



GEOMETRICS

Innovation • Experience • Results

MetalMapper Manual

Preliminary

Look for the latest full version of this manual at
Software CD or www.geometrics.com

on the DOWNLOADS pages

Geometrics Inc.
2190 Fortune Dr
San Jose, CA 95131
Phone 408.954.0522 • Fax 408.954.0902
EMAIL:sales@mail.geometrics.com

Table of Contents



GEOMETRICS

Innovation • Experience • Results

| | | |
|--------|---------------------------------------|----|
| 1. | Introduction | 5 |
| 2. | Equipment Specifications..... | 6 |
| 2.1. | System Orientation | 6 |
| 2.2. | Physical Assembly | 9 |
| 2.2.1. | Transmitter/Receiver Array | 9 |
| 2.2.2. | Acquisition Computer | 12 |
| 2.2.3. | Battery..... | 14 |
| 2.2.4. | External Display, Serial Mouse..... | 15 |
| 2.2.5. | External sensors | 15 |
| 3. | Software..... | 15 |
| 3.1. | Quick Start..... | 16 |
| 3.1.1. | Quick Start – Point Acquisition | 16 |
| 3.1.2. | Quick Start – Line Acquisition | 16 |
| 3.2. | Software Startup..... | 16 |
| 3.3. | Parameter Window..... | 19 |
| 3.4. | EM3D Plot | 24 |
| 3.5. | Map Window..... | 27 |
| 3.5.1. | Cued Data File Formats | 31 |
| 3.6. | Data Table Window..... | 33 |
| 3.7. | Control Window | 34 |
| 3.8. | Error Window | 35 |
| 3.9. | Vector Window | 35 |

4. EM3DAcquire.INI..... 36

List of Figures

| | |
|---|----|
| Figure 1 - Transmitter Coil Orientation Diagram | 6 |
| Figure 2 - Receiver Cube Locations | 7 |
| Figure 3 - Schematic of Orientations and Polarities | 8 |
| Figure 4 - Receiver Cube With Pre-Amp Board Attached | 8 |
| Figure 5 – Attaching X Transmitter Coil | 9 |
| Figure 6 - Parts for attached Y-Transmitter Coil (Thicker Wooden Blocks) | 10 |
| Figure 7 - Vertical transmitter coil stabilization blocks..... | 10 |
| Figure 8 - Details of GPS Platform Assembly..... | 10 |
| Figure 9 - Assembled Transmitter-Receiver Array | 11 |
| Figure 10 - Acquisition Computer | 12 |
| Figure 11 - Acquisition Computer with Transmitter/Receiver Cabling Attached | 13 |
| Figure 12 - External Ports on Acquisition Computer..... | 14 |
| Figure 13 - Default WInow Layout | 17 |
| Figure 14 - Parameter Window | 19 |
| Figure 15 - MetalMapper Transmitter Waveform | 20 |
| Figure 16 - Parameter Set Dialog | 24 |
| Figure 17 - Main Plot Window | 25 |
| Figure 18 - Example Plot Window | 26 |
| Figure 19 - Map Window a) Static (point) mode and b) Dynamic (line) mode..... | 28 |
| Figure 20 - Map Setup Dialog..... | 30 |
| Figure 21 - Data Table Window..... | 34 |
| Figure 22 - Control Window..... | 34 |
| Figure 23 - Main Control Window..... | 35 |
| Figure 24 - Vector Window | 35 |

List of Tables

| | |
|---|----|
| Table 1 - MetalMapper Window Icons | 18 |
| Table 2 - Recommended Acquisition Parameters..... | 23 |
| Table 3 - Plot Window Icon Functions | 27 |
| Table 4 - Map window icon descriptions | 28 |
| Table 5 - Map Setup Parameter Descriptions | 31 |

1. Introduction

The MetalMapper is an advanced electromagnetic induction system (EMI) configured for the detection and characterization of UXO. This technology represents a significant departure from existing commercially available EMI instruments for UXO detection. Although the MetalMapper can be used in the survey or mapping mode for target detection, it's most important application is for use as a system for "Cued-ID" target characterization. In the cued ID mode, data are acquired at one or more locations in close proximity to the target. Precision static measurements at these locations permit the calculation of the target characteristics. For isolated targets, a measurement at a single field point suffices. These target characteristics are then used to generate a prioritized dig list that identifies each target as either one that needs to be removed or one that is non-hazardous.

It is the result of several years of research and development activities in the area of characterization of buried metallic objects in order to reduce the costs of remediating sites contaminated with Unexploded Ordnance.

It is a system that uses time domain electromagnetic (TDEM) principles to induce electrical currents in buried metallic objects and then measure the effects of those currents in receivers on the surface. It has three (3) orthogonal transmitter coils. Each is approximately 1 m x 1 m in size. One coil is oriented horizontally to generate vertical fields and the two other coils are mounted vertically orthogonal to each other. Within the box containing the horizontal coil are seven (7) receiver cubes, each one containing three (3) orthogonal coils to measure the fields resulting in 21 different receiver coils. The receiver coils are oriented in the same manner as the transmitter coils. The transmitter coils are powered using a bipolar half duty cycle and the time decay of the subsurface currents (transients) are measured during time off of the transmitter coils.

The transmitter coils are activated in sequence and measurements are recorded in all 21 receiver coils, for a measurement where all transmitter coils are used, this will result in 63 different EM transients being recorded.

1. The software covered in this manual controls the generation, processing of the signals involved in TDEM data acquisition as well as how the data is saved. In addition, the navigation features of the software that facilitate line oriented and cued data acquisition are discussed. This manual doesn't cover any of the post-processing required to invert the transient measurements in order to characterize subsurface metallic objects.

2. Equipment Specifications

2.1. System Orientation

The system is based on orthogonal coil orientations. The positive and negative directions are based on the “right hand rule” where the positive direction of current flow is counter-clockwise when the coil is oriented with the top up.

The three transmitter coils are the larger square loops that are approximately 1 m by 1 m, each of the coils has an coil with 10 turns in order to generate the signals. The Z (horizontal) coil is the bottom coil and contains the receiver coils within the frame. It is the only coil that is required during dynamic data acquisition. The X and Y coils are vertical coils oriented perpendicular to each other. They are of slightly different size in order to fit together. The X coil measure the EM fields in the “cross-line” direction or along the direction of travel and the Y coil is oriented to measure “in-line” (perpendicular to direction of travel) EM fields.

A diagram of the coils and their orientation are shown in Figure 1.

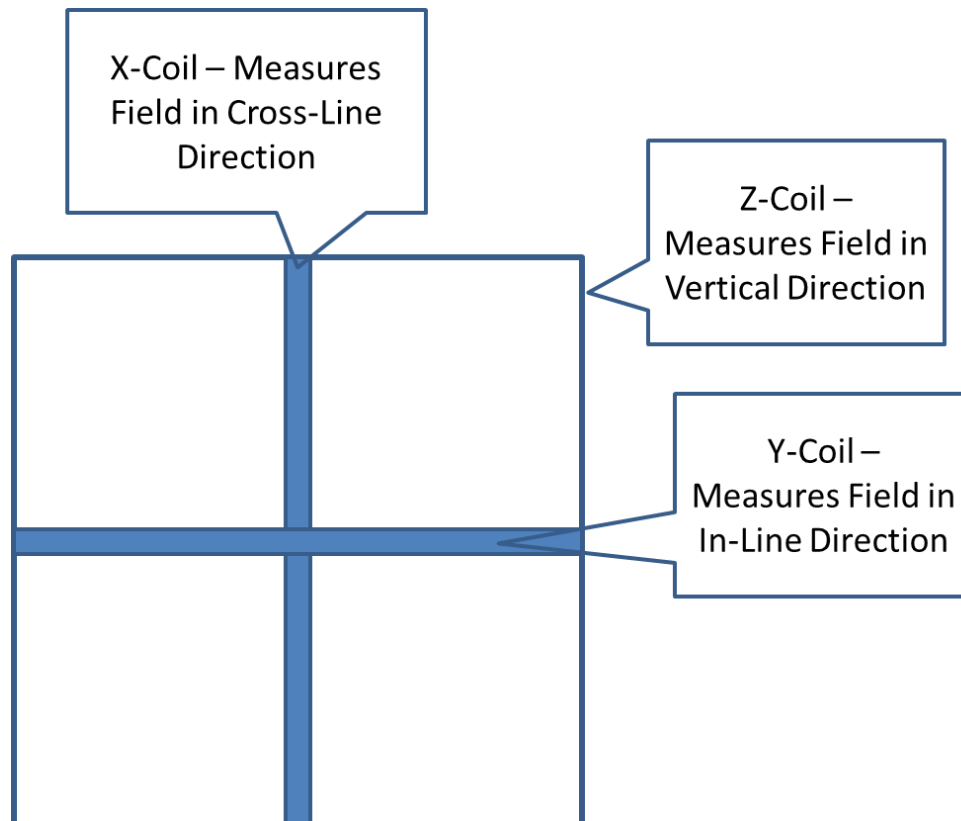


Figure 1 - Transmitter Coil Orientation Diagram

There are 7 identical receiver cubes contained within the Z transmitter coil. Each cube has three orthogonal coils that are oriented in the same manner as the transmitter coils. The three coils are all of

slightly different sizes and number of turns. The number of turns of the coil wire are varied so that the difference in size is compensated and there is no difference in the effective gain between the coils.

The 7 cubes are distributed in the Z coil so that when the array is collecting dynamic acquisition the coils are spaced every 13 cm across the line. A diagram showing the location of the receiver coils is shown in Figure 2. The location of the coils is designed to acquire data from a wide range of offsets and directions from a target in the middle of the coil.

