CSAMT Operation Manual

Prepare and Plan the CSAMT Layout

Equipment Required

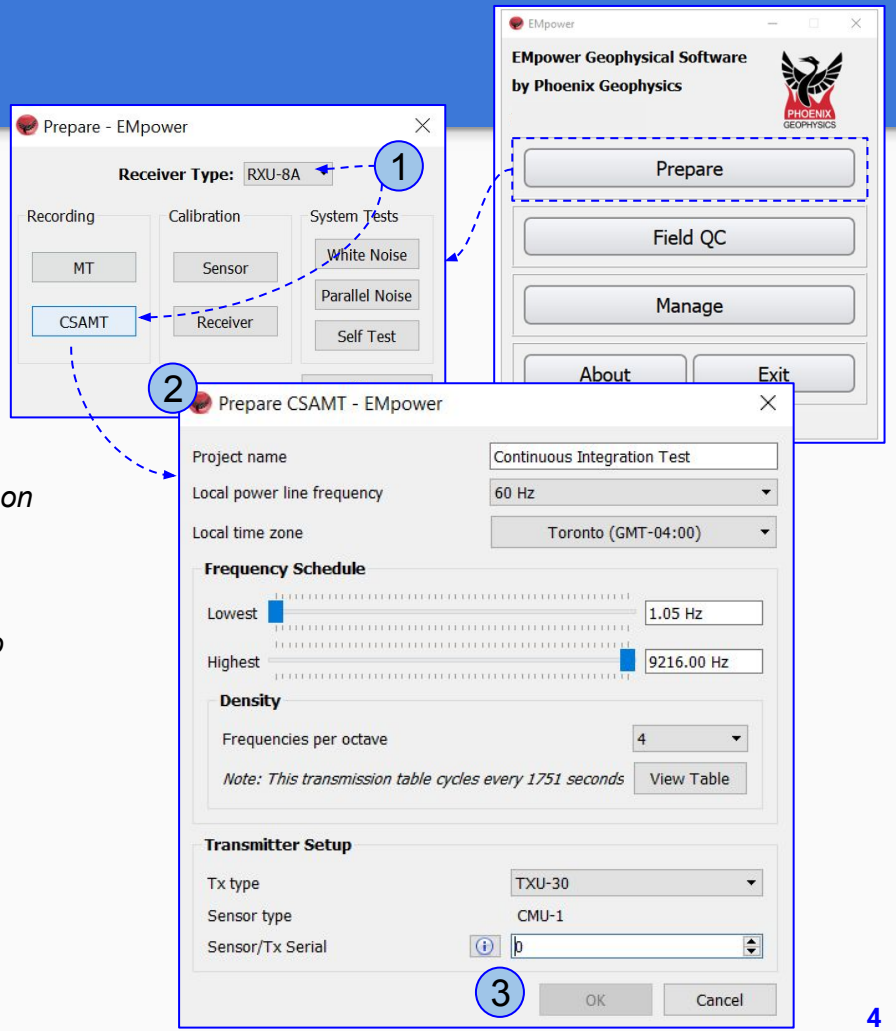
Transmitter Side	Receiver Side	General equipment	Tools & Supplies

• TXU-30 or T3 transmitter and connecting cables
  ○ Aluminium plates or Steel stakes for dipole
  ○ Electric wires
  ○ PE5 electrodes or steel stakes for grounding
• Remote Controller
• CMU-1 *(only with TXU-30)*
• TXD-1 transmitter Driver
  ○ SD Card
  ○ GPS antenna and cable
  ○ 12V Battery and Battery cable
  ○ PE5 electrodes or Steel stakes for grounding
• 3 Phase Motor Generator
  ○ Steel stake for grounding
	• Receiver
	• GPS antenna and cable
	• 12V Battery and Battery cable
	• Steel stakes or PE5 for dipoles and for grounding
	• E-line wires
	• Magnetic sensor and cable
	• SD Card with config file for each operation
	  ○ Receiver Calibration
	  ○ Sensor Calibration
	  ○ CSAMT recording
		• Configuration Layout Sheet
		• Laptop
		• EMpower + License *(v2.1 or above)*
			• Shovel and picks *(as needed)*
			• Hammer, to install steel stakes
			• Container of salt water *(50 g/L)*
			• Handheld compass
			• Measuring tape
			• Multimeters *(Analog and digital)*
			• Pencil and permanent marker
			• Bubble Level
			• Wire cutters
			• Electrical tape / Flagging tape
			• Tarp

