File Name	File Size(KB)	Folder
1	1008202108122145.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
2	1008202108122145.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
3	1008202108122150.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
4	1008202108122150.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
5	1008202108122155.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
6	1008202108122155.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
7	1008202108122200.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
8	1008202108122200.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
9	1008202108122205.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
10	1008202108122205.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
11	1008202108122210.ts1	157,444	C:\Eh5Data\EH5-data\Gant Ranch tes
12	1008202108122210.ts2	28,953	C:\Eh5Data\EH5-data\Gant Ranch tes

Figure 6-11 – Time series menu

Clicking on a time series and **Open Cur. Ts File** allows you to view all the time series for that record. Also notice the "Combine" button. If that is cliced all the TS1 files will be combined in a single large TS1 file and given a name indicating the station for the data. For example if you are working in station "Site1" and clicked "Combine" it would create new TS1, TS2, and TS3 files as shown below.

Name	Date modified	Type	Size
Site1_1013202303260123.ts2	5/23/2023 9:50 AM	TS2 File	544,013 KB
Site1_1013202303260125.ts3	5/23/2023 9:50 AM	TS3 File	6,683 KB
Site1_1013202303260123.ts1	5/23/2023 9:50 AM	TS1 File	742,473 KB

This each file combines all the TS file of its type fot that station. If you want to review all the mid-band TS2 files you would do the following after creating the TS station files:

F. Click "Time Series\Open Time Series File"

G. Select the combined TS file you want to edit, for example "Site1_1013202303260123.ts2"

H. Click Open to see the time series

I. Use the “Enter” key to move forward through the records and he back arrow key to more back. The the “Delete” key to mask out a time series record.

J. After editing the file go to “Time Series\Save Time Series File”.

K. Select the file and give it a new name. Perhaps “Site1_1013202303260123-edit1.ts2

6.5 Viewing EH5 acquisition parameters:

6.5.1 EH5 Parameters:

The EH5 Data Acquisition Parameters table provides information about the EH5 receiver acquisition parameters. To change the receiver parameters from EH5Pro do the following.

A. Open parameter file at **File\EH5 Acquistion Parameters**

B. Review or change the acquisition parameters

C. Click **Save Prm File** to save the changes.

D. Click **Save Prm to EH5** to update the acquisition parameters in the EH5 receivers. You must be connected to the EH5 WiFi for this to work.

E. **The Power Line Frequency box** allows the user to select the power lines filters to be used on the site. North America and parts of South America and the Caribbean use 60 Hz power lines. Most of the rest of the world, with a few exceptions, use 50 Hz.

F. **Help:** About EH5Pro. This menu provides information about the EH5Pro license.

7.0 Top Tool Bar Icons (from left to right)

7.1 Editing data apparent resistivity and phase data points

A. **Edit** icon : The edit icon allows the user to edit individual apparent resistivity and phase points from the Apparent Resistivity and Impedance Phase curves. In all screens, the **red** points are for the X-direction Ex:Hy sounding curve, and the **blue** curves are for the Y-direction Ey:Hx sounding curve.

   a. Click on the **pencil** icon to active the edit mode.

   b. **Left** click on a point to mask it out. It is not permanently deleted but simply masked so it is not used in the data processing. A masked data point is grayed out and will not be used in the data processing.

   c. To un-mask the data point left click it again. It will go back to the original color and become active again.

   d. Masking an apparent resistivity point will not automatically mask the associated impedance phase resistivity point. Phase points can be masked independently.

   e. Right clicking on a point will swap the positions of the X-direction and Y-direction at that frequency. The nature of an MT measurement is that sometimes there is ambiguity between the tensor X and Y directions. This feature allows the user to swap the directions if it is obvious from the curve that it should be done. Right clicking again will swap them back to their original positions.

B. Left and Right Arrow icons: These are used to scroll through various sites when reviewing data.

C. **Sine Wave** icon: This Sine icon is clicked to stop the time series scrolling when viewing time series. When viewing other screens it will refresh the screen. For example when editing apparent resistivity points the refresh icon must be clicked to see the change in the Bostic resistivity curve.

D. **Umbrella** icon: The umbrella icon is clicked to mask out time series segments or to mask out individual sites so they are not included in the data processing or exported. This only works when looking at the "Impedance Curves" screen. When a site is masked and not to be used the page heading of the impedance curves screen turns red.

E. **Reverse** icon: The reverse icon will switch from the site location map and the impedance curves of the selected station on the map. The site is selected by hovering the pointer over the desired station then right clicking to go back to the impedance curves. When viewing time series display clicking the reverse icon will change it from a times series to a frequency series showing frequency amplitudes.

8.0 Top Tool Bar Pull-Down Menus (from left to right)

8.1 Processed data display list

A. **Impedance Curves:** Display of apparent resistivity, Impedance phase, coherency, Bostick resistivity and depth, strike and skew, E and H spectral power densities.

B. **Impedance polars**: Multiple graphs of polar diagrams as shown below:

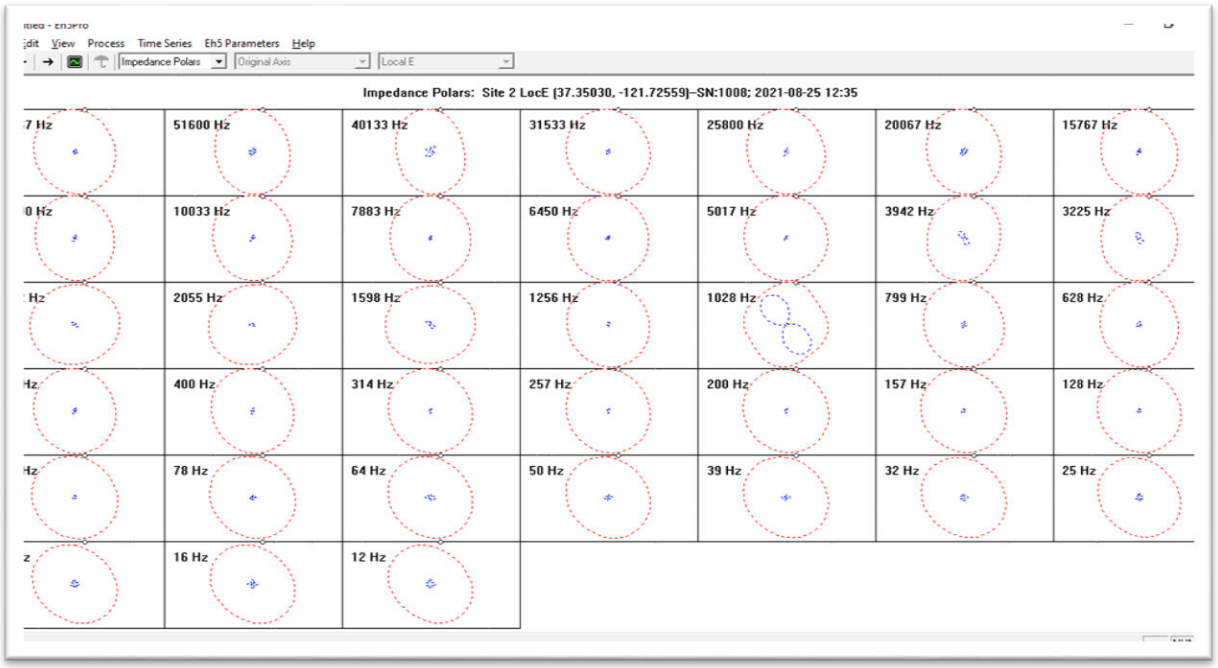


Figure 8-1 – Polar diagrams

Polar curves and skew are indicators of the dimensionality of the geology. The outer red curves are an indication of the change in Zxy impedances as the sensors are mathematically rotated a full 360 degrees. If the blue inner curves are small the geology is 1-D. If the blue curve is large the geology is 2-D or 3-D. When the skew is less then 0.3 the geology is 1-D. When skew is greater than 0.3 the geology is considered to be 2-D or 3-D. The white dot on the red curve is an indication of the orientation of the sensors in the survey line. North is the top of each box and East is the right side of each box. Clicking the left and right arrows on the top menu bar allows you to scroll through the impedance polar diagrams of the stations along the survey line.

C. **Tipper curves**: Only used if vertical H field measurements are done.

D. **Tipper polars**: See “B” above.

E. **Aparent resistivities**: Apparent resistivivities of all sites.

F. **Impedance phase**: Impedance phase of all sites

G. **Bostick Transform**: Bostic curves of all sites

H. **Impedance Strike and Skew**: All sites

I. **EMAP Section**: See details below.

J. **Site Location Map**: Location profile of all sites using GPS locations.

K. **Time Series**: Currently active time series display that have been read in via the Time Series menu.

L. **Parallel Noise**: A test done in the field for quality control purposes. This displays noise when the two magnetic sensors are parallel to each another and the two electric sensors are also parallel to one another but perpendicular to the two magnetic coils. The results of a parallel noise test will display spectral power density of the electric and magnetic fields, scalar resistivity for X and Y, and X and Y impedance phase.