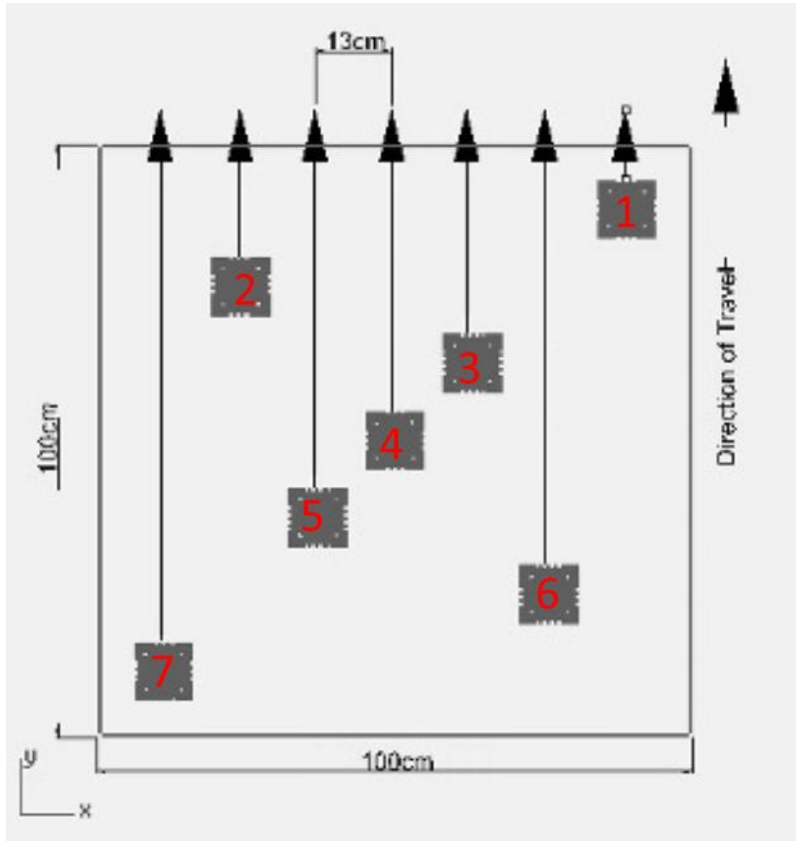


Figure 2 - Receiver Cube Locations

A schematic of the assembled array that defines the orientations of the Tx and Rx arrays are shown below. The standard right hand rule is used to define the polarities of the transmitted signals and the received signals.

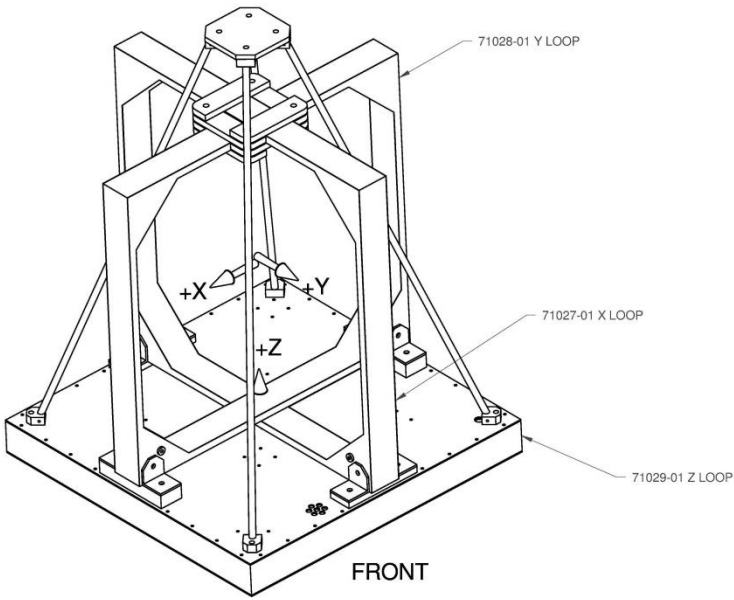


Figure 3 - Schematic of Orientations and Polarities

A close up of a receiver cube with a pre-amp board attached is shown in Figure 4. Each cube is 10 cm on a side.

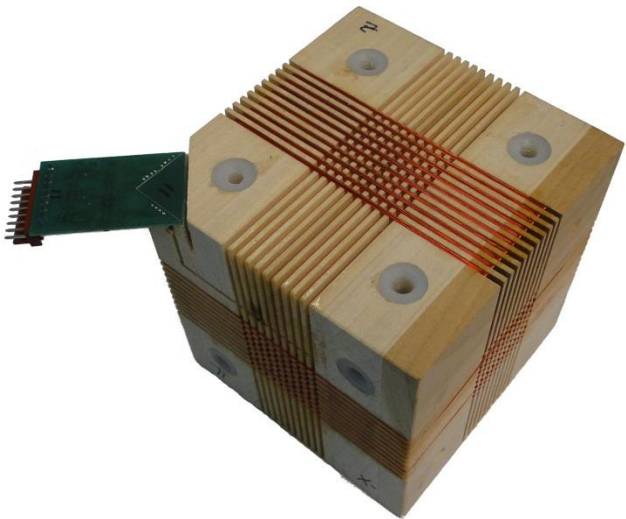


Figure 4 - Receiver Cube With Pre-Amp Board Attached

2.2. Physical Assembly

2.2.1. Transmitter/Receiver Array

The transmitter receiver array assembly consists of the bottom Z-coil which contains all the receiver arrays and the two vertical transmitter coils. Each of the two vertical coils are attached to the Z transmitter box using wooden blocks, fiberglass right angle braces and nylon nuts and bolts. The coil labeled the X coil is mounted first. Under the X-coil are two wooden blocks that are the thinner of the two sets of blocks that are used to mount the X and Y transmitters.

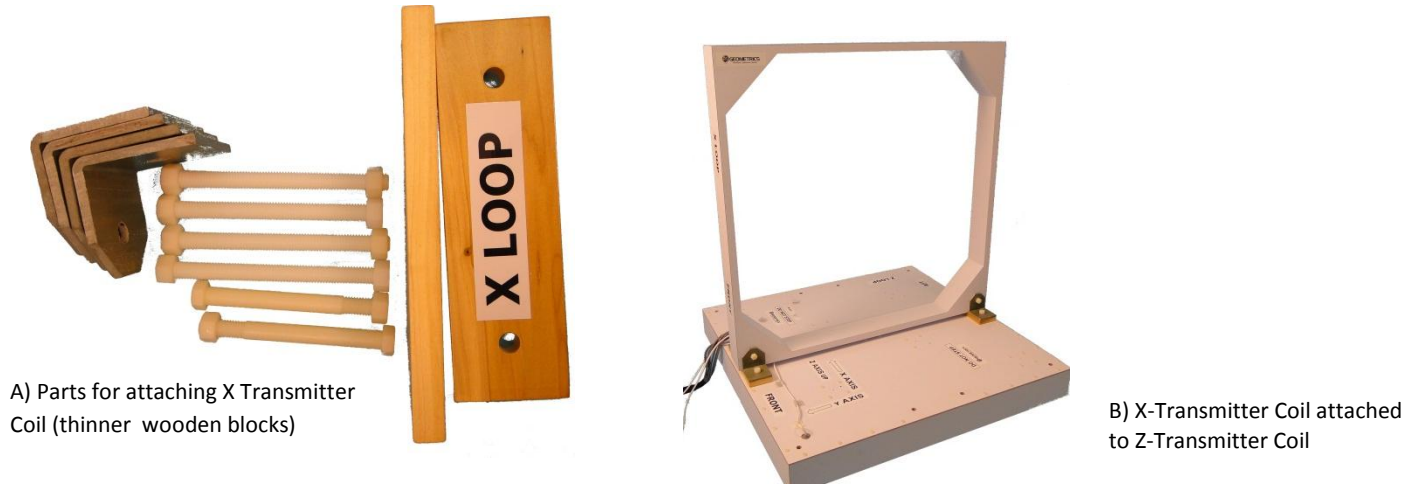


Figure 5 – Attaching X Transmitter Coil

An image of the X transmitter coil once attached is shown in Figure 5. Once the X transmitter coil assembly is completed, then the Y transmitter coil is assembled in a similar manner with the larger wooden blocks. The Y transmitter coil is mounted to the thicker wooden blocks and fits inside the X transmitter coil. Placing the transmitter receiver assembly on sawhorses helps ease the assembly as some of the bolts require access to the bottom of Z transmitter coil. Always use nylon bolts, as any metallic items will cause distortions in the measurement.



Figure 6 - Parts for attached Y-Transmitter Coil (Thicker Wooden Blocks)

Once the coils are assembled, the blocks that stabilize the tops of the transmitter coils are assembled as shown below.



Figure 7 - Vertical transmitter coil stabilization blocks

In addition, there is a wooden frame for mounting the GPS antenna on the transmitter/receiver array. It is bolted with nylon bolts to the Z-coil. It currently provides a 3/8" mounting bolt on a platform for a standard GPS antenna. Details of the platform construction are shown below.



A) Base of GPS Platform



B) Top of GPS Platform

Figure 8 - Details of GPS Platform Assembly

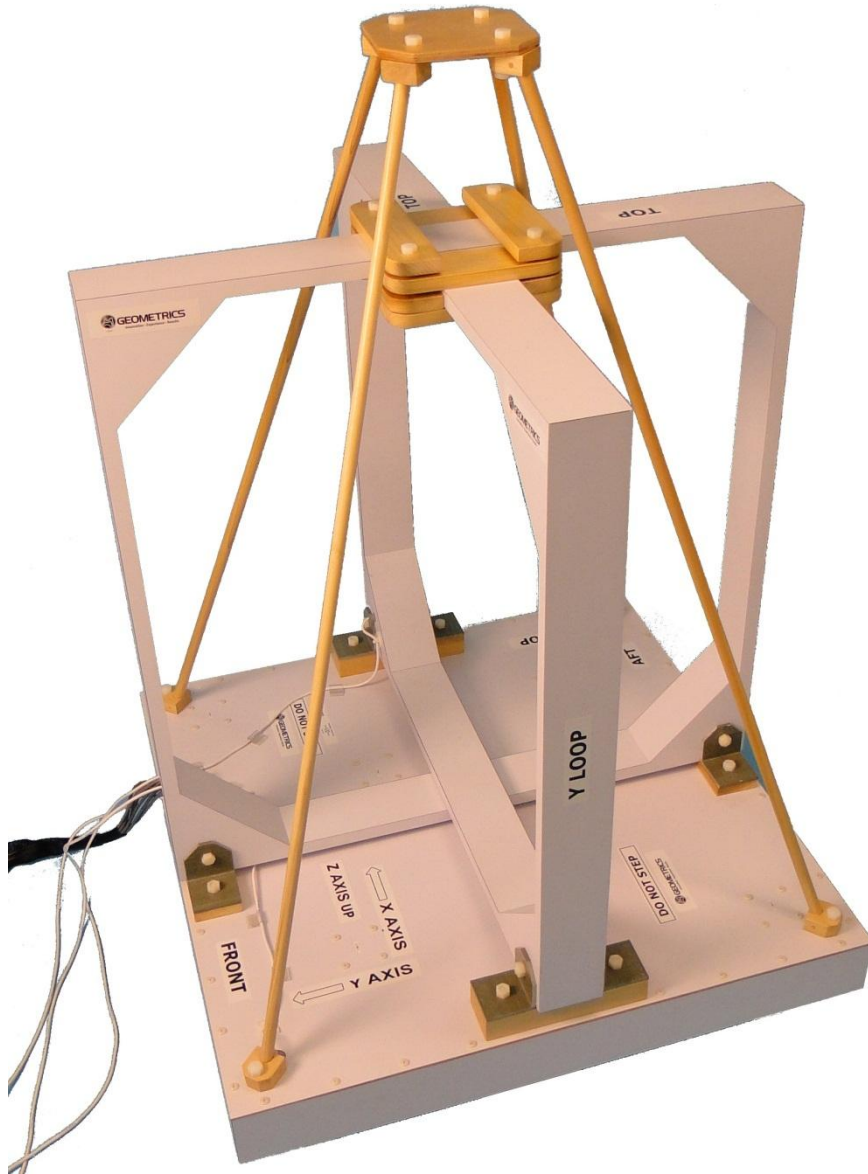


Figure 9 - Assembled Transmitter-Receiver Array

From the Z transmitter coil there are 7 cables that exit from the box through grommets on the top of box. These are connected to the 7 receiver cubes. At the other end of these cables they are labeled with the number of the coil that they receive signals from. The receiver cube cables are bundled together in a protective sheath for protection.