Configuring Acquisition with EMpower

1. Select the **Receiver Type** and choose the **CSAMT** as recording type
2. **Prepare CSAMT** Setup Wizard
   - Type the **Project name**
   - Select the **Local power line frequency**
   - Choose the **Local time zone**
   - **Frequency Schedule**
     - Define the lowest and highest frequencies of interest *(Depending on target and operation needed)*
   - **Density**
     - Select the desired data ***Frequencies per octave***

     Note: the denser the data, the longer it will take for the transmitter to cycle through all requested frequencies
   - **Transmitter Setup**
     - Select the Transmitter **Tx type**
     - Type the **Sensor/ Tx serial** number
     - For TXU-30 *(external sensor)*
       - Use the CMU-1 sensor Serial Number
     - For T3 *(internal sensor)*
       - Type the serial number of the transmitter *(4 digits)*
3. **Click OK**



Configuring acquisition with EMpower

Default channels settings *(optimal for CSAMT)*

Gain: Normal
Low Pass Filter: 10 kHz

4. Define the Electric **Dipole** length expected in the field, usually between 10 m to 200 m

5. Define the H1 **Magnetic Channel Settings** *(recommended)* and disable channels H2 and H3.

6. Review the **Frequency Transmission Schedule** *(shows the frequencies and duration schedule configuration)*

7. Use the **Configuration Layout** to complete the information layout *(Optional)*

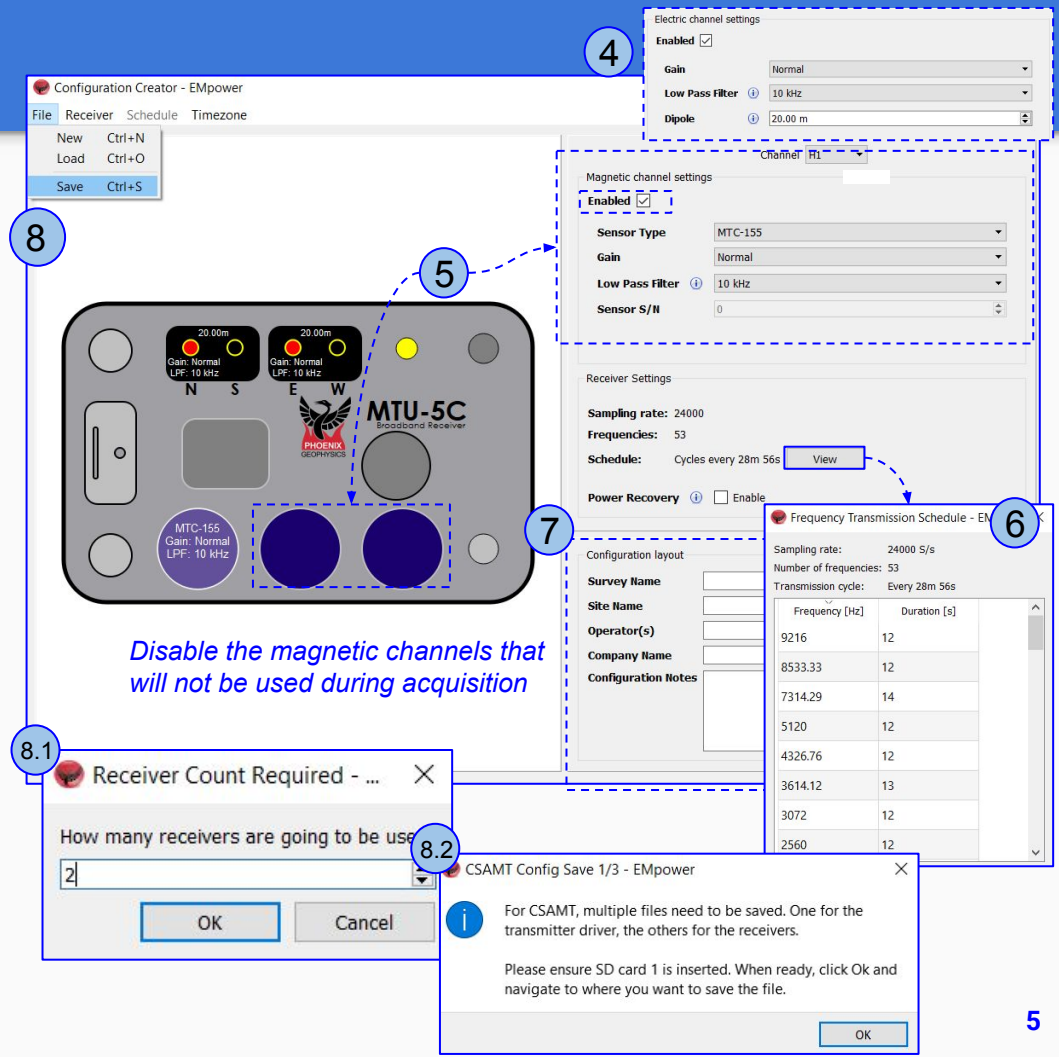
8. Save the Config files

** 1 SD card for TXD-1 + 1 SD card per receiver*

8.1. Select the number of receiver(s)

8.2. EMpower will create one configuration file for the transmitter drive and one Configuration file per receiver

**The SD cards are interchangeable for any equipment (only when using the same receiver type).*



Scalar CSAMT Layout Configuration
The controlled source recording grid

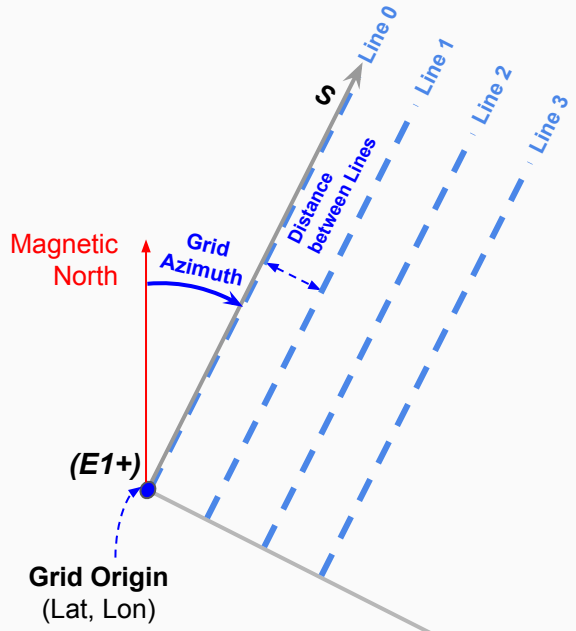
A grid is a set of lines arranged along two perpendicular imaginary axes which have their origin at a specific geocoordinate:

1. The ***L*** axis, along which the numeric ID of lines increases

2. The ***S*** axis, along which station numbers increase in numeric ID. All lines are parallel to this ***S*** axis (ideally)

The grid axes can be rotated via an azimuth angle, which is measured clockwise with respect to the magnetic north line, where the magnetic north is measured at the grid origin.

Each controlled source station recorded is located in reference to this grid.