M. **Short Circuit Noise**: Quality control test done in the factory.

8.2 Displaying 2-D Bostick-EMAP sections

A. **EMAP section**: An EMAP section is created using 1-D Bostick transform of apparent resistivity and frequency to resistivity and depth. It is not a 2-D inversion. It is based on a 1-D Bostick transformation of multiple stations with a lateral smoothing filter used to reduce station to station noise and to reduce the effects of static offset. See Figure 8-2 below.

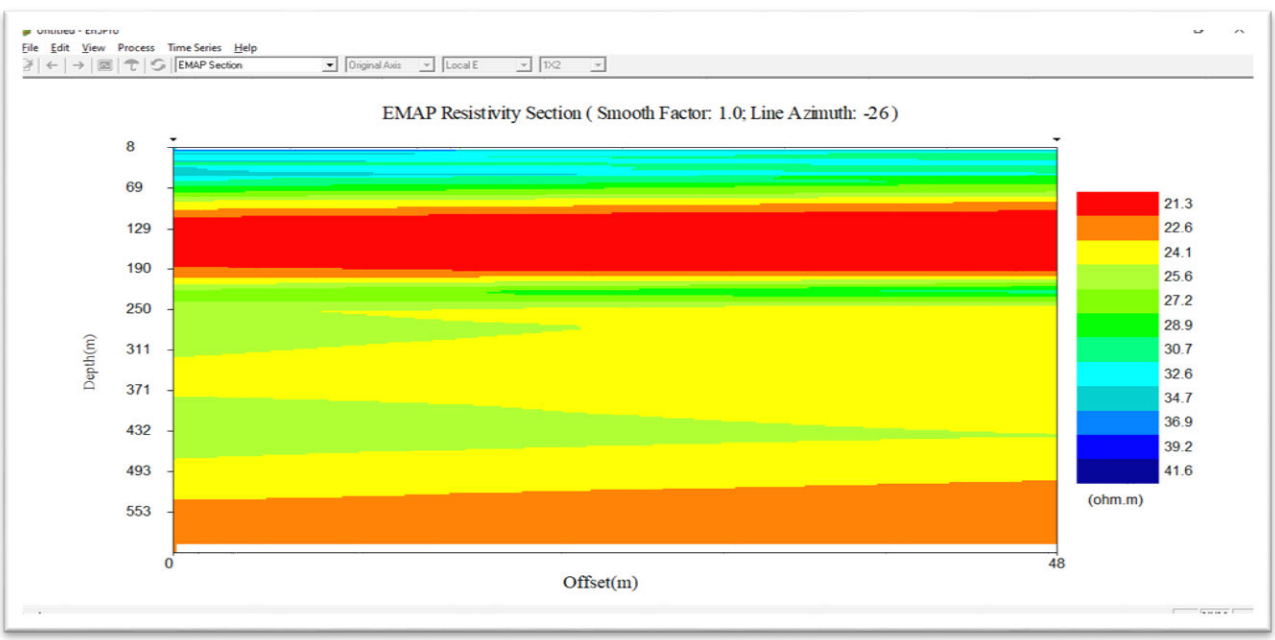


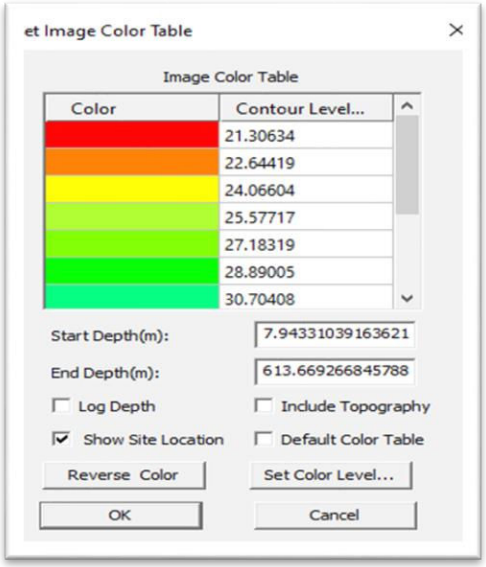
Figure 8-2 Bostick-=EMAP depth section

Figure 8-3 – Table used for customizing the image display.

B. **EMAP display control**: To see the EMAP display control menu, you must first create an EMAP section such as the one shown above. This is done after multiple stations are read into EH5Pro and "EMAP Section" is selected from the plot type menu on the top tool bar.

C. Click **View** from the top menu bar and select **Set Image Color Table** to see the control menu below.

D. To change the depth scale, enter **Start Depth(m) and End Depth(m)**. For example, in the image above, the depth range is set between 0 to 500 meters. After clicking **OK**, you will see the new section range as below



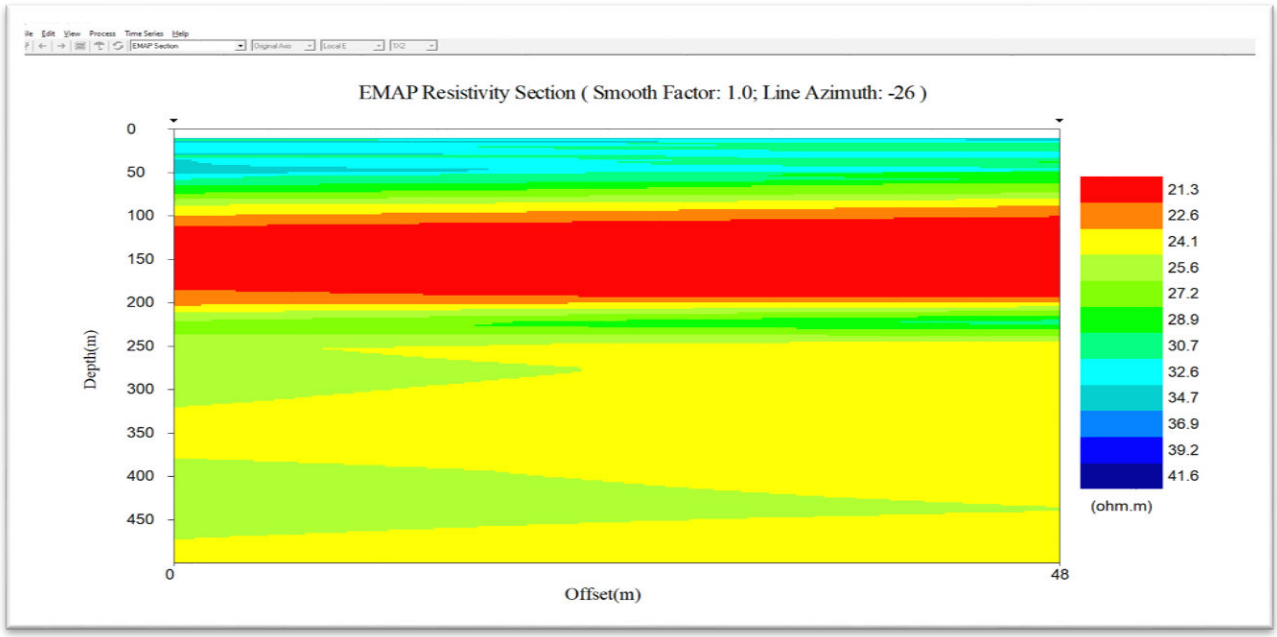


Figure 8-4 – Updated section with adjusted depth scale.

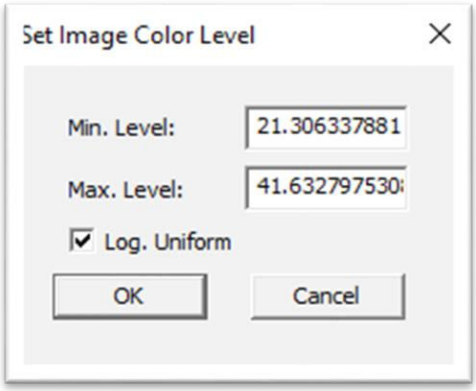


Figure 8-5 – Screen for updating the section's color level.

E. To change the color scale click Set Color Level. The resistivity range can be set on the color level range window displayed after clicking the "Set Color Level" button.

For example, to get a color range from 20 to 35 Ohm-meters enter these values in **Min Level** and **Max Level** and click OK. When the **Set Image Color Table**. is displayed again click on **OK** to see the depth section with the new color settings as below.