Each of the three transmitter coils also has a single cable attached to it. The cables connected to the transmitter coils are labeled X, Y, and Z. They plug into the similarly labeled receptacles on the transmitter board assembly in the acquisition computer box.

2.2.2. Acquisition Computer

The acquisition computer is a ruggedized acquisition computer built by National Instruments that contains three 8 channel A/D cards capable of digitizing the data at a rate of 250 kHz. (4 usec interval) with 16 bit accuracy. In the case with the acquisition computer are two receiver modules which deliver the signals to the A/D cards. The transmitter unit controls the currents and timing of the transmitter signal.

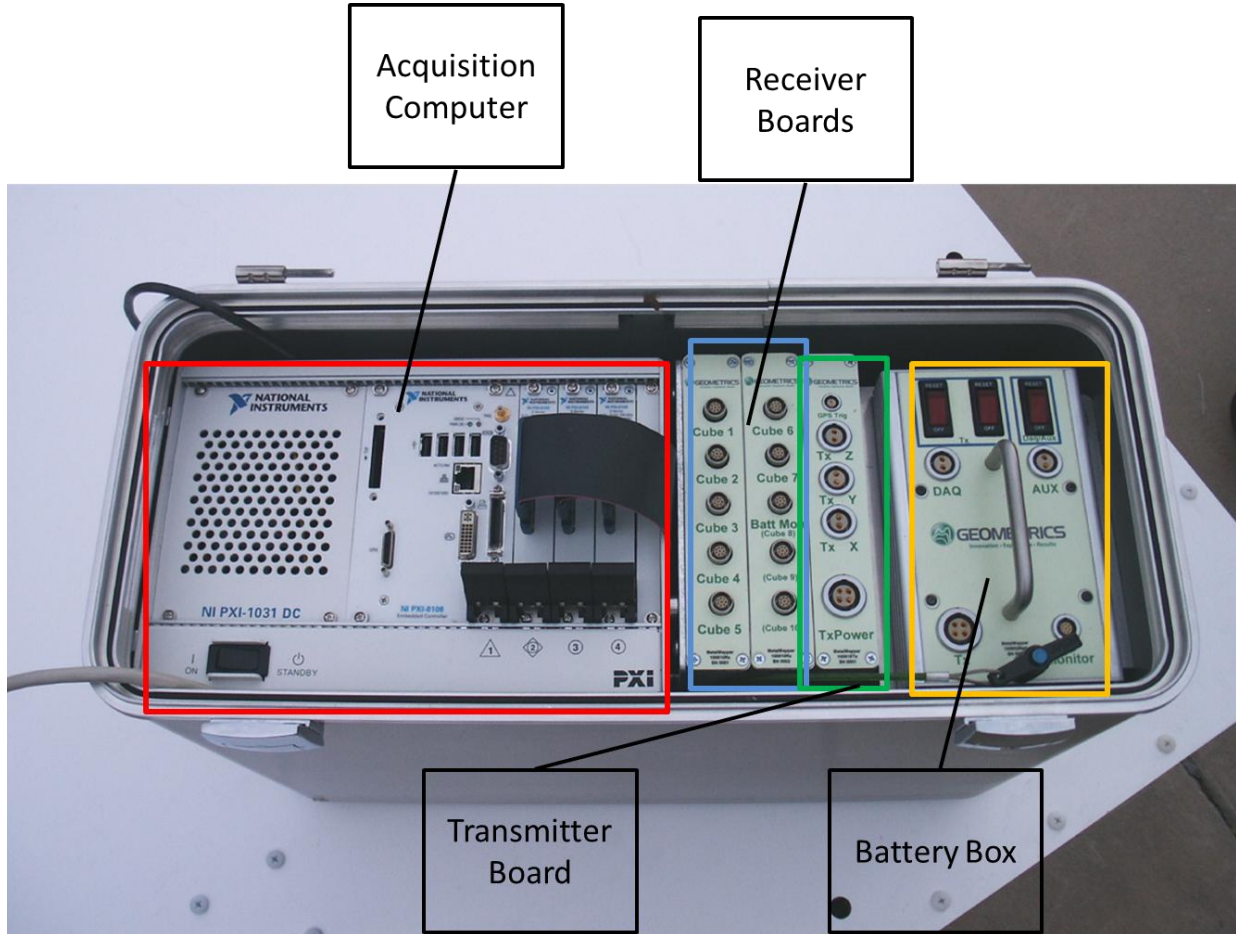


Figure 10 - Acquisition Computer

The acquisition computer once all the transmitter/receiver cabling is attached.

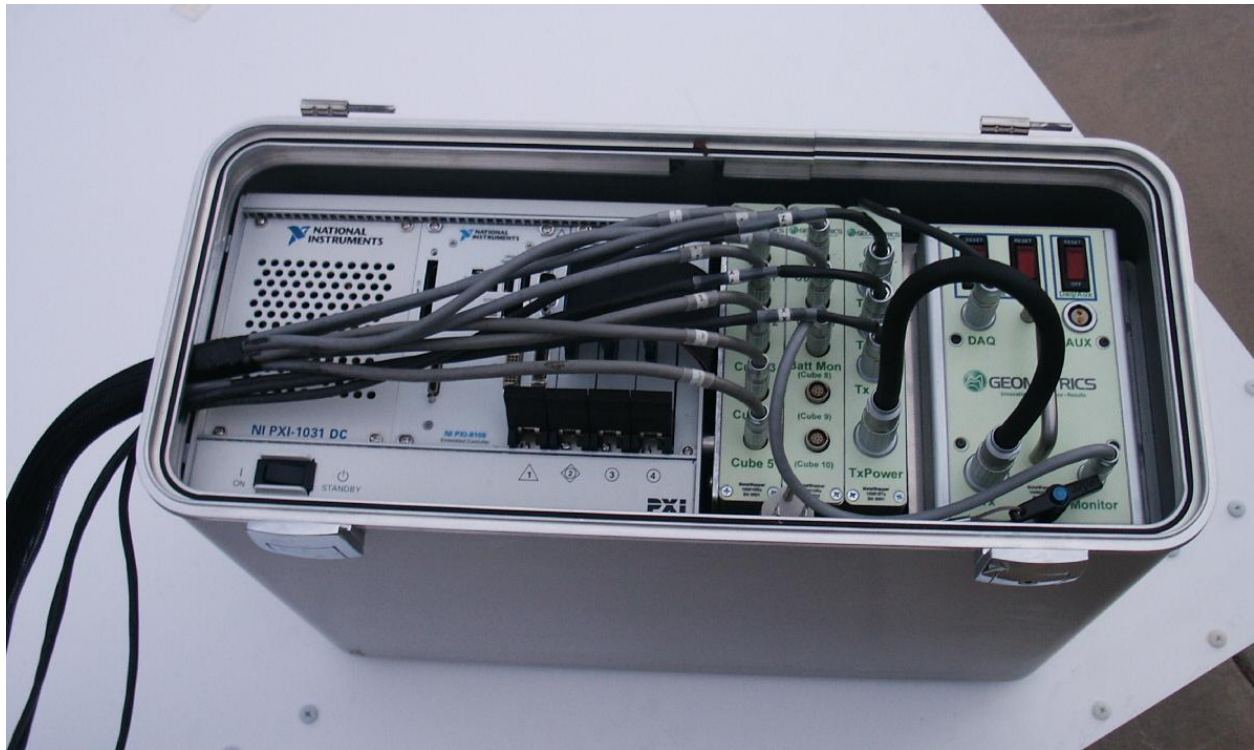


Figure 11 - Acquisition Computer with Transmitter/Receiver Cabling Attached

The monitor, touchscreen mouse, external USB-Serial Port adaptor must also be attached. A close-up of the acquisition computer with the ports labeled is shown in Figure 12.