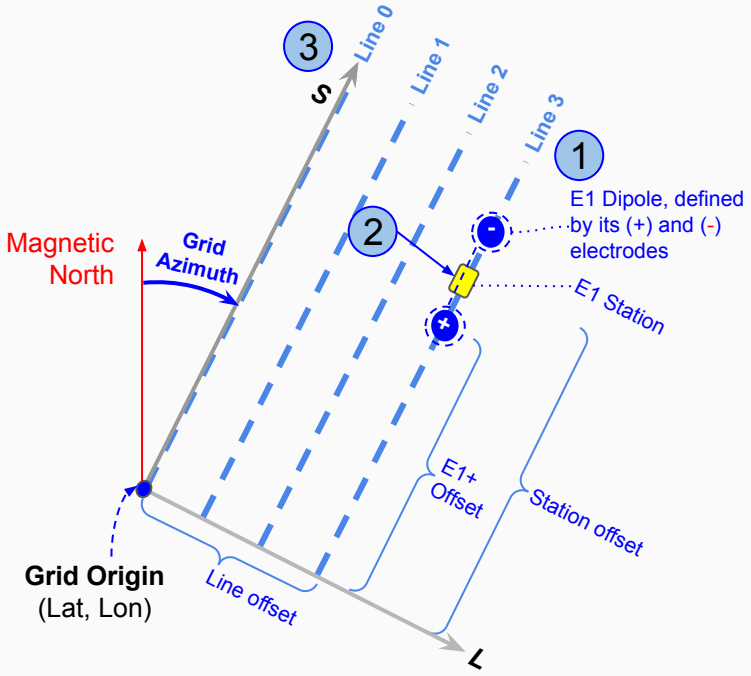


A **Grid Origin is the geocoordinate of the first electrode **(E1+)** of the line. All station and line offset which use the same grid will be calculated using the distance from **Grid Origin**.*

Scalar CSAMT Layout Configuration
Location of a scalar CSAMT station in a grid

A station is located at the centre of each dipole in scalar CSAMT surveys. Dipoles are installed on top of the lines defined in the grid.

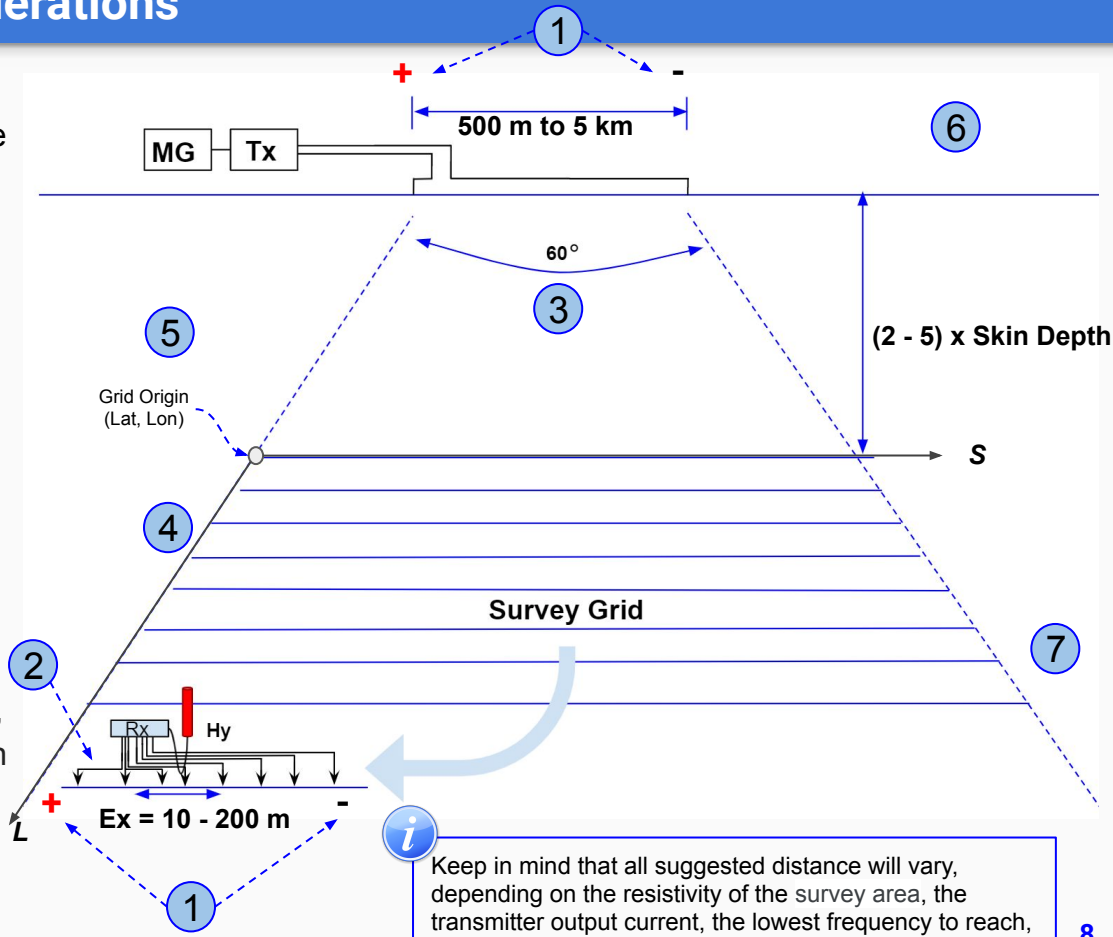
1. A dipole is defined by the positive (+) and negative (-) electrodes connected to a channel (i.e channel *E1*). The electrodes of a channel should be installed in the direction (+)→(-) following the direction of the ***S*** axis.
2. **"Station Offset"** is located at the midpoint of each electrode couple. The position of a station offset is defined by ***Line*** and ***Station*** offsets. These are defined as the distance of the station from the ***Grid Origin***, projected onto the ***L*** and ***S*** axes respectively.
3. The channels of a receiver should increase in the direction of the ***S*** axis. For instance, the station defined by *E1* should be installed closer to the origin than the station defined by channel *E2*.