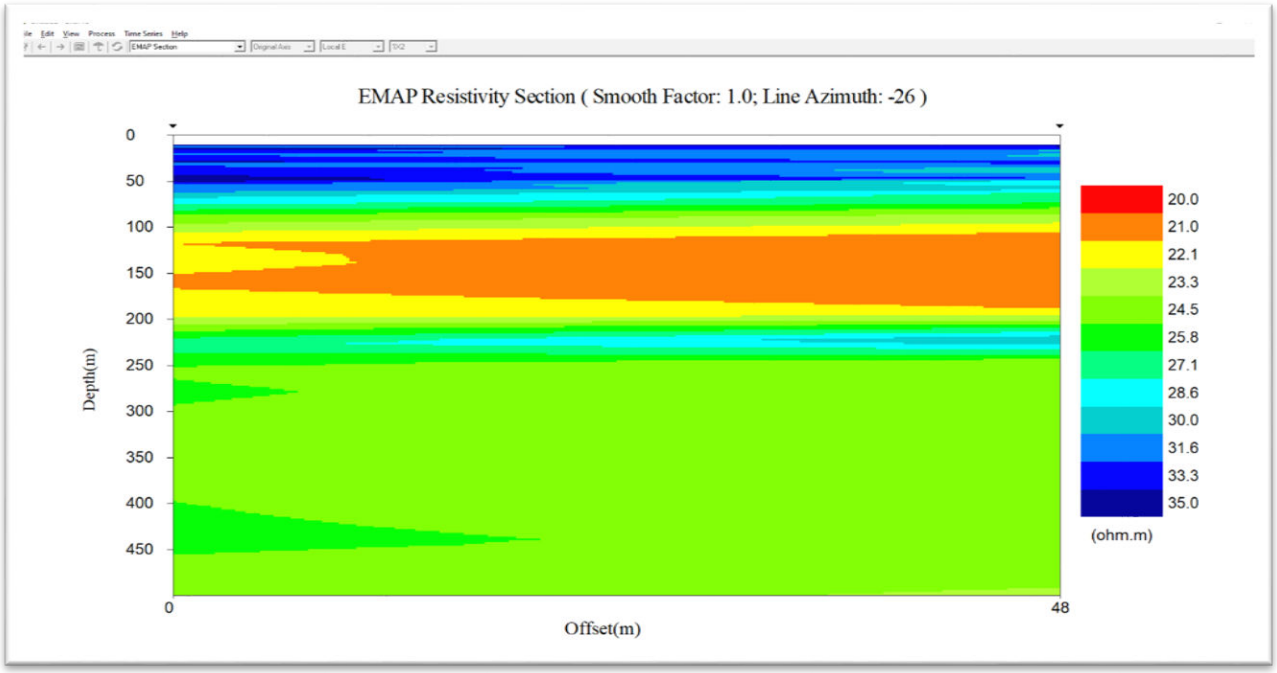


Figure 8-6 – Resistivity section with adjusted color levels.

8.3 Mathematically rotating station orientation

B. **Rotation axis pull-down list**: The difference in this section is the "Edit" above was to rotate all stations. This version will allow the user to rotate each station individually.

1. Original Axis: Use the original orientation of the station.
2. Max Zxy: Rotates the station to the maximum X-direction impedances
3. Max Zyx: Rotates the station to the maximum Y-direction impedances
4. Fixed Strike: Rotates the station to the users choice of orientation.
5. Swap: Swaps the rotation of X and Y sensor orientations.

C. **Local and remote reference pull-down list**: This allows the user to determine the type of referencing desired in the data processing. Remote and local referencing is a method in improve data quality by looking at the spectral content of different channels and using that difference to reduce local and system noise.

D. **Remote:** This is used where there are more than one receiver on a network. The remote reference will be from another receiver's sensors.

E. **Local E:** Is used when there is only one receiver box. The E channels are used as a reference for the other channels.

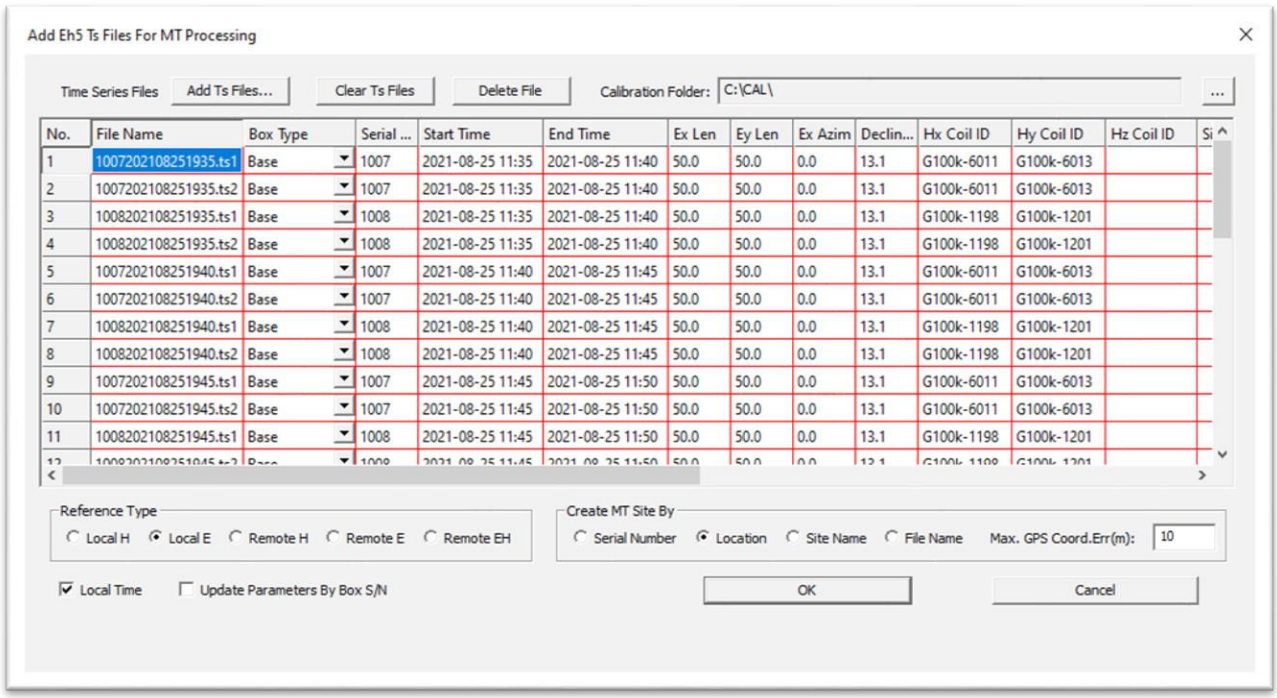
F. **Local H:** Is used when there is only one receiver box. The H channels are used as a reference for the other channels.

9.0 Notes on the use of remote reference

9.1 Setting up remote reference:

The purpose of a remote reference is to remove local noise at the measurement site. Remote referencing requires two receivers at different locations. The remote referencing software will compare the spectral content of the remote reference site to the spectral content at the measurement site. The software will not use frequencies at the measurement site that are not also present at the remote site. The actual processing is more complex than this but the basic concept is valid. The reference can be done using the magnetic sensors, the electric sensors, or both. A remote site with both H and E measurements can also be used as a sounding site.

The **reference** and **sounding** sites are set when the TS files are opened. Go to **Process\MT Process\Add TS Files**. Select the TS files you want to process and click **Open** to see the menu below.



No.	File Name	Box Type	Serial ...	Start Time	End Time	Ex Len	Ey Len	Ex Azim	Declin...	Hx Coil ID	Hy Coil ID	Hz Coil ID
1	1007202108251935.ts1	Base	1007	2021-08-25 11:35	2021-08-25 11:40	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
2	1007202108251935.ts2	Base	1007	2021-08-25 11:35	2021-08-25 11:40	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
3	1008202108251935.ts1	Base	1008	2021-08-25 11:35	2021-08-25 11:40	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
4	1008202108251935.ts2	Base	1008	2021-08-25 11:35	2021-08-25 11:40	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
5	1007202108251940.ts1	Base	1007	2021-08-25 11:40	2021-08-25 11:45	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
6	1007202108251940.ts2	Base	1007	2021-08-25 11:40	2021-08-25 11:45	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
7	1008202108251940.ts1	Base	1008	2021-08-25 11:40	2021-08-25 11:45	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
8	1008202108251940.ts2	Base	1008	2021-08-25 11:40	2021-08-25 11:45	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
9	1007202108251945.ts1	Base	1007	2021-08-25 11:45	2021-08-25 11:50	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
10	1007202108251945.ts2	Base	1007	2021-08-25 11:45	2021-08-25 11:50	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
11	1008202108251945.ts1	Base	1008	2021-08-25 11:45	2021-08-25 11:50	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	

Figure 9-1 – Table showing which MT files are being processed.

To set a site as the remote reference click on **Box Type** and select **Remote** for the serial number of the receiver at the remote site. It will make that serial number the remote for all the acquisitions with that receiver serial number. For example you can see the information available for receiver 1008 below.