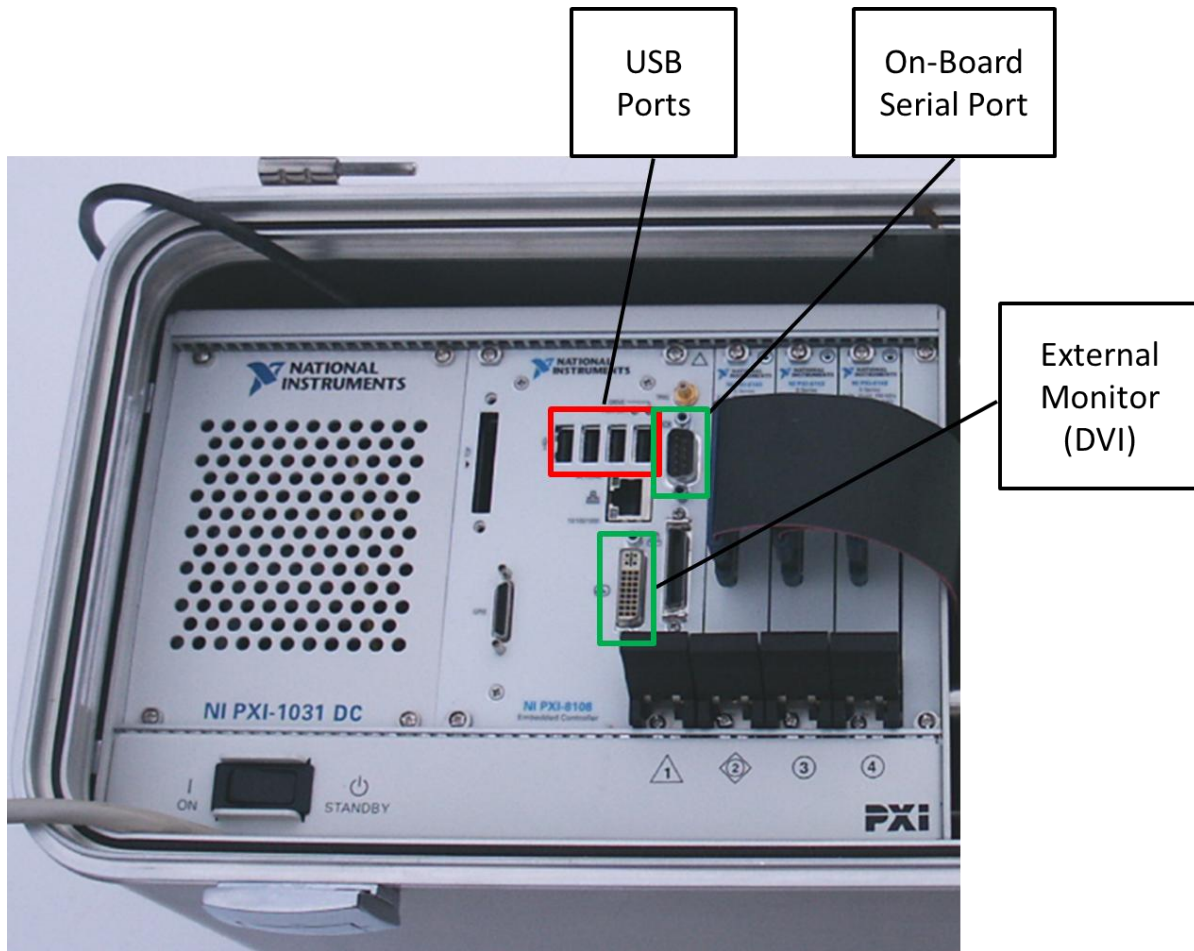


Figure 12 - External Ports on Acquisition Computer

2.2.3. Battery

The acquisition unit also contains a battery unit which can hold up to 4 Li-Ion batteries. These batteries can be used to power the entire system (computer and transmitter/receiver electronics) or just the transmitter/receiver electronics. The acquisition computer can also be powered by two 12-volt batteries connected in series to provide 24 volts or by AC power. In order for the system to function, the cable must be used to connect the Tx Power port to the Tx port on the battery box. Both Tx switches should be set to “reset”. If you are powering the acquisition computer using the Li-Ion batteries, then the power cable for the computer must be connected to the DAQ port and the DAQ/Aux switch set to reset.

2.2.4. External Display, Serial Mouse

The acquisition computer provides a DVI port to connect to an external monitor. The system comes with a 15" daylight readable touch screen system that requires a serial connection to the computer. The system is configured to have the touch screen mouse connected to the on-board serial port of the controller. The monitors provided with the system can run off either 120 volt AC or 12 V DC power.

2.2.5. External sensors

In addition to the transmitter/receiver data, the system also requires two external sensors to provide the orientation and location of the sensor.

The data from these sensors is streamed via serial ports provided by a USB serial converter. The serial port parameters are set in the EM3DAcquire.ini file.

Orientation sensor

There are currently two types of orientation sensors that can be used with the MetalMapper. The standard unit is the MicroStrain 3DM-GX1 which provides magnetic heading, pitch and roll of the instrument. The sensor is mounted on the GPS platform or on the X or Y transmitter coil. Care should be taken to not mount it too close to the GPS antenna as the metal in the GPS antenna can distort the magnetic field and provide inaccurate headings. The parameters of the serial port used in the communication are specified in the ORIENTSENSOR section of the EM3DAcquire.ini file.

Global Positioning System (GPS)

The system requires real time kinematic (RTK) accuracy systems to locate the targets. The GPS data needs to be provided in one of two formats. Either NMEA standard GPGGA or the Novatel specific format GPGGARTK. The parameters of the serial port used in the communication are specified in the GPSENSOR section of the EM3DAcquire.ini file.

3. Software

The software runs in Windows XP or Windows 7 (professional editions). The program is called EM3DAcquire. The software is responsible for controlling the data acquisition parameters, storage of the data and quality control plots.

3.1.Quick Start

The system is provided with two default measurement types. Static measurements are acquired when the system is stationary over a known target. It acquires the data over 8.328 ms using all three transmitter coils. These parameters have proven successful in several demonstrations for a variety of targets. The other default measurement type is dynamic acquisition. This is intended for use while towing the MetalMapper over an area. In this mode only the Z coil is used and the decay is measured over .924 ms with only a single stack. These parameters are discussed further in the section below, but this section is intended to get a user quickly using the system with standard parameters.

3.1.1. Quick Start – Point Acquisition

- 1) Select “Static” from the drop down list at the right hand side of the control window.
- 2) Click on the “Setup” button in the map window and load the file containing the target locations and numbers then click Done.
- 3) Select the target icon in the map view by double clicking on it.
- 4) Hit the Green Acquire button on the left hand side of the control window.
- 5) Select another target and repeat.

3.1.2. Quick Start – Line Acquisition

- 1) Select “Dynamic” from the drop down list at the right hand side of the control window.
- 2) Click on the “Setup” button in the map window and load the file containing the line locations and numbers.
- 3) Click on the “Points Mode” button to toggle to line mode acquisition, then click “Done”
- 4) Double click on the line on which you wish to acquire data. Click the Green Acquire button on the left hand side of the window when you are near the beginning of the line.
- 5) Begin driving down the line using the map and navigation bar to stay on the desired track.
- 6) Click the “Stop” button when the line is complete.
- 7) Click the “Map Next” or “Map Previous” Button to go to the next line that you want to acquire. Note that you can acquire the data on lines in either direction.

3.2.Software Startup

To start the program double-click on the EM3DAcquire program on the desktop of your acquisition computer. This will bring up several windows, some hidden behind others.



Once the program has started the windows default locations are shown in the image below:

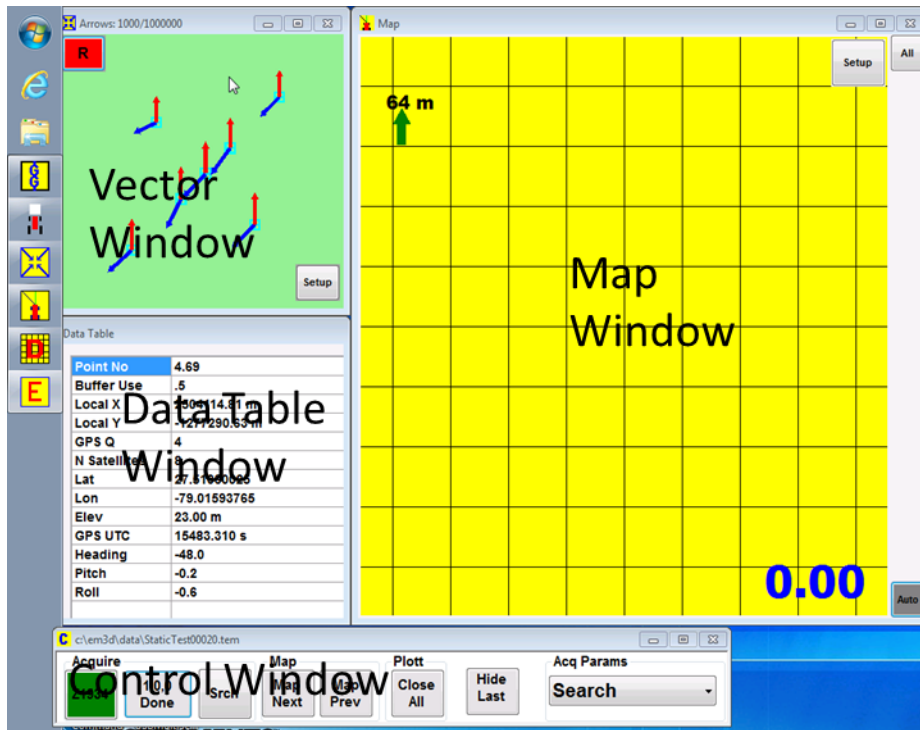


Figure 13 - Default Window Layout

The functions and features of the individual windows will be described below, but Table 1 below summarizes the functions of each of the windows.








| | |
|--|--|
|  EM3D  | Acquisition parameter control window, sets and saves parameters for data acquisition |
|  EM3D Control | Overall control window for starting and stopping acquisition, select saved parameter set and selection of line or cued point |
|  Arrows: 1000/1000000 | "Dancing Arrows" display – window displaying the vector direction and magnitude of each of the receiver cubes |
|  Map | Map window – displaying the position of the sensor array, acquired points and lines and loaded line and point cues |
|  Data Table | Data table window displaying selected information on the external sensors (GPS and Orientation Sensor) |
|  Error Message | Error Window – normally not visible only seen when error message are displayed. |

Table 1 - MetalMapper Window Icons

3.3.Parameter Window

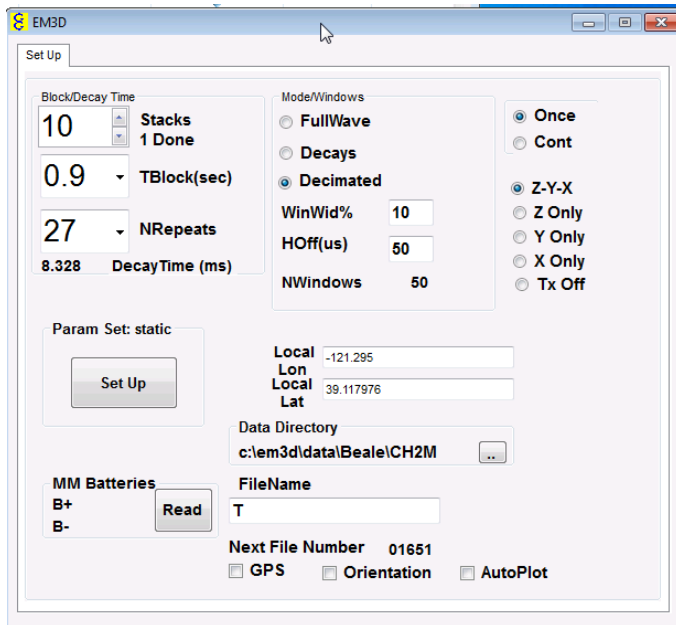


Figure 14 - Parameter Window

The parameter window is shown above. It allows control over how the data is collected and saved. The Block/Decay time section controls the transmitter turn on/off timing, number of decays measured and the length of the decays. The system used a bipolar half duty waveform shown in the figure below.