For convenience, EMpower lets users to define the location of stations based on first electrode position for each recording, which is easier to relate to the field layout

Scalar CSAMT Layout Configuration
Transmitter/Receiver layout considerations

1. If the geological strike is known, plan the survey lines and Tx dipole to be perpendicular to the strike direction as much as possible. In the field, try to keep the survey lines as parallel as possible to Tx dipole to maximize coupling.
2. Minimum Tx-Rx distance is controlled to avoid extreme “Near-field” effect, which is related to ground resistivity and to lowest frequency of interest
3. Maximum Tx-Rx distance can be as far as the signal strength is strong enough to record acceptable CSAMT data
4. Signal strength depends on Tx current, ground resistivity, frequencies, Tx dipole length
5. Rx E-dipole length ranges between 10 m to 200 m, depending on lateral resolution requirement and on productivity
6. Ensure to use the same polarity for Transmitting and for Receiving dipoles *(reverse polarity can be corrected later in EMpower)*

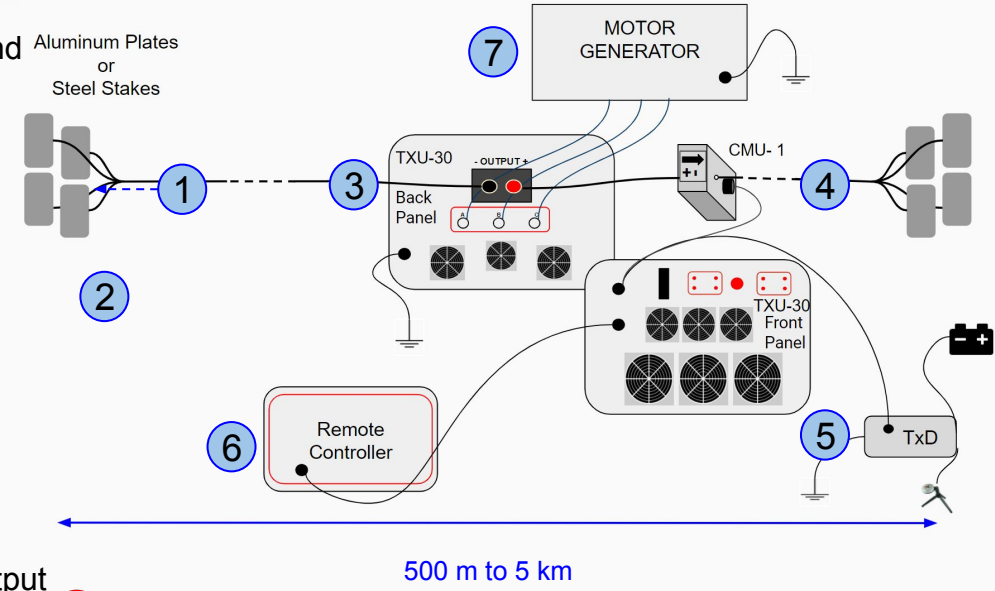


Keep in mind that all suggested distance will vary, depending on the resistivity of the survey area, the transmitter output current, the lowest frequency to reach, the near field effect and the lateral resolution needed.

Setting up the Site

Connections on the Transmitter side - Using a TXU-30

1. Install transmitting Electric wires
   - The dipole length will depend on the contact resistance, and the output current needed *(Ohm's Law)*
2. Install plates/stakes at each end of the transmitting dipole
   - To lower the contact resistance, increase the number of aluminium plates/steel stakes, and/or add salted water
   - For better contact resistance, prefer aluminium plates over steel stakes.