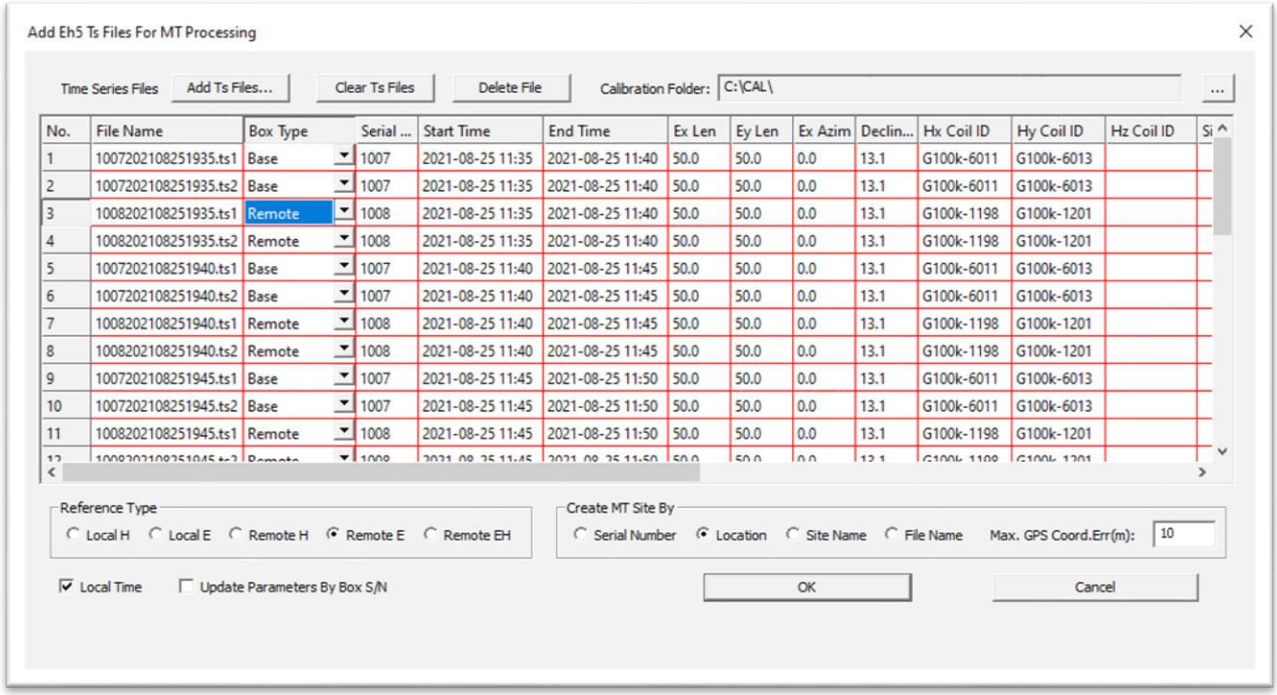


Figure 9-2 – screen showing

9.2 General notes to take in consideration on selecting a remote reference site.

The site should be electrically clean without a lot of local noise interference. It should not be near any local noise sources, away from heavy traffic, railway lines, and other potential noise sources such as well pumps, electric-magnetic train tracks, heavily electric industrial or urban sites, etc.. The sensor orientation of the remote reference site should be parallel to the sounding measurement site. For example, if the sounding has X direction as North (0 degrees N) and the Y direction as East (90 degrees) then the remote should be X = 0 degrees and Y = 90 degrees as well.

It is also recommended that the remote site should be over simple geology.

A transmitter cannot be used with remote reference. A hybrid-source transmitter (HSAMT Tx) cannot be used because the remote reference will be out of the range of the HSAMT transmitter. That means the remote receiver will not detect the transmitter frequencies so not of the transmitter frequencies will be used in the data processing.

10.0 The Tipper

Tipper Definition: Hz = TxHx + TyHy

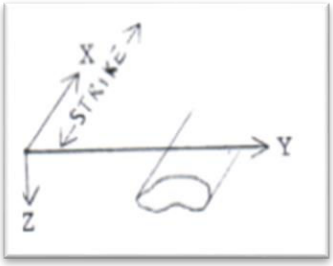


Figure 10-1 - Coordinate System

Tipper Amplitude: $T^2 = Tx^2 + Ty^2$

High Tipper Amplitude indicates 2D or 3D case.

Tipper Phase: $Tphs = (Tx^2 * Txphs + Ty^2 * Typhs) / (Tx^2 + Ty^2)$

If the resistivity of earth changes across a vertical contact, Hz will be in phase with the horizontal magnetic component that points from more conductive ground toward the more resistive. Thus the tipper phase indicates horizontal direction towards increasing resistivity. The MT site is located on south bank of Yougding River which is east-west direction in this area (Figure 2). The tipper phase is about -10 degree indicating the MT site is located on conductive side of a contact and the resistive side (river channel sandstone) is one the north side of the MT Site.

Tipper coherency is coherency between Hz and Hx&Hy, indicating tipper data quality. Hz is much weaker than Hx&Hz and is more likely affect by wind noise because it is very hard to bury the whole Hz into the earth. That's why tipper data is not as good as impedance, and tipper coherency is lower comparing impedance coherency. When analyzing tipper data, the user needs to judge which frequency band is reliable by coherency.

Tipper Strike in Figure 10-1 is either about 90 or -90 degree for the frequencies less than 500 Hz in which coherency is relative high(figure 3), indicating the strike is east-west around this frequency range. This also agrees with tipper phase data.

Tipper skew and **beta**. Both skew and beta are zero indicating a true 2D case. The skew and beta data is not good in Figure 3 which is normal for tipper data.

Combined coherency data, More or less reliable data is tipper beta about 100 – 300 Hz. The beta value is about 0.2 indicating a weak 2D case.

Tipper Polars: The tipper polars (figure 4) are consist north-south peanuts indicating the strike are east-west, agreeing with tipper phase and tipper strike data.

In impedance curves (figure 5), the impedance is rotated to Maximize Zxy. The impedance strike is about -90. Indicate the strike is either east-west or north-south. With combined tipper data we can conclude that the strike on this site is east-west direction, eliminating the ambiguity of impedance strike only.