MetalMapper BiPolar Half Duty Waveform

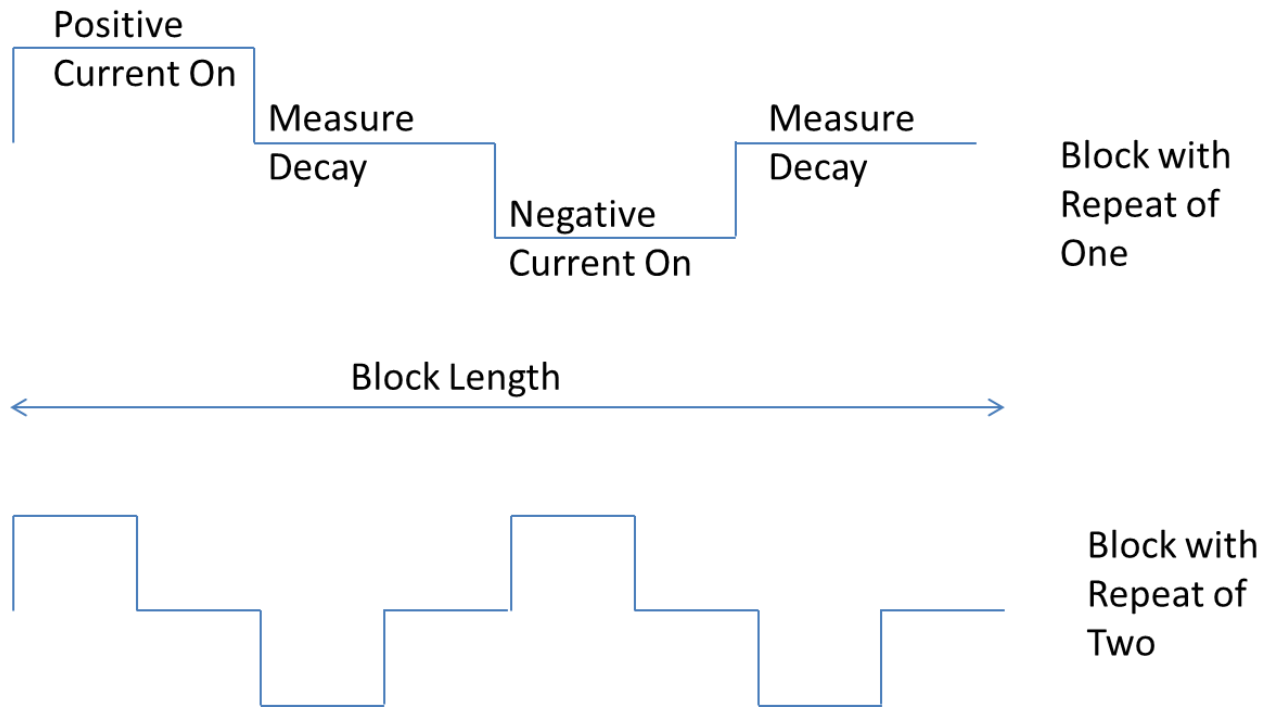


Figure 15 - MetalMapper Transmitter Waveform

The measurements in a TDEM system are made during the time when the current is off in the transmitter, so the decay is a portion of the total block length. There are two parameters that control the length of the decay measured. The first is the “TBlock(sec) measurement which is the total length of time of the waveform. The other parameter that controls the length of the decay measured is the “NRepeats” measurement which is the number of times that the bipolar waveform is repeated within the block time. The figure shows two waveforms below, the first with an “NRepeats of 1 and the 2nd with NRepeats of 2. The combination of those two parameters determines the duration of the decay measured. The decay time that is measured is computed as follows.

$$\text{DecayTime} = \text{TBlock Time}/(4*\text{NRepeats})$$

The factor of 4 is used because each individual decay that is measured is only $\frac{1}{4}$ of the total waveform time.

So a block time of 0.1 s with 9 nRepeats results in a decay length of $.1/(4*9) = /2.77$ ms. The resulting DecayTime is displayed at the bottom of the section. You cannot adjust the DecayTime directly, but only through modifying the TBlock and NRepeats parameters.

If we increase the TBlock time to 0.3 s, then the decay time will be 3 times longer or 8.33 ms. If we decrease the number of NRepeats to 3 while maintaining the TBlock of time of .1 s, then we will also measure a decay time of 8.33 ms. All the decays that are measured within a specific block are corrected for polarity (i.e. transients measured after the negative current turn off are multiplied by -1) and then averaged together. So if you have an nRepeats of 9, then the system will output a single measured decay that is the average of 18 decays (two measured decays per bipolar waveform). If you increase the NRepeats to 27 then you will average 54 decays.

There is also a nStacks parameter which can then average a set of decays that are obtained for different blocks. This also controls the output frequency of the decay measurements. If you are in continuous mode (discussed later) then with an NStacks value of 1, you will get a decay measurement every block. If you increase the NStacks number then a measurement will be output at an interval of $NStacks * TBlock$. So with an NStacks of 4 and a block length of .1 s, a measurement will be output every .4 s. With an NStacks of 1, a measurement will be output every .1 s.

The next section is the Mode/Windows section. This controls how the raw data is saved. The initial measurements are made with the data constantly sampled at 250 kHz. For almost all uses of the MetalMapper, this is significantly more information than is required for analysis. Therefore the data is averaged over a window. (although the option is available to save the raw data as well). Because of the measured field falls off rapidly, it is best to create data points that are sampled linearly in log time. So that when the data is plotted in a logarithmic scale the data will appear evenly spaced. There are three options to process and save the data.

1. FullWave – This option performs no data processing and saves the entire data set over the entire block length. This will result in very large data sets.
2. Decays – Selecting this will not perform any windowing, but will correct for polarity and average(stack) all the decays from different polarities and blocks into a single decay curve.
3. Decimated – This is the option most frequently used. In this case, time windows are specified so that all the data points within that window are averaged and then output as a single point. The width of the time window is controlled by the “WinWidth%” parameter. This parameter computes the window width as a function of the time, so windows later in time are wider. If you set WinWidth% to 10% then the window width will be 10% of the length of time from the time at the beginning of the window. If the

beginning of your window is at .9 ms, then the window width will be .09 ms. Because the data is sampled at 250 kHz., this will average 2,250 points and output a single value. If you select a 5% WinWidth, then the window at the same time will be .045 ms wide (1,125 points). If the start of the window is at .2 ms, then the window width will be .02 ms at 10% WinWidth% (500 points) and .01 ms at 5% WinWidth% (250 points). The next window will then be centered at the time of the window plus the width of the time gate. So with the case of a window at .9 ms and a window width of .09 ms, then next time gate will be centered at 0.99 ms. This process of averaging points over a window and then computing the start of the next window is repeated until the end of the total recorded time is reached. Using smaller WinWidth values will result in a larger number of windows. Generally a WinWidth% of 10% is sufficient for most static data point inversions.

The HOff(us) parameter specifies when the first time gate is output. In the initial 50-100 us after the current is turned off, the measured data is saturated by the field directly generated from the coil and not the currents in the buried metal objects, so it is generally ignored. In this case, all the data points between the start of the measurement and the Hoff time are averaged and output as a single measurement, however this data is rarely used in the inversion algorithms.

The total number of windows is a function of both of the above parameters and is displayed at the bottom of the group. This value cannot be directly input.

Transmitter Function Group.

This group has two sets of radio buttons. The first group controls whether only a single set of data as specified by the Block/Decay time is acquired or whether the data is acquired continuously until the operator stops data collection. The 2nd set of radio buttons controls which transmitters are used. The operator has the option of selecting all three transmitters, a single transmitter only or none of the transmitters. The transmitters are operated one at a time, so data acquisition with all three transmitters used will take three times longer than using a single transmitter.

Based on modeling and field results the following table shows recommended parameters for static (point), dynamic (mapping) and dynamic characterization parameters.

| Mode | Window Width | Hold-Off (µS) | Num Stacks | Num Blocks | Block Length (s) | Tx Coils | Repeat |
|------|--------------|---------------|------------|------------|------------------|----------|--------|
|------|--------------|---------------|------------|------------|------------------|----------|--------|

| | | | | | | | |
|-------------------------------|-----|-----|----|----|----|-----|-------|
| Static | 10% | 50 | 10 | 27 | .9 | ZXY | Once |
| Dynamic | 20% | 100 | 1 | 9 | .1 | Z | Cont. |
| Dynamic - Characterization | 20% | 100 | 1 | 3 | .1 | Z | Cont. |

Table 2 - Recommended Acquisition Parameters

The Local Lon and Local Lat parameters are used for display purposes. In the Data Table window. A simple calculation based on a flat surface is used to subtract the local lon and lat and display the resulting difference between the actual GPS location and the input values in the Data Table window.

The Data Directory parameter specifies the directory into which all the data files will be saved. FileName is the prefix for all files that will be saved. The files will be numbered consecutively and no file will be overwritten. You can only specify the file prefix and not the number.

The “GPS” and “Orientation” checkboxes determine whether or not the GPS and Orientation sensor data is stored in the data file. The AutoPlot box determines whether a plot is displayed after every data point is collected.

The Param Set: block brings up the following window. It is a tabular form of all the saved parameters sets with the parameters that can be set from the initial window. This window allows you to save a configuration as a specified name so that it can be easily recalled from the main control window. One thing to note is that in order to enter the window mode, transmitter mode and continuous mode you must use numerical characters rather than the text that is displayed.

When you are running the survey you should minimize the window when you are done with it, don't close the window as this will shut down the acquisition program.

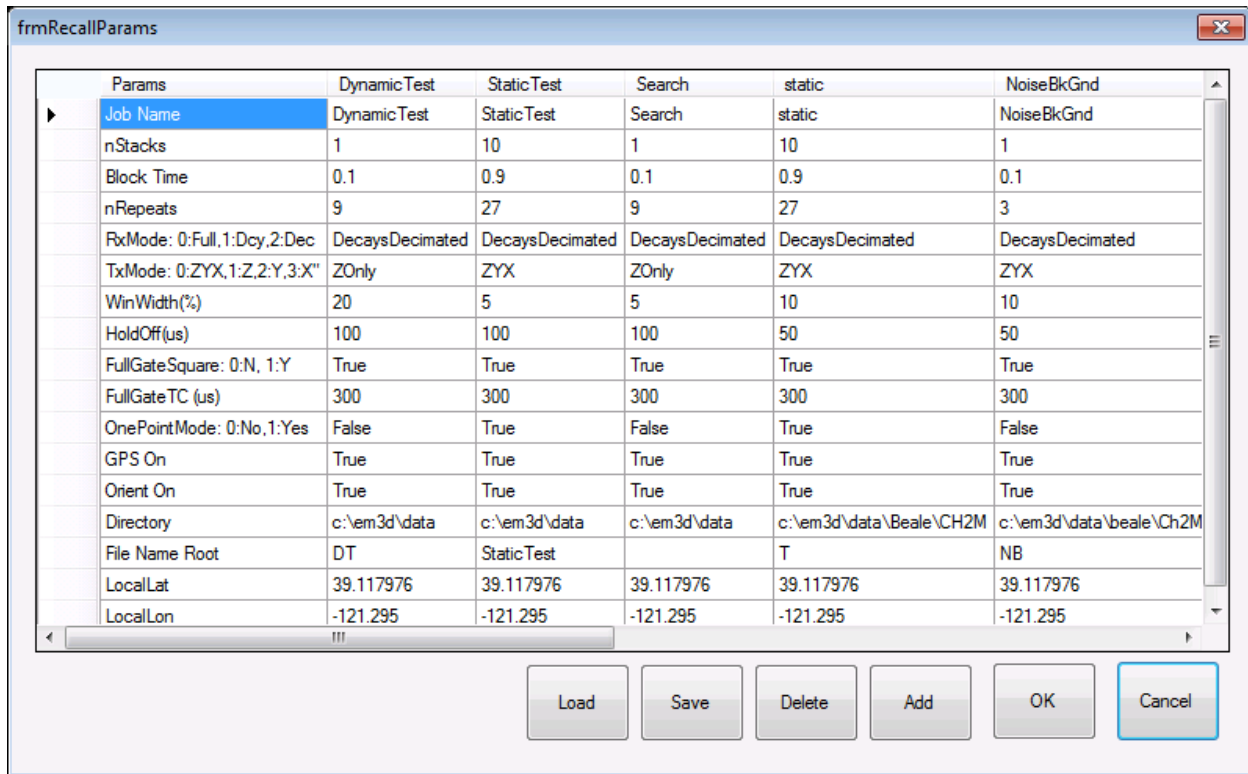


Figure 16 - Parameter Set Dialog

The data is saved in a binary object file whose format is defined by Microsoft .NET libraries. It is a format that contains both the data and a description of how the data was saved. A TEM2CSV program is provided that will translate the binary file to an ASCII format CSV file that is suitable for input into Geosoft routines for advanced processing.