3. Install TXU-30 transmitter
   - Connect to ground electrode
4. Install CMU-1 in the right polarity (+/-)
   - Slide the transmitting electric wire through the hole in the CMU-1, and then connect transmitting wires to TXU-30 output
5. Install TXD-1 transmitter Driver
   - Connect the GPS antenna, ground electrode and 12V battery
6. Connect TXU-30 to CMU-1 and TXD-1
7. Connect the Remote Controller to the TXU-30
8. Install and connect the Motor Generator to the TXU-30
   - Connect to ground electrode



The transmitting dipole injects a high voltage current. Be careful when operating the transmitting side and NEVER touch the aluminum plates or steel stakes when the transmitter is injecting current. **Secure the installation of aluminum plates or steel stakes by placing a fence around it with caution tape as a warning.*

Connection options for receiver electrode layout - RXU-8A

Select electrode locations that form 5 adjacent dipoles measuring the same length, and choose one of these two options

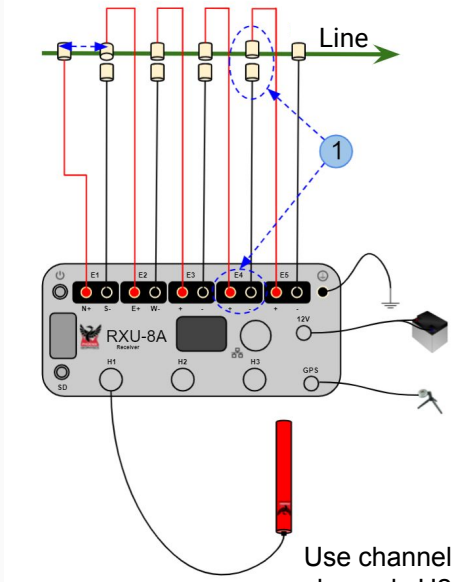
Option 1 *(Independent electrodes)*

1. All posts of all channels are connected to an electrode. All electrode holes in the middle use a double electrode
   - Electrodes sharing a location should be installed a few cm apart without altering the dipole length
   - To avoid electrodes layout or connection mistakes, follow the drawing instructions

Option 2 *(Shared electrodes)*

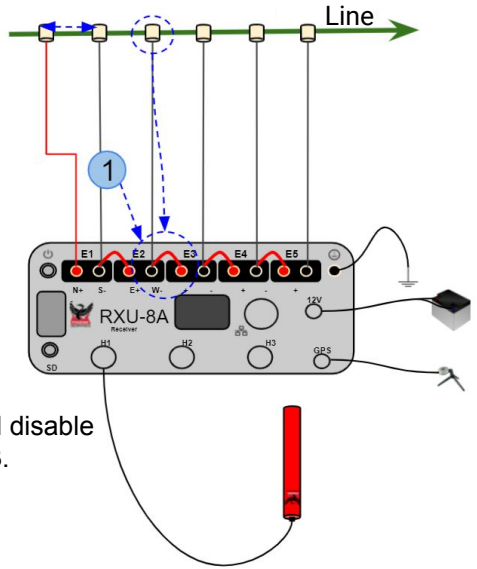
1. Six binding posts are connected to electrodes (not counting the ground). To share electrodes, the binding posts between central channels are bridged with wire as per the illustration
   - To avoid mistakes with electrodes layout or connections, follow the instructions in the drawing

Option 1



Use channel **H1** and disable channels H2 and H3.