Figure 10-2 – MT Site location

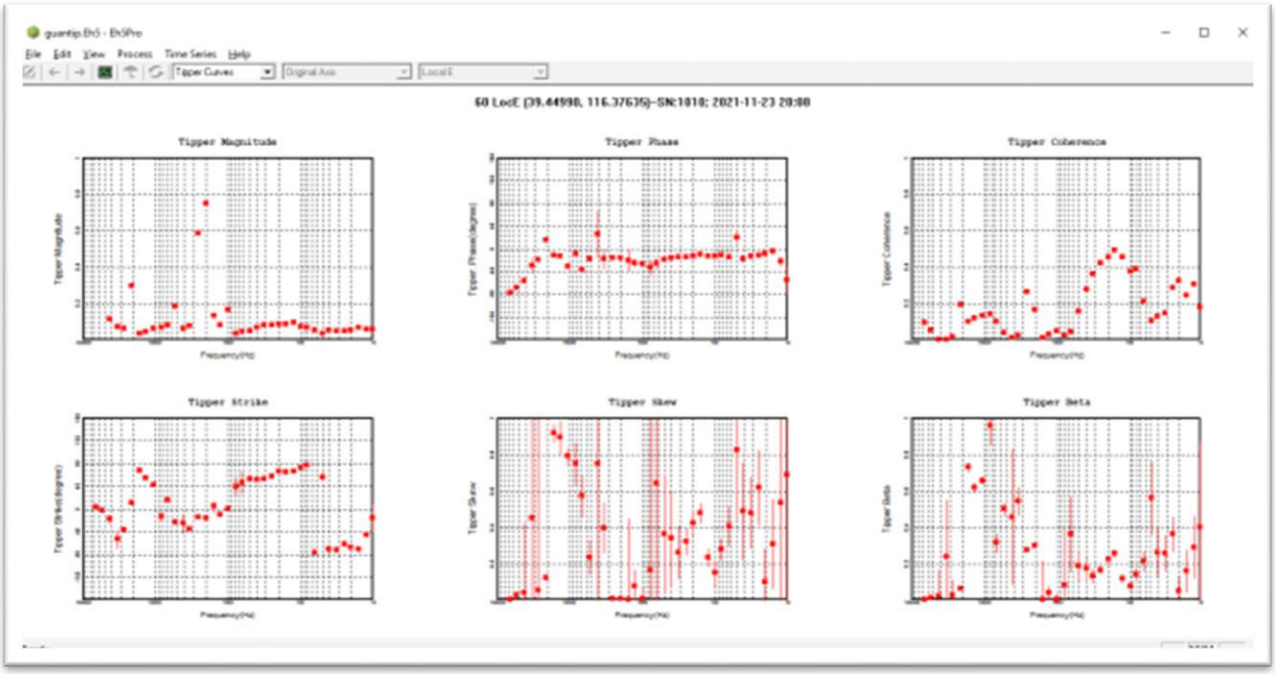


Figure 10-3

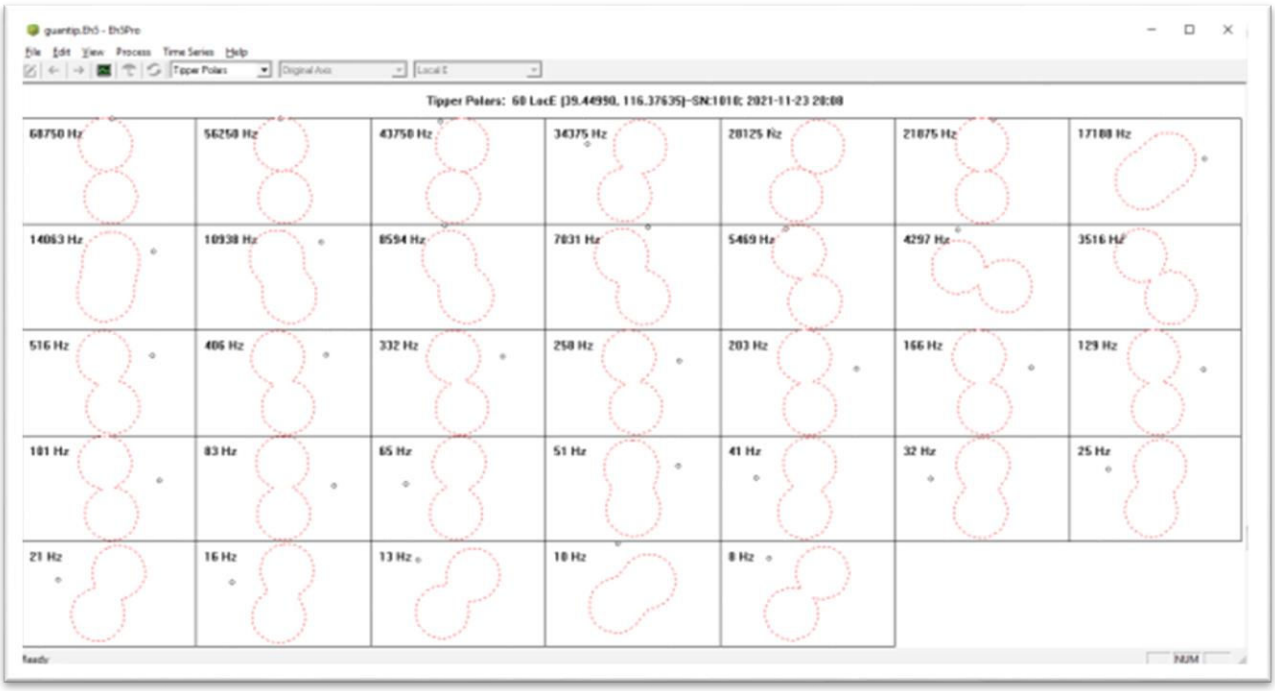


Figure 10-4 Tipper Polars

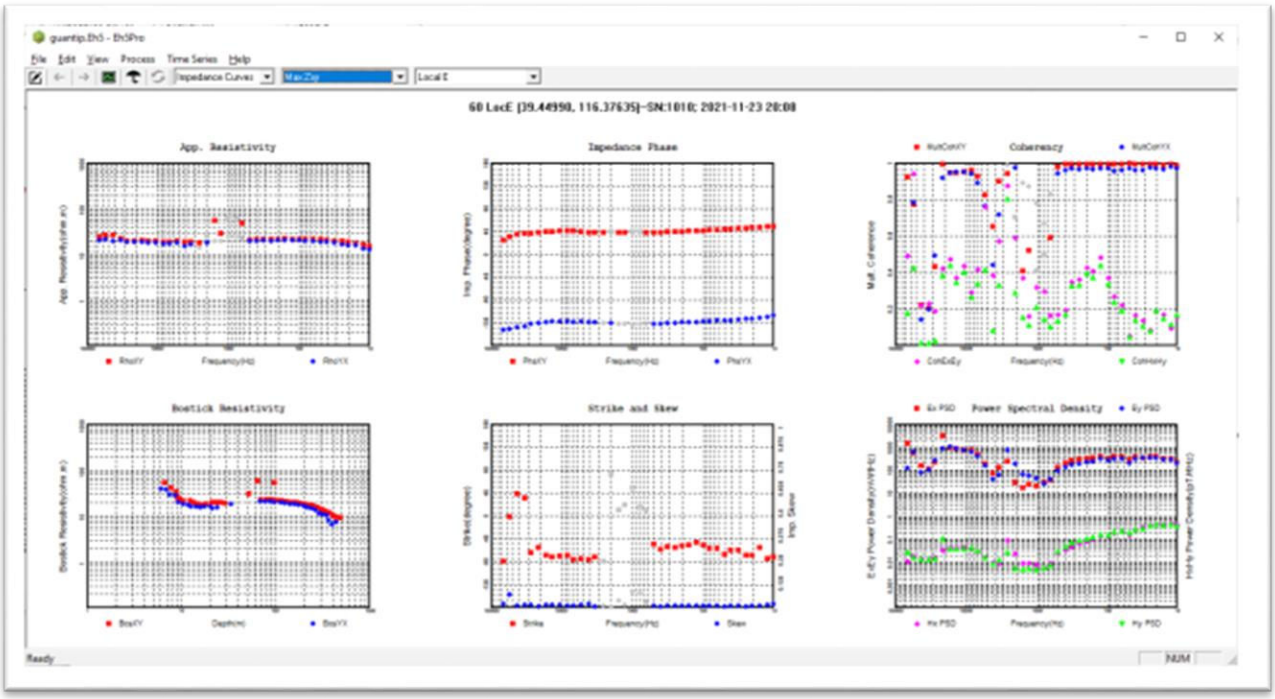


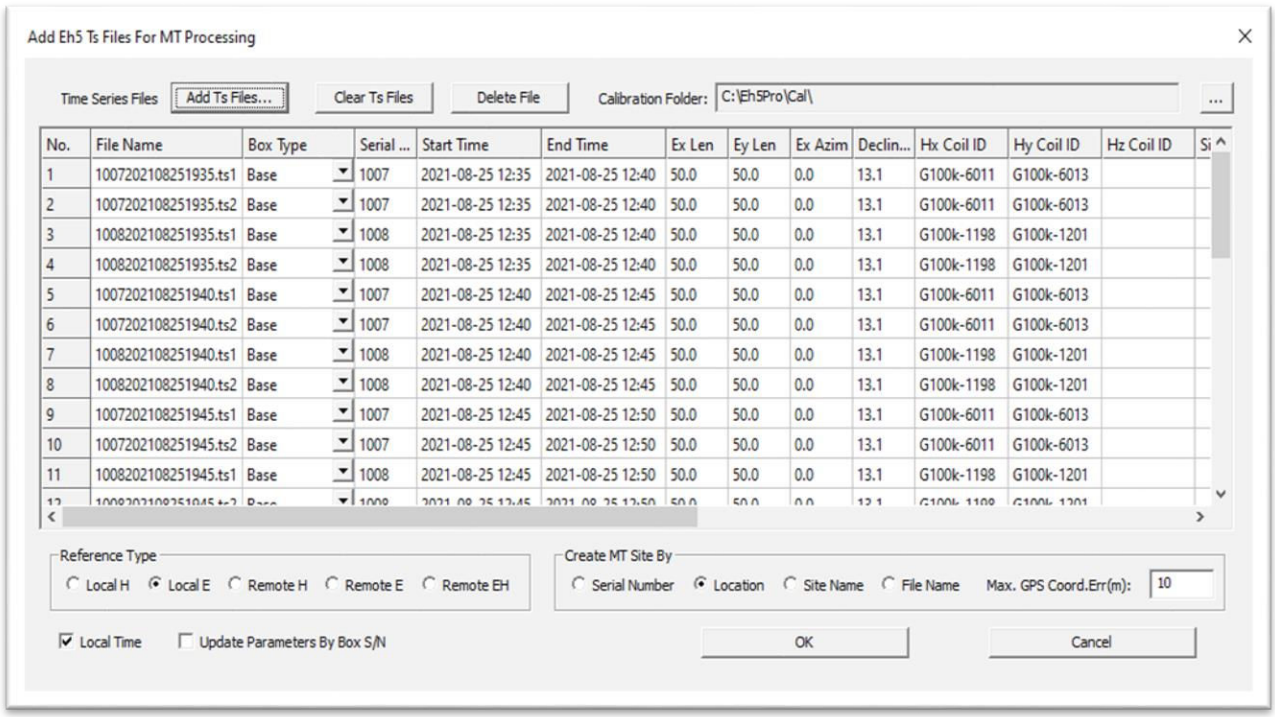
Figure 10-5 – Impedance curves

11.0 Summary of data processing step-by-step procedure

This section is intended as a review of the steps to get from data that was collected as .TS files in the field and downloaded to your processing computer, to create .EH5 data files or .EDI processed data files that can be exported to third-party MT inversion software such as Emage2D and other commercially available data processing programs.