To facilitate data processing it is recommended that several parameters be set up with the same acquisition parameters except for the File Name Root and possibly the directory for different purposes of data acquisition. Such different purposes include target acquisition, background acquisition, and instrument verification. For instance the files that were acquired for target characterization could have a file name root of "T", the background files could have a root name of "BK" and the files for instrument verification could all start with a prefix of "IV". This greatly simplifies separating the files later, as the data processor won't have to read through field notes to determine which files have what kind of data. Alternatively the different types of files could be stored in different directories.

3.4.EM3D Plot

Clicking on the EM3D plot icon brings up the following window. This controls the plotting of the decays that you have measured. If you have acquired data, then the table on the left will display the parameters of the last point taken. The graphic in the middle shows the location of each of the receiver coils. You can select which cubes you want to plot the data from individually by clicking them or you can click the "All" button to plot the data from all receiver cubes ("None" – will deselect all the receiver cubes). The buttons below select which transmitter decay curves you want to plot. Clicking the "ZXY3"

button will plot the decay curves from all three receiver orientations in a single window, but with three separate plots. If the button is not selected, the plots will appear in a separate window for each receiver orientation.

The EM3DPlot window also provides the ability to display previously recorded files. You can use the buttons on the right side of the window to load a single file, load the first file in the directory, load the next file in the directory, etc.

When the system has collected a new data point with the plot window open, the data will automatically be updated. However, if you select the NewFigures option, a new set of plot windows will open for each new data point. The buttons in the bottom of the section change the default setting for the plot axes. Clicking on the button cycles through the options of plotting in logarithmic, log-linear and linear for the X(time) and Y(amplitude axes).

EM3DPlot also allows you to save a file as a background data set, and then if the “Bkg Sub” checkbox is selected then the background data will be subtracted from all subsequent plots. In areas of a strong background response this can provide better information on whether data was acquired over a metallic object or not. There is also an option for smoothing the data.

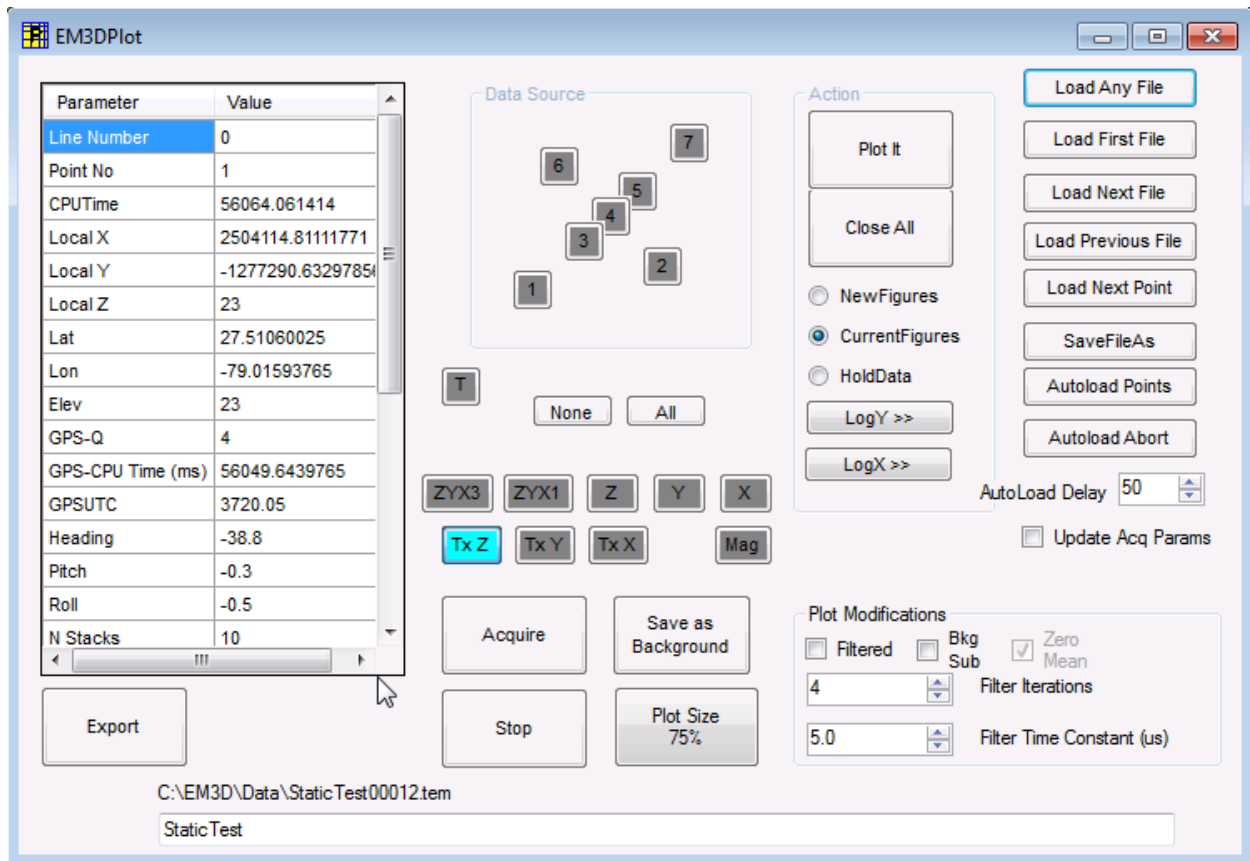


Figure 17 - Main Plot Window

The plots are organized by receiver coil orientation. Each window will have the data from all the receiver cubes at a particular orientation. For instance, one plot will show the decay curves for the X coils in all the receiver cubes selected. The decay curves are plotted in different colors for each receiver cube. The curves are labeled by the receiver orientation, the receiver cube number and the transmitter orientation. So the curve labeled Rx4Z is for the X receiver coil from receiver cube 4 with data collected when the Z transmitter was being used. The plots show the computed rate of change of the magnetic field within the coil. An example plot is shown below.

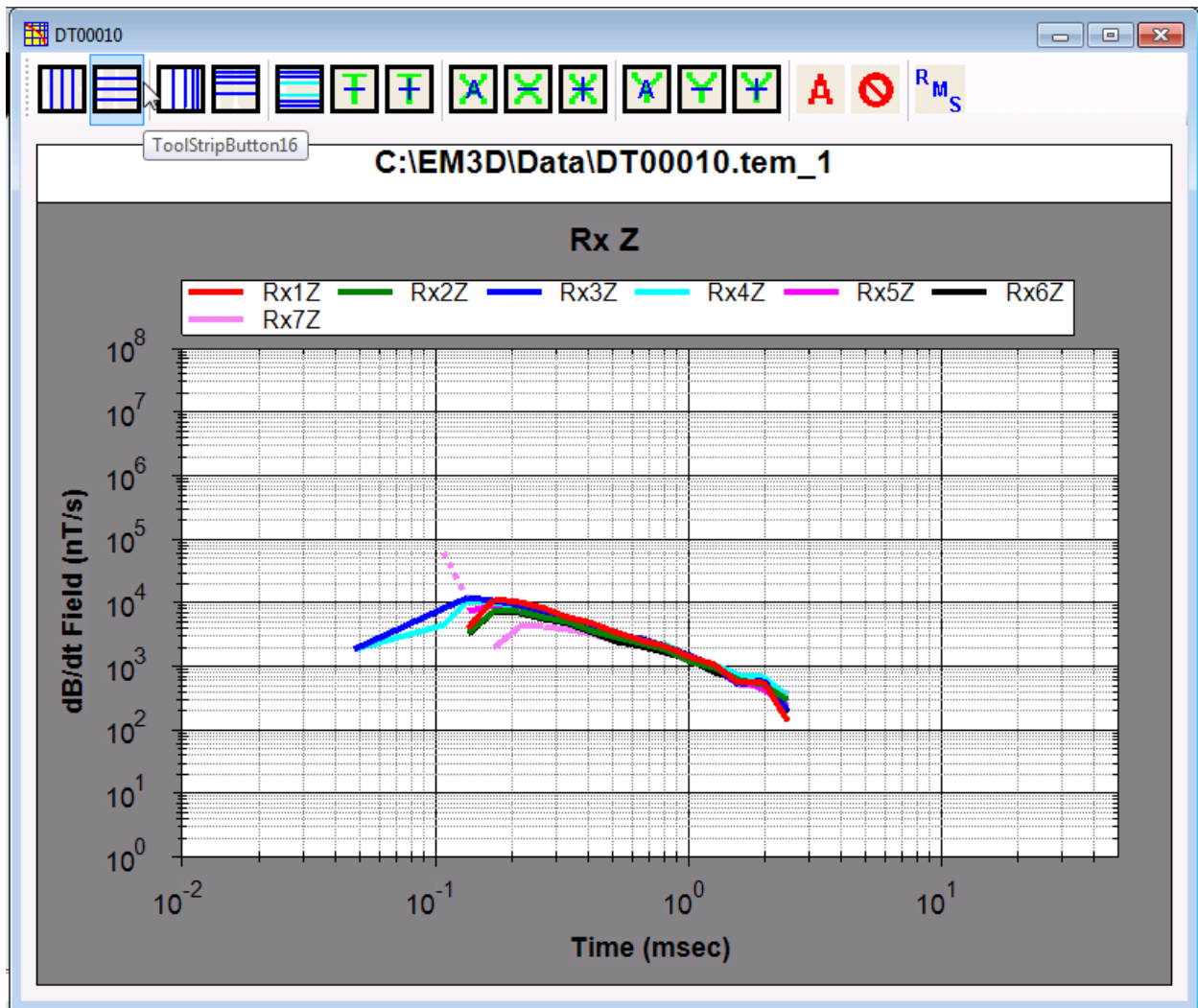


Figure 18 - Example Plot Window

The buttons on the top of the plot allow changing the plotting parameters. They do not affect the data collection. The function of the buttons from left to right is as follows:

| Icon | Function |
|------|------------------------------|
| | Plot the data in linear time |
















| | |
|---|---|
|  | Plot the data in linear amplitude |
|  | Plot the data in logarithmic time |
|  | Plot the data in logarithmic amplitude |
|  | Plot the data in linear amplitude in the middle of the plot, but logarithmic outside the blue lines |
|  | Decrease the area over which the data is plotted in linear amplitude |
|  | Increase the area over which the data is plotted in linear amplitude |
|  | Zoom out in the time axis to show all the data |
|  | Zoom out the time axis |
|  | Zoom in the time axis |
|  | Zoom out to show all the data in the amplitude axis |
|  | Zoom out the amplitude axis |
|  | Zoom in the amplitude axis |
|  | Acquire another set of data |
|  | Close all plots |
|  | List the RMS energy for each curve |

Table 3 - Plot Window Icon Functions

3.5.Map Window

The map window provides a dynamic graphical representation of the planned survey and the location of the coil. It can be used in cued acquisition mode to position the sensor over a previously mapped target or to navigate the sensor over a planned line. It can be configured to suit individual operators preference.