Option 2

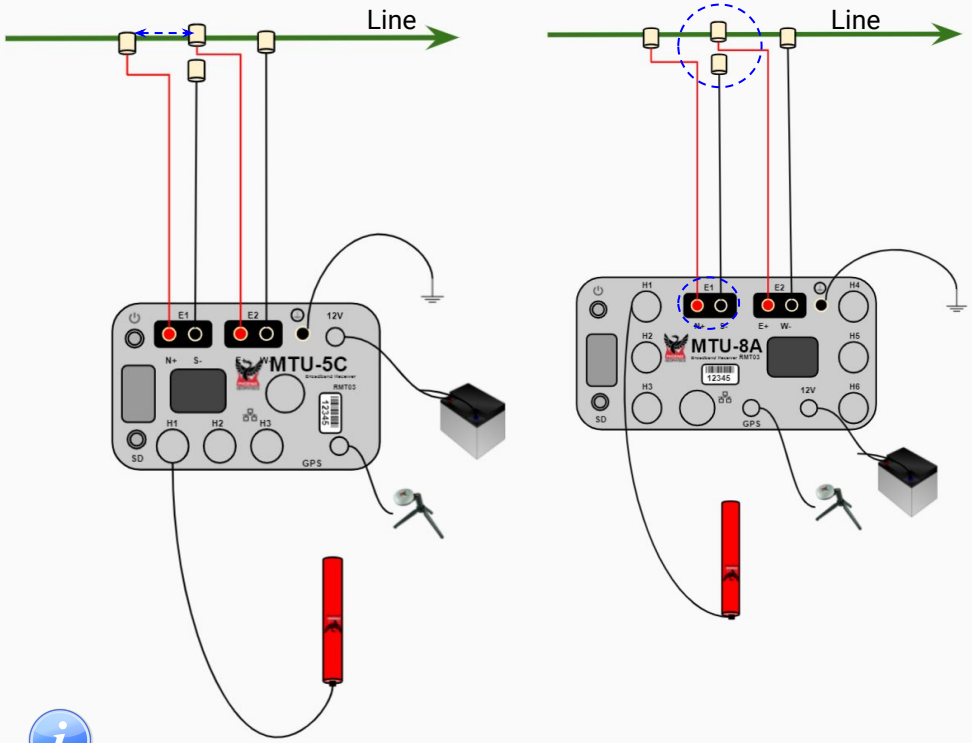


The spacing shown between electrodes in these drawings is not to scale

CSAMT Connection MTU-5C / MTU-8A

As shown in the image, the CSAMT connection layout guidelines previously shown for RXU-8A can work using any receiver type.