11.1 Reading in .TS files for MT processing in EH5Pro

From the main menu go to "Process\MT Process\Add Ts files". Navigate to the directory where you TS1, TS2, and TS3 files are stored. Select the files to process and click on "Open". You will see the menu below:



No.	File Name	Box Type	Serial ...	Start Time	End Time	Ex Len	Ey Len	Ex Azim	Declin...	Hx Coil ID	Hy Coil ID	Hz Coil ID
1	1007202108251935.ts1	Base	1007	2021-08-25 12:35	2021-08-25 12:40	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
2	1007202108251935.ts2	Base	1007	2021-08-25 12:35	2021-08-25 12:40	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
3	1008202108251935.ts1	Base	1008	2021-08-25 12:35	2021-08-25 12:40	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
4	1008202108251935.ts2	Base	1008	2021-08-25 12:35	2021-08-25 12:40	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
5	1007202108251940.ts1	Base	1007	2021-08-25 12:40	2021-08-25 12:45	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
6	1007202108251940.ts2	Base	1007	2021-08-25 12:40	2021-08-25 12:45	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
7	1008202108251940.ts1	Base	1008	2021-08-25 12:40	2021-08-25 12:45	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
8	1008202108251940.ts2	Base	1008	2021-08-25 12:40	2021-08-25 12:45	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	
9	1007202108251945.ts1	Base	1007	2021-08-25 12:45	2021-08-25 12:50	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
10	1007202108251945.ts2	Base	1007	2021-08-25 12:45	2021-08-25 12:50	50.0	50.0	0.0	13.1	G100k-6011	G100k-6013	
11	1008202108251945.ts1	Base	1008	2021-08-25 12:45	2021-08-25 12:50	50.0	50.0	0.0	13.1	G100k-1198	G100k-1201	

Figure 11-1 – Screen showing available files for MT processing.

The details of this screen are discussed in Section 4.0.

11.2 Viewing processed parameters

Click **OK** To see the following screen:

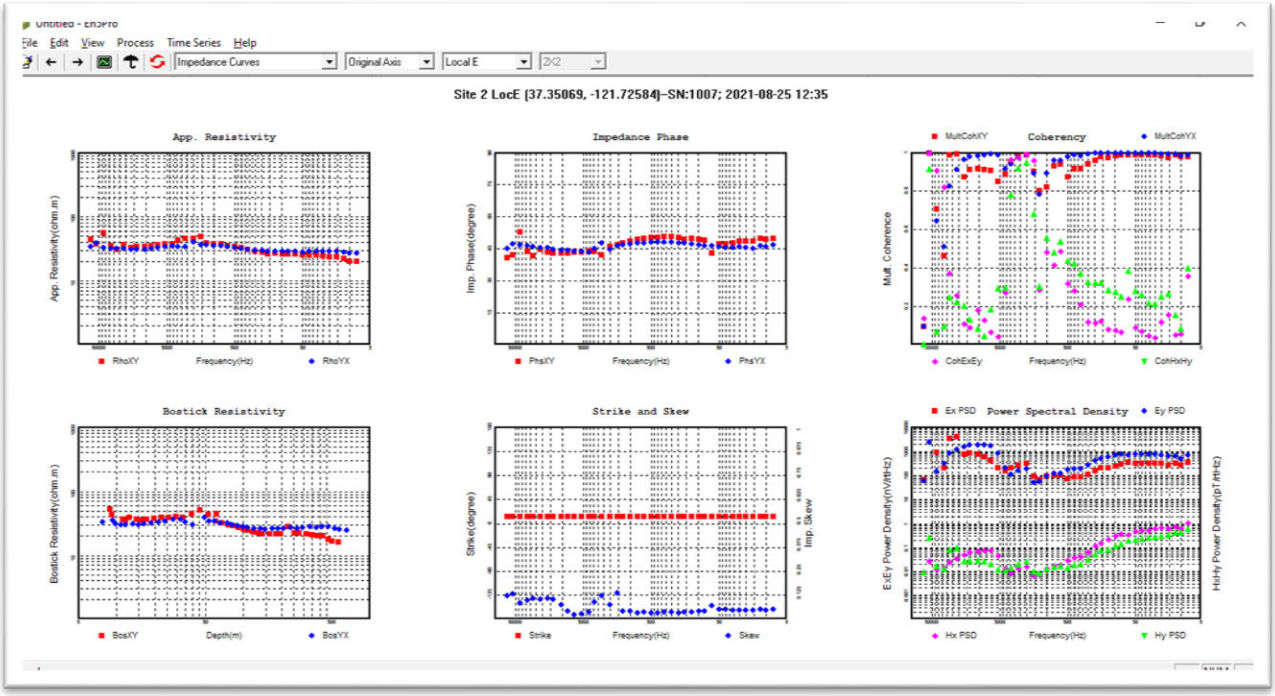


Figure 11-2 – Processed data

Details of all the processed MT parameters are covered in "Process" - Data Processing and Re-Processing.

11.3 Review current time series:

To see currently open time series click **Time Series** from the top menu bar and choose **Check current site time series** to see the a list of open site time series. Click on the desired time series file to see the first record of the file, as shown below: Clicking "Combine" will create new files with all the TS1 files combined to one file, all the TS2 together in another file, and all the TS3 files in another file. These will be huge files of several hundred megabytes.

geo Time Series Files

No.	File Name	File Size(KB)	Folder
1	1008202108122315.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
2	1008202108122315.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
3	1008202108122320.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
4	1008202108122320.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
5	1008202108122325.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
6	1008202108122325.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
7	1008202108122330.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
8	1008202108122330.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
9	1008202108122335.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
10	1008202108122335.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
11	1008202108122340.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
12	1008202108122340.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
13	1008202108122345.ts1	192,005	C:\Eh5Data\EH5-data\Gant Ranch tes
14	1008202108122345.ts2	35,166	C:\Eh5Data\EH5-data\Gant Ranch tes
15	1008202108122350.ts1	104,963	C:\Eh5Data\EH5-data\Gant Ranch tes

Combine | Open Ts File | Copy To... | Exit

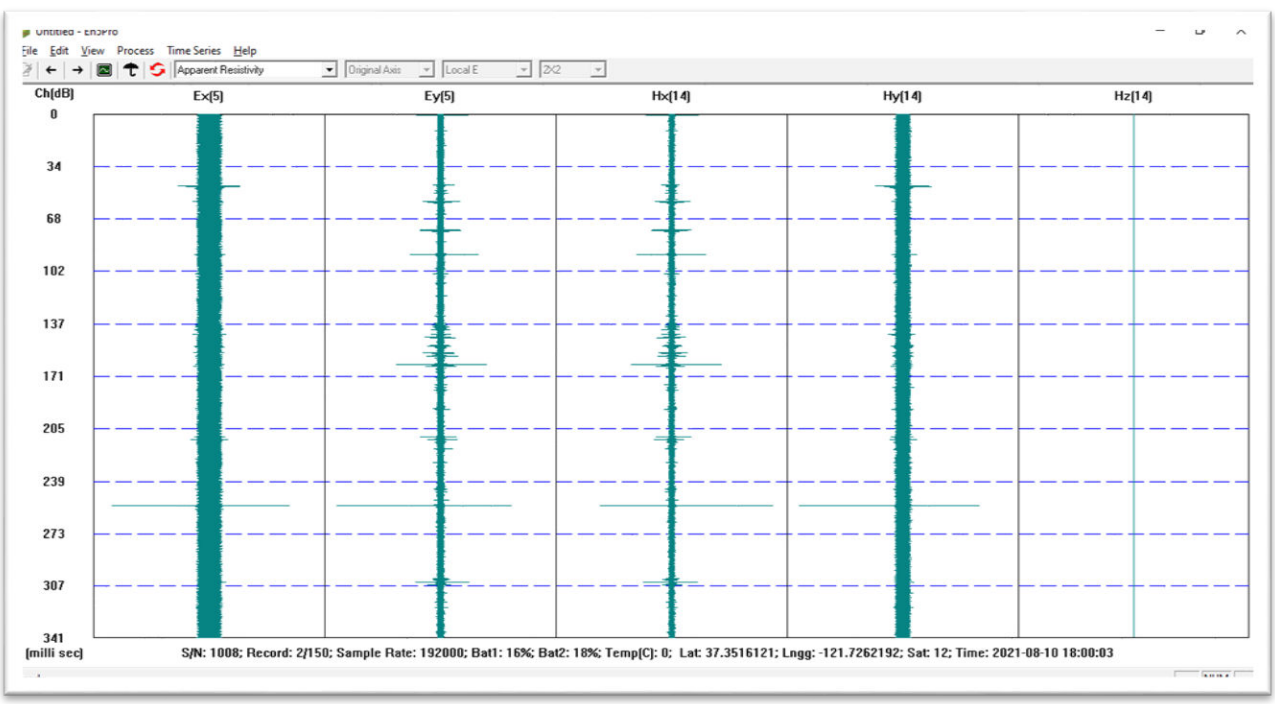


Figure 11-3 - Details of review time series are covered in Time Series Viewing and Editing