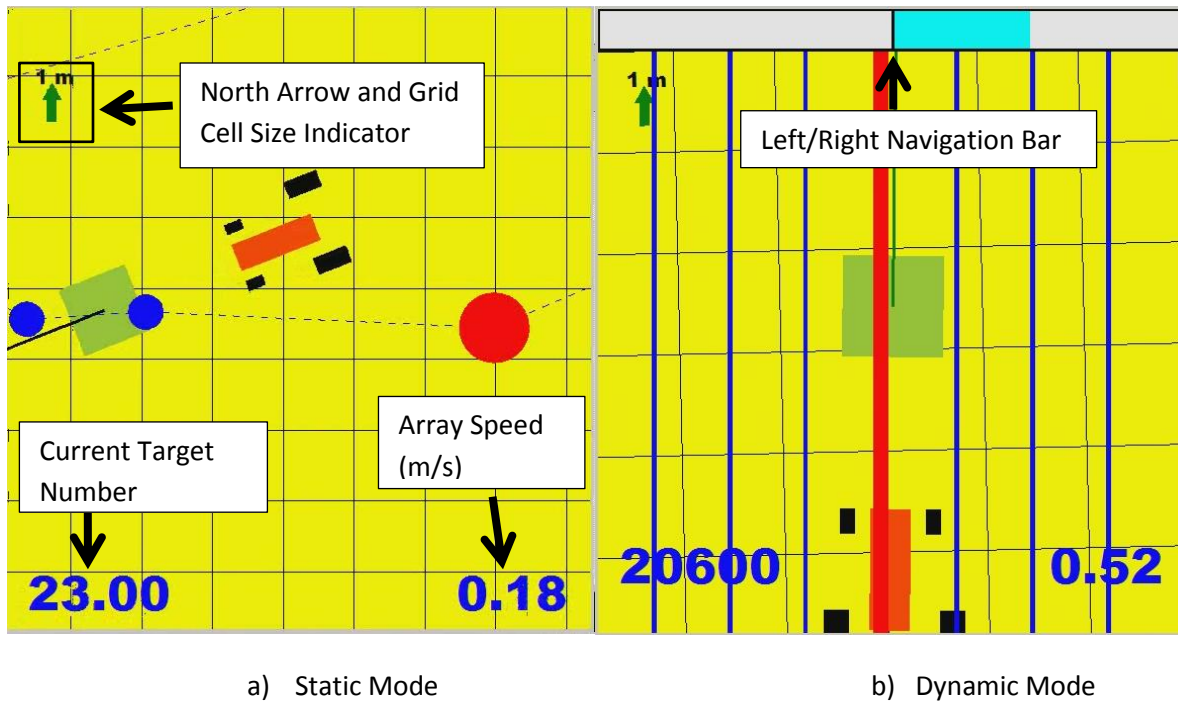


Figure 19 - Map Window a) Static (point) mode and b) Dynamic (line) mode

The meaning of the icons on the map are provided below:









| | |
|---|--|
|  | Location of MetalMapper Transmitter/Receiver Array |
|  | Current Target Point |
|  | Target Point |
|  | Acquired Cued Mode Point |
|  | Planned survey line |
|  | Current survey line |
|  | Acquired survey line |
|  | Location of tow vehicle |

Table 4 - Map window icon descriptions

On the lower right hand it displays the speed of the array in meters/second. The number of currently selected point or line is shown in the lower left. The upper left corner of the map displays the current grid cell dimension. When the map is zoomed in or out the size of the displayed grid cells will change, so this value allows the operator to gauge the distance required. The green arrow in the upper left corner also displays a North Arrow.

The cue icons (either point or line) can be selected by double-clicking on them. If you double-click on a point cue icon, then its color will change from blue to red and it will be displayed with a larger circle. The selected target number will also be displayed in the lower left hand corner. When a data point is acquired then the target number will be saved with the data file. A black "X" will also be displayed on the map at the location of the transmitter/receiver array. If you are in Line Mode, then you can select the track along which you can acquire dynamic data. When you are in Line Mode, an additional bar will appear across the top of the map view which displays the distance from the transmitter/receiver array to the right or left of the target line.

The right side of the map window has four controls:

- 1) "All" button – This will zoom out to display all cues and acquired data that is currently loaded into the program.
- 2) A slider bar that zooms the map in or out.
- 3) "Auto" button. This will automatically zoom in the map as the transmitter receiver array comes closer to the selected target. This button acts as a toggle and will be highlighted in yellow when it is active. When it is active the ability to zoom and pan the map interactively is disabled.
- 4) The "Setup" button.

Clicking on the "Setup" button displays the following window, which allows loading of planned surveys, the location of previously acquired data, and control over the map display parameters.

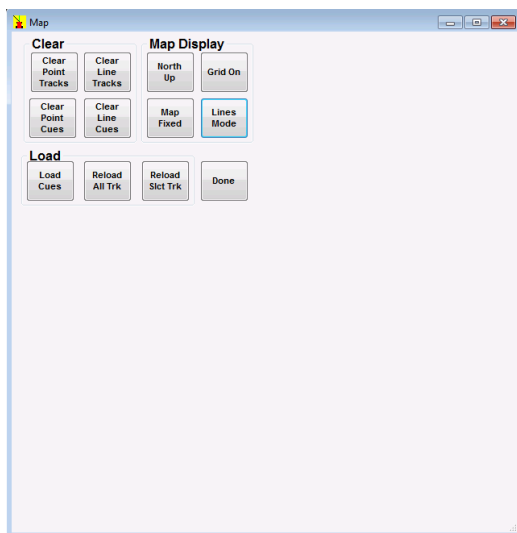


Figure 20 - Map Setup Dialog

The Map Setup has three main functions

1. Loading and clearing of “Cues” which are defined as point targets or planned line paths.
2. Loading and clearing of “Tracks” which are locations where data has been acquired either in point mode or line mode.
3. Control of how the map is displayed in terms of its orientation, scale and centered location.

The functions of the buttons are as follows:

| | |
|--------------------|---|
| CLEAR GROUP | |
| Clear Point Tracks | If any tracks – either point tracks (Locations where data has been acquired in point mode are in the buffer) the data will be cleared and no longer displayed. |
| Clear Line Tracks | Same as above, but for line data |
| Clear Line Cues | Line Cues are planned lines along which dynamic data is to be collected. If there are any line cues loaded in the buffer, they will be cleared and no longer displayed on the map. |
| Clear Point Cues | Same as above for point data. |
| LOAD GROUP | |
| Load Cues | Load either point (pre-determined anomaly locations) or line (planned line acquisition) into the buffer for display. The expected file extensions are either “.dat” or “.xyz”. The format is defined below. When the button is clicked a dialog box will open up and can be used to select a file with either target or line locations. |
| Reload All Trk | This function allows you to reload all point or line data in a directory. The format is the binary format output by EM3DAcquire and will have the “.tem” extension. It will pop-up a file select dialog box and you will need to select a directory that contains the desired .tem files. |
| Reload Select Trk | This button will perform the same function as above, but reload only the selected files. |
| MAP DISPLAY GROUP | |
| North Up/Cart Up | This controls whether the map is displayed with North always oriented to the top of the map, or whether the forward direction of the transmitter/receiver array is always oriented towards the top of the map. The button functions as a toggle and the currently selected mode is always displayed. |
| Grid On/Off | Toggle button to display whether or not the grid |

| | |
|----------------------------------|---|
| | lines are displayed on the map. |
| Map Fixed/Cart Fixed/Auto Center | <p>Toggles button which selects between three modes of selecting which area of the map is centered.</p> <ol style="list-style-type: none"> 1) Map Fixed – The center of the map remains in the same location. 2) Cart Fixed – The location of the transmitter/receiver array will always remain in the same location in the map window regardless of its actual location. The area of the map that is displayed in the window will pan to keep the location centered. 3) Auto Center – The central point between the selected target and the transmitter/receiver array will always be in the center of the map. The area of the map that is displayed in the window will pan to keep the location centered. |
| Points Mode/Line Mode | Toggles between point (Cued) mode which will display an X when a data point is acquired and line (Dynamic) mode which will “paint” an area where data has been acquired |
| Done | Click when map setup is complete. |

Table 5 - Map Setup Parameter Descriptions

The map window can be panned by left-clicking on any location in the map, holding the button down and moving the mouse so that the desired area is displayed. This function is disabled when the “auto” function is enabled.

When the transmitter receiver array is stationary, a single black line that originates from the center of the transmitter/receiver array is displayed that shows the direction that the array is headed as determined by the orientation sensor. This heading is corrected by the declination as specified in the EM3DAcquire.ini file. When the array is moving an additional green line originating from the same location is shown that is computed using the GPS data. When the array is moving in a single direction, both lines will plot as a single line, provided that the declination value is correct.

3.5.1. Cued Data File Formats

There are two types of cued data formats the program accepts. One for point acquisition and the other for line oriented acquisition. Both of these formats expect the location data to be in the format of longitude, latitude in decimal degrees.

Point File Format

Example File

```
-121.295013253973, 39.1179712347127, 2  
-121.295068493616, 39.1179828552634, 3  
-121.295123776703, 39.1179926743533, 4  
-121.295183641402, 39.1180043625086, 5
```

The format is a ASCII csv file format that displays the longitude and latitude in decimal degrees and the point number.