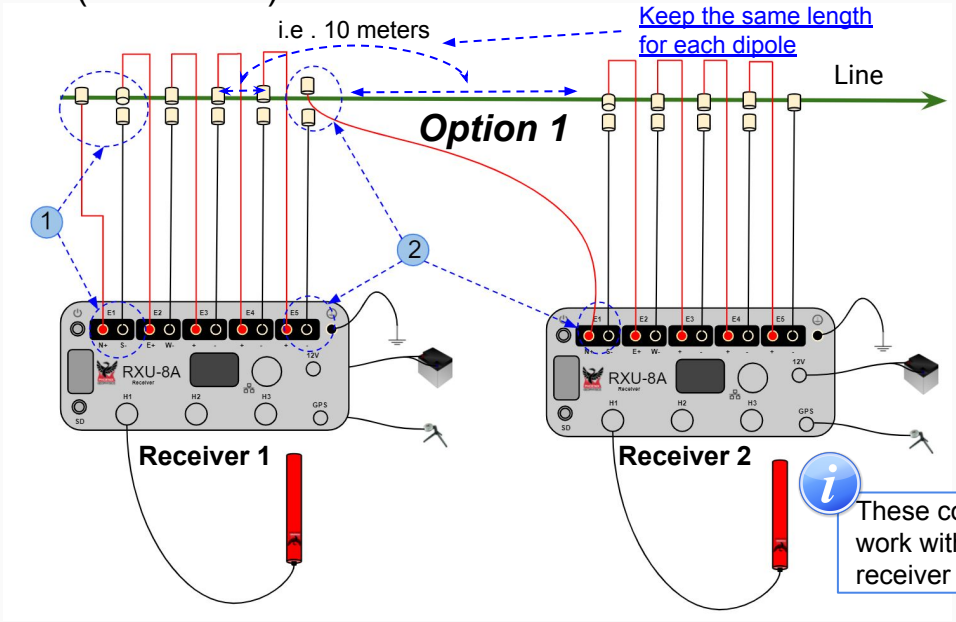
Ensure that the configuration files for all receivers and for the TXD-1 are generated at the same time. This will ensure that they are using the same transmission frequency schedule



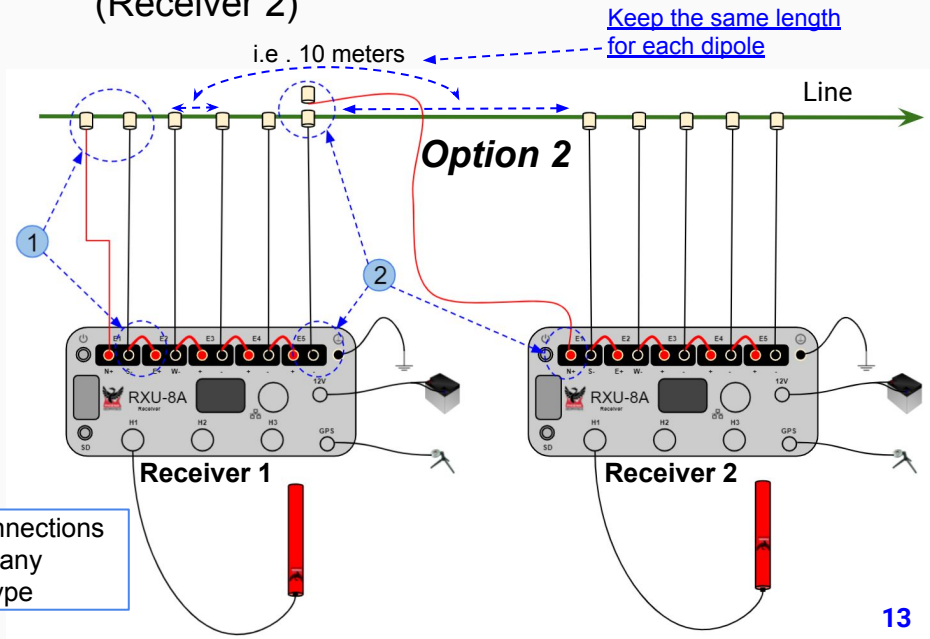
These drawings show one connection option only. See the *Connection options* page for more information

Working with more than one receiver

1. To work with more than one receiver, follow the correct connection, using the **Option 1** *(See connection options page)*
2. Following the drawing instructions, use the E5 (-) spot (Receiver 1) to install the electrode E1(+) (Receiver 2)



1. To work with more than one receiver, follow the correct connection, using the **Option 2** *(See connection options page)*
2. Following the drawing instructions, use the E5 (-) spot (Receiver 1) to install the electrode E1(+) (Receiver 2)



Recording CSAMT Data

Recording CSAMT Data - General Workflow

To record CSAMT data, you would normally have two types of the crew, one operating the transmitter, and one or many other crews operating the receivers. In this case, a normal survey day sequence would be as follows:

1. The transmitter crew installs the transmitter and starts transmitting a high power signal
2. Each receiver crew installs their recorder in predetermined stations and waits for the transmitter crew to indicate that