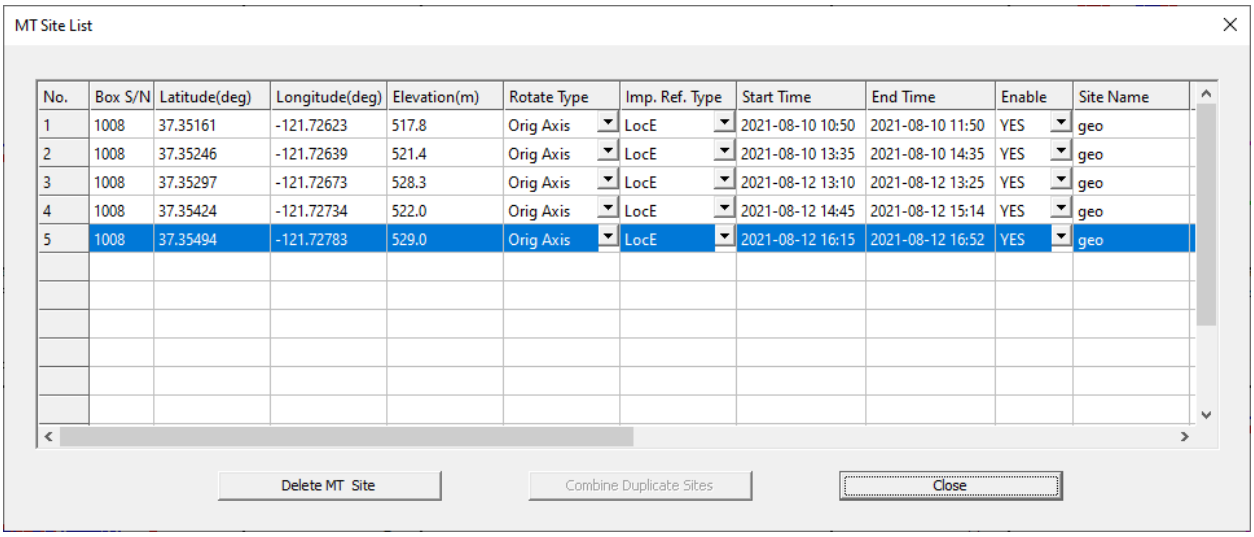
12.0 File Export Options of Processed Data

There are several file export options available with a licensed copy of EH5Pro. These are as follows:

12.1 Export EDI File

EDI files are a standard file format for MT data. Most commercial programs such as WinGLink, Geotools, Emage2D, Zond MT2D, and other commercial MT inversion programs, as well as most academic MT inversion programs will read standard EDI files. Although the EDI format is considered a standard there are slight differences between programs from different commercial and academic publishers of the inversion software programs. Geometrics cannot guarantee that the EH5Pro EDI export file will work with a program that has not been verified by Geometrics, Inc.

To export EDI files from EH5Pro go to "**File\Export EDI Files**" . Choose the folder to save the files and click "**OK**". Navigate to the folder to store the EDI file and click OK. The files will be saved in the selected folder and given the names selected by the user. The file names are given by clicking "Edit\MT Site List" and entering the names for each site, as shown below.



No.	Box S/N	Latitude(deg)	Longitude(deg)	Elevation(m)	Rotate Type	Imp. Ref. Type	Start Time	End Time	Enable	Site Name
1	1008	37.35161	-121.72623	517.8	Orig Axis	LocE	2021-08-10 10:50	2021-08-10 11:50	YES	geo
2	1008	37.35246	-121.72639	521.4	Orig Axis	LocE	2021-08-10 13:35	2021-08-10 14:35	YES	geo
3	1008	37.35297	-121.72673	528.3	Orig Axis	LocE	2021-08-12 13:10	2021-08-12 13:25	YES	geo
4	1008	37.35424	-121.72734	522.0	Orig Axis	LocE	2021-08-12 14:45	2021-08-12 15:14	YES	geo
5	1008	37.35494	-121.72783	529.0	Orig Axis	LocE	2021-08-12 16:15	2021-08-12 16:52	YES	geo

12.2 Export KMZ File

KMZ files are used by Google Earth to located the GPS position on a map. Details are given in Chapter 5 Top Menu Bar Options.

12.3 Export EMAP to XYZ File.

An EMAP file is a 2-D depth section created on 1-D soundings along a profile line. The 1-D soundings are created by the 1-D transformation of apparent resistivity and frequency to a point-by-point true resistivity and depth. Details are explained in Displaying 2-D Bostick-EMAP sections.

13.0 Magnetotelluric Theory

13.1 Electromagnetic waves

The electromagnetic waves of interest to the MT practitioner are described by Maxwell's equations. In differential form they are

$$\nabla \times \mathbf{E} = -i\omega\mu\mathbf{H} \quad \text{(Faraday's Law)} \quad (1)$$
$$\nabla \times \mathbf{H} = (\sigma + i\omega\varepsilon)\mathbf{E} \quad \text{(Ampere's Law)} \quad (2)$$
$$\nabla \cdot \mathbf{H} = 0 \quad (3)$$
$$\nabla \cdot \mathbf{E} = \rho/\varepsilon \quad \text{(Coulomb's Law)} \quad (4)$$

where **E** is the electric field, **H** is the magnetic field, σ is conductivity, ε is permitivity, and ρ is free electric charge. Here the notation **E** and **H** indicates vector harmonic time dependency

$$e^{-i\omega t} = \cos(\omega t) - i\sin(\omega t)$$

so that the peak instantaneous vector value E of **E** is given by

$$\mathcal{E} = \mathrm{Re}(\mathbf{E}e^{i\omega t}) .$$

where ω is angular frequency (2πf), i=√-1, t is time and Re indicates the real part. A differential equation for **E** is obtained by taking the curl of equation (1) and substituting equation (2) to get

$$\nabla \times \nabla \times \mathbf{E} = -i\omega\mu(\sigma + i\omega\varepsilon)\mathbf{E} .$$

It is customary to let $k^2 = -i\omega\mu\sigma + \omega^2\mu\varepsilon$ and apply the vector identity

$$\nabla \times \nabla \times \mathbf{A} = -\nabla^2\mathbf{A} + \nabla(\nabla \cdot \mathbf{A})$$

to obtain

$$\nabla^2\mathbf{E} + k^2\mathbf{E} = 0 , \quad (5)$$

where we have also assumed that there is no free charge present (Ñ·**E** = 0). Equation (5) is the Helmholtz equation for E and *k* is the propagation constant. The source of MT signals is in the atmosphere where the conductivity is near 0, and here the propagation constant is

$$k = \omega\sqrt{\mu_0\varepsilon_0} .$$

In the earth

$$k \approx \sqrt{-i\omega\mu\sigma}$$

because, for earth materials, σ >> ωε at the frequencies we are interested in.

13.2 Propagation of electromagnetic waves

A fundamental assumption when interpreting MT measurements is that the source fields impinge on the earth as uniform plane waves: the **E** and **H** fields are constant in planes perpendicular to the direction of propagation. For a plane wave propagating into a uniform earth, where the z direction is positive downward, we need only consider the field components E_x and H_y and can set the other components of the **E** and **H** fields to zero. With

$$\nabla^2 \times \mathbf{E} = \nabla^2 E_x \hat{x} + \nabla^2 E_y \hat{y} + \nabla^2 E_z \hat{z}$$

equation (5) becomes

$$\frac{d^2 E_x}{dz^2} + k^2 E_x = 0 \qquad (6)$$

because the plane wave does not vary in the x and y directions. This differential equation has a general solution

$$E_x = E_0^+ e^{-ikz} + E_0^- e^{ikz}$$

where the coefficients E_0^+ and E_0^- are constants which can be found by applying boundary conditions. Because of the requirement that a wave not gain amplitude in the direction of propagation, the coefficients E_0^+ and E_0^- represent the amplitudes of the electric field waves traveling in the +z direction (downward) and -z direction (upward) respectively. For a plane wave propagating in a uniform earth, E_X is 0 at an infinite depth because we are infinitely far from the plane wave source. This implies that E_0^- represents the amplitude of a reflected wave, and in a uniform earth where there are no reflectors, its amplitude must also be zero. So

$$E_x = E_0^+ e^{-ikz} = E_0^+ e^{-iz\sqrt{-i\omega\mu\sigma}} = E_0^+ e^{-z(1+i)\sqrt{\omega\mu\sigma/2}}$$

Or

$$E_x = E_0^+ e^{-z\sqrt{\omega\mu\sigma/2}} e^{-iz\sqrt{\omega\mu\sigma/2}} .$$

The term with the imaginary exponent represents the wave component of the electric field and the term with the real exponent defines the decay of the wave's amplitude with depth. It is convenient to specify distance in terms of the wavelength and, where EM waves penetrate conductors, it is customary to use one radian as the standard distance. This distance is called a skin depth. One wavelength is 2π radians so one skin depth is a bit less than one sixth of a wavelength. Wavelength is given by

$$\lambda = \frac{2\pi}{\kappa}$$

so one skin depth is given by

$$\delta = \frac{1}{\kappa}$$

where the wave number κ is

$$\kappa = \sqrt{\frac{\omega\mu\sigma}{2}} \quad \text{so}$$

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} = \sqrt{\frac{1}{4\pi^2 10^{-7}}}\sqrt{\frac{\rho}{f}} \approx 503\sqrt{\frac{\rho}{f}} \quad \text{(meters)}$$

At the earth's surface (z = 0) and from equation 6, $E_X(0) = E_0^+$. At the skin depth δ, the amplitude of the down-going wave has deceased to

$$E_x(\delta) = E_0^+ e^{-1}$$

which is 1/e or about 37 percent of its surface value. If a reflective layer existed at a depth δ, then the reflected, up-going wave would also be attenuated by 37 percent resulting in a total attenuation of about 86 percent relative to the surface value of the down going wave.

The presence of uniform plane-waves implies that the wave's source is distant: nearby sources are likely to generate waves with a spherical wave front that will not be uniform in the survey area. If sources are nearby, equations 1 and 2 are incomplete; they lack the appropriate source terms for a complete description of the fields and their interaction. Because it is difficult to specify sources that are beyond our control, it is best if they can be avoided. Both experimental results and numerical simulations indicate that at distances greater than 3 skin depths (1/2 wave length) from an electromagnetic transmitter, the uniform, and plane portion of the waves are dominant and at 6 or 7 skin depths (1 wave length) the waves are completely uniform and plane relative to the precision with which we can measure them.

13.2.1 Impedance

In the air, above a uniform earth, we expect to find an electromagnetic field composed of electromagnetic waves propagating downward and reflected waves propagating upward. This situation is described for an electric field component by

$$E_x^0 = E_0^+ e^{-ik_0 z} + E_0^- e^{-ik_0 z} \qquad (7)$$

The coefficient subscripts '0' indicate that this expression applies to layer 0, (the air) and the superscripts indicate the direction of travel (positive down). In a uniform earth (layer 1) there are no reflectors so:

$$E_x^1 = E_1^+ e^{-ik_1 z} \qquad (8)$$

The propagation constants in these expressions are:

$$k_0 = \omega\sqrt{\mu_0 \varepsilon_0}\,. \quad \text{and} \quad k_1 = e^{i\pi/4}\sqrt{\frac{\omega\mu}{\rho}}\,.$$

A solution for the unknown constants in equations 7 and 8 is obtained by enforcing the conditions that E_x and H_y must be continuous at the earth-air boundary. Applying Faraday's law to 7 and 8 gives the magnetic fields

$$H_y^0 = \frac{E_0^+}{\eta_0} e^{-ik_0 z} + \frac{E_0^-}{\eta_0} e^{-ik_0 z} \quad \text{and} \quad H_y^1 = \frac{E_1^+}{\eta_1} e^{-ik_1 z}$$

where η_0 and η_1 are the intrinsic impedance of the air and the earth given by

$$\eta_0 = \frac{i\omega\mu_0}{ik_0} = \sqrt{\frac{\mu_0}{\varepsilon_0}} \quad \text{and} \quad \eta_1 = \frac{i\omega\mu_0}{ik_1} = \sqrt{\omega\mu_0\rho} e^{i\pi/4}$$

Equating E and H fields at z = 0 yields

$$E_1^+ = E_0^+ + E_0^- \quad \text{and} \quad \frac{E_1^+}{\eta_1} = \frac{E_0^+}{\eta_0} - \frac{E_0^+}{\eta_0} .$$

The solution of these equations yields the amplitude of the transmitted wave and the reflected wave:

$$E_1^+ = \frac{2\eta_1}{\eta_0 + \eta_1} E_0^+ \quad \text{and} \quad E_0^- = \frac{\eta_1 - \eta_0}{\eta_0 + \eta_1} E_0^+ .$$

These equations lead to expressions for the electric and magnetic field in the air in terms of impedance of the air and earth give by

$$E_x^0 = E_0^+ \left[e^{-ik_0 z} + \frac{\eta_1 - \eta_0}{\eta_1 + \eta_0} e^{-ik_0 z} \right] \quad \text{and} \quad H_y^0 = \frac{E_0^+}{\eta_0} \left[e^{-ik_0 z} - \frac{\eta_1 - \eta_0}{\eta_1 + \eta_0} e^{-ik_0 z} \right] .$$

Similarly, in the earth we have

$$E_y^1 = E_0^+ \frac{2\eta_1}{\eta_1 + \eta_0} e^{-ik_1 z} \quad \text{and} \quad H_v^1 = E_0^+ \frac{2}{\eta_1 + \eta_0} e^{-ik_1 z} .$$

At the surface of the earth, these two sets of expressions are equal and the ratio of E_x/H_y is called the surface impedance Z. For the case of a homogeneous earth, Z = η. This is the basis for defining the apparent resistivity ρ_a: it is the resistivity of a homogeneous earth, which would yield the same surface impedance as measured over an inhomogeneous earth at a particular location and frequency. Because

$$\eta_1 = \frac{E_x}{H_v} = e^{i\pi/4} \sqrt{\omega\mu_0\rho} ,$$

we can write

$$\rho_a = -\frac{i}{\omega\mu_0}\left(\frac{E_x}{H_y}\right)^2 .$$

In general, apparent resistivity is complex (e.g. the IP phenomena), but we restrict our attention to the real component which is defined as

$$\rho_a = -\frac{i}{\omega\mu_0}\frac{|E_x|^2}{|H_y|^2} .$$

13.2.2 Impedance estimation

Modern magnetotelluric systems are designed to record variation of both the electric and magnetic fields in two orthogonal directions and use these records to calculate the surface impedance at a measurement site. The surface impedance **Z** is complex, frequency dependent, and, due to the presence of noise and earth structures, is also a tensor:

$$\overline{E}(\omega) = \overline{\overline{Z}}(\omega)\cdot\overline{H}(\omega) \quad \text{or} \quad \begin{aligned} E_x &= Z_{xx}H_x + Z_{xy}H_y \\ E_y &= Z_{yx}H_x + Z_{yy}H_y \end{aligned} .$$

It can be helpful to think of the surface impedance tensor as a two input, two output linear system where the inputs are the magnetic field components and the outputs are the electrical field components. This formulation of surface impedance is preferred over the scalar formulation because, when the source fields are nearly plane waves, the impedance elements Z_{ij} are time invariant. The scalar surface impedance

$$Z_{ij} = \frac{E_i}{H_j}$$

is easier to calculate but can vary as the direction of the source fields vary. The Stratagem system makes use of both controlled and natural source fields and its processing includes the tensor formulation.

The tensor impedance can be calculated from a number of records (N) using the least-squares method where the difference between a measured electric field component is minimized relative to the predicted electric field component. For example just considering E_x, H_x and H_y

$$\psi = \sum_{i=1}^{N}(E_{xi} - Z_{xx}H_{xi} - Z_{xy}H_{yi})(E_{xi}^* - Z_{xi}^*H_{xi}^* - Z_{xy}^*H_{yi}^*)$$

and minimization with respect to Z_{xx} and Z_{xy} requires

$$\frac{\partial\psi}{\partial(reZ_{xx})} = \frac{\partial\psi}{\partial(imZ_{xx})} \quad \text{and} \quad \frac{\partial\psi}{\partial(reZ_{xy})} = \frac{\partial\psi}{\partial(imZ_{xy})}$$

which yields

$$\langle E_xH_x^*\rangle = \langle H_xH_x^*\rangle Z_{xx} + \langle H_yH_x^*\rangle Z_{xy} \quad \text{and} \quad \langle E_xH_y^*\rangle = \langle H_xH_y^*\rangle Z_{xx} + \langle H_yH_y^*\rangle Z_{xy} .$$

where, for example

$$\left\langle E_x H_x^* \right\rangle = \frac{1}{N} \sum_{i=1}^{N} E_{xi} H_{xi}^*$$

is an average cross power density spectrum and E_x is the discrete Fourier transform of the measured field E_x. The (*) symbol indicates complex conjugation. The two cross power expressions above combine to yield

$$Z_{xx} = \frac{\left\langle E_x H_y^* \right\rangle \left\langle H_y H_x^* \right\rangle - \left\langle E_x H_x^* \right\rangle \left\langle H_y H_y^* \right\rangle}{\left\langle H_x H_y^* \right\rangle \left\langle H_y H_x^* \right\rangle - \left\langle H_x X_x^* \right\rangle \left\langle H_y H_y^* \right\rangle} \quad \text{and} \quad Z_{xy} = \frac{\left\langle E_x H_y^* \right\rangle \left\langle H_x H_x^* \right\rangle - \left\langle E_x H_x^* \right\rangle \left\langle H_x H_y^* \right\rangle}{\left\langle H_y H_y^* \right\rangle \left\langle H_x H_x^* \right\rangle - \left\langle H_y X_x^* \right\rangle \left\langle H_x H_y^* \right\rangle}$$

and expressions for Z_{yx} and Z_{yy} are obtained in a similar way.

The surface impedance is usually expressed as apparent resistivity and impedance phase and they are calculated from the surface impedance components as

$$\rho_{ij} = \frac{1}{\omega \mu_0} \left| Z_{ij} \right|^2 = \frac{.2}{f} \left| Z_{ij} \right|^2 \quad \text{and} \quad \phi_{ij} = \tan^{-1} \left(\frac{\mathrm{Im}\left(Z_{ij} \right)}{\mathrm{Re}\left(Z_{ij} \right)} \right)$$

whether they are based on scalar or tensor calculations.