Line File Format

Example

```
//Flight 0  
//Date 2011/06/27  
  
Line E-W  
-121.2950701771 39.1179635437  
-121.2948389263 39.1179601604  
  
Line N-S  
-121.2949567233 39.1178717804
```

```

-121.2949523802      39.1180519239
Line  NE-SW
-121.2950723485      39.1178734719
-121.2948367546      39.1180502322
Line  NW-SE
-121.2948410980      39.1178700887
-121.2950680057      39.1180536154

```

The format is a standard Geosoft ASCII XYZ format. The first line must contain the word “Line” as the first characters, then a line name. The next line describes the beginning of the line in latitude and longitude in decimal degrees. The next line describes the end of the line in the same format.

3.6.Data Table Window

The data table window displays the current values of the external sensors (GPS and orientation sensor) as well as the memory status of the program. The information shown includes the in GPS location, number of satellites, quality of GPS fix. The local X and Y (using the parameters provided in the setup window). Latitude, Longitude, elevation and time directly from the GPS sensor. The heading, pitch and roll are displayed from the orientation sensor data.

| Data Table | |
|---------------------|---------------|
| Point No | 5714 |
| Buffer Use | .2 |
| Local X | 2504114.81 m |
| Local Y | -1277290.63 m |
| GPS Q | 4 |
| N Satellites | 8 |
| Lat | 27.51060025 |
| Lon | -79.01593765 |
| Elev | 23.00 m |
| GPS UTC | 18602.090 s |
| Heading | -48.2 |
| Pitch | -0.4 |
| Roll | -0.5 |
| | |

Figure 21 - Data Table Window

3.7.Control Window

The main control window is shown below. Once the parameters are setup as desired, this is the only window that the operator needs to interact with. Closing this window will result in the program stopping. The window displays a count of the number of data points or intermediate stacks acquired in the first button, and the rest of the buttons performs functions.

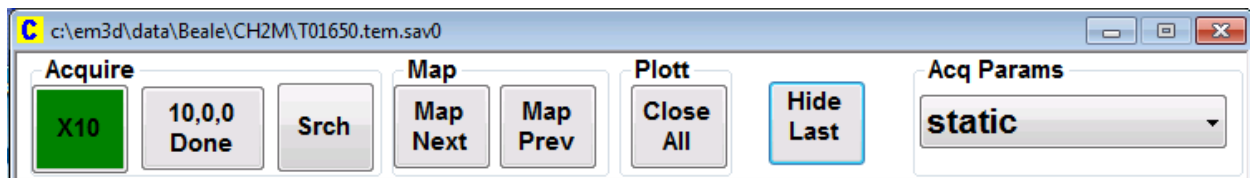


Figure 22 - Control Window

From left to right the buttons perform the following functions:

Green Button – When not acquiring this button is green and when pressed will turn to yellow. If the data is in single point mode, it will display the current transmitter being used and the stack count. It will automatically turn to green again once the data collection is complete.

The 2nd button will turn to red and display the word “Stop” when data acquisition or search mode is occurring and will allow the operator to stop data acquisition.

The “Srch” button enters search mode which can be used to better position the array over an anomaly and is further described in the section on the vector window.

The next two buttons in the “Map” group allow you to scroll through the cued items (either points or lines) to select the desired item. When acquiring line data, it can be used to easily move to the next or previous line in grid.

The “Plott” group contains a single button that closes all open plot windows.

The “Hide Last” Button will take the last file and rename it with a “.savX” extension name where “X” is a number incremented from 0. This is provided for when there is an error in the acquisition and file is not needed. This allows easier separation of files that are not required for the final analysis.



Figure 23 - Main Control Window

3.8. Error Window

The error window will pop to the forefront when an error occurs. Most often it is an error in the GPS data stream. When RTK quality is lost or the number of satellites drops down the error will be shown.

3.9. Vector Window

The vector windows is provided to allow improved positioning. It is a display that shows the magnitude of the fields measured in each receiver coil as a red arrow (always pointing up) and the vector sum of the fields measured in the X and Y coils in Blue. When the array is centered directly over the target all the Blue arrows will be pointing towards the center. If the array is not centered over the anomaly then the blue arrows will point towards the location of the peak of the anomaly. While this sounds a bit complicated, it is easier to understand when viewed in real time. Note that this doesn't mean that the array will be centered over the object. In situations with long dipping targets or multiple objects, the anomaly peak can be off-center from the main target.

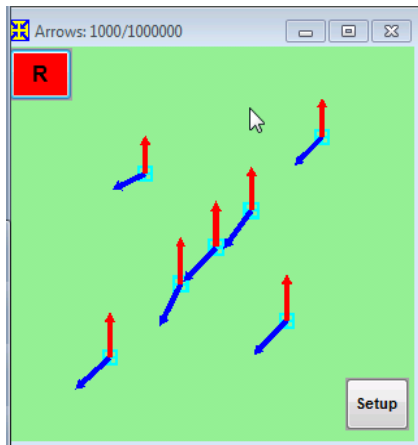


Figure 24 - Vector Window

4. EM3DAcquire.INI

A parameter file is provided to provide control of parameters that are less often changed. These include things such as coil locations, size and orientations. The only edits that should be made to this file are the serial port parameters for the external sensors and the magnetic inclination setting. An example file is shown below.

```
[SYSTEMID]
SystemID = MM2010

[ORIENTSENSOR]
OrientPort = COM4           ;COM11
OrientBaudRate = 38400
OrientParity = None
OrientDataBits = 8
OrientStopBits = 1
OrientHandshake = None
OrientReceiver = MICROSTRAIN3DMGX1; or CrossbowAHRS400; or .....

[GPSENSOR]
GPSPort = COM3             ;COM1
GPSBaudRate = 38400
GPSParity = None
GPSDataBits = 8
GPSStopBits = 1
GPSHandshake = None
GPSTiming = FreeRun; Or "Triggered"
GPSReceiver = GPGGA; or GPGGARTK; or NOVATELSPAN; or GPGGA;

[ANTENNACONFIGURATION]
nTransmitters = 3;
nSensors = 7;
NumComponentsPerSensor = 3           ;3 for cubes
'Z
TxVertices(1) = 0.5,0.5,0.0,    -0.5,0.5,0.0,    -0.5,-0.5,0.0,    0.5,-0.5,0.0
TxTurns(1) = 20;
'Y
TxVertices(2) = 0.5,0.0,0.05,    0.5,0.0,1.0,    -0.5,0.0,1.0,    -0.5,0.0,0.05
TxTurns(2) = 20;
'X
TxVertices(3) = 0.0,-0.5,0.05,    0.0,0.5,0.05,    0.0,0.5,1.0,    0.0,-0.5,1.0
TxTurns(3) = 20;

RxCenter(1) = +0.39, +0.39, 0.0;
RxCenter(2) = -0.26, +0.26, 0.0;
RxCenter(3) = +0.13, +0.13, 0.0;
RxCenter(4) = 0.00, 0.00, 0.0;
RxCenter(5) = -0.13, -0.13, 0.0;
RxCenter(6) = +0.26, -0.26, 0.0;
RxCenter(7) = -0.39, -0.39, 0.0;

;Distance from antenna array coord system center to ground
HeightAboveGround = 0.071;

GPSAntennaCoordinate = 0,0,0.0;
OrientationSensorCoordinate = 0, -0.1, 1.5;
```

```

[MAPORIENTATION]
;Cart heading for forward motion and map viewing relative to loop coordinate system
CartHeading = 0;
;MagDeclination = 10; Grand junction
;MagDeclination = -8.9; Butner
MagDeclination = 14.3; Beale

[DAQCHANNELS]
;These parameters define the physical hardware in the system
NumModules = 3
NumChannelsPerModule = 8
SamplingInterval = 0.000004
VoltsFullScale = 5.0 ;ADC volts full scale

;Values stored will be VoltsAtADC / AmpGain * RxUnitsFactor
;Units Factor is raw factor applied to measured voltage.
Units = T/s; or nT/s or V or uV (Units are T/s for RxUnitsFactor = 1 and for gain as
below
RxUnitsFactor = 1; or 1e9 for nT/s or 1 for V or 1e6 for uV
TxUnitsFactor = 1; Normally amps

;Stacking polarity is Used for older systems (AOL2, MPV) that sense Tx current in same
polarity independent of actual current direction in loop
; Enter 0 to stack normally, 1 to stack without sign change
RxStackingPolarity = 0;

;Sensor mapping is the connections between external signals and ADC channels within the
DAQ
; Parameters are entered in the order: 1Z,1Y,1X, 2Z,2Y,2X, 3Z,3Y,3X, etc.
;AmpGain is 'effective' area of loop and amplifiers.
;AmpRxGain can include area of receiver loop and total amplifier gain up to DAQ.
; Use gain of 1 to store volts at input to DAQ, or gain of preamp (without loop) to
store volts at output of loop.
; Gain of MM preamp and signal conditioning circuits is 1000
; Use negative gain to change polarity of sensor
;
; 1,1,1 2,2,2 3,3,3 4,4,4 5,5,5 6,6,6 7,7,7 This is a
template line to line up values below
;
; z,y,x, z,y,x, z,y,x, z,y,x, z,y,x, z,y,x, z,y,x Ditto
RxModule = 1,1,1, 1,1,1, 1,1,2, 2,2,2, 2,2,2, 3,3,3, 3,3,3
RxChannel = 2,1,3, 5,4,6, 8,7,1, 3,2,4, 6,5,7, 2,1,3, 5,4,6
ADCRxGain = 1.0,1.0,1.0, 1.0,1.0,1.0, 1.0,1.0,1.0, 1.0,1.0,1.0, 1.0,1.0,1.0,
1.0,1.0,1.0, 1.0,1.0,1.0; These values are always 1 for PXI6143 modules in DAQ
AmpRxGain = -1162.1,-1089.5,-1252.8, -1162.1,-1089.5,-1252.8, -1162.1,-1089.5,-1252.8,
-1162.1,-1089.5,-1252.8, -1162.1,-1089.5,-1252.8, -1162.1,-1089.5,-1252.8,
-1162.1,-1089.5,-1252.8,
;AmpRxGains above include precise calculation of cube effective areas, combined with gain
of preamp and signal conditioning.

;Current sensor is 0.5 ohm for MM, and signal conditioner gain is 0.5, therefore
effective gain is 0.25 to convert volts at ADC to amps of transmitted current.
TxStackingPolarity = 0;
TxIModule = 2,2,2;
TxIChannel = 8,8,8;
ADCTxIGain = 1,1,1;
AmpTxIGain = 0.25, 0.25, 0.25;

;If connected, channels 8 and 7 of the third module are battery sensing channels.
BattModule = 3,3;
BattChannel = 8,7;
ADCBattGain = 1,1;

```

AmpBattGain = 0.06772, -0.07176; These gains were experimentally determined. They are complicated by last minute changes in MM3 and MM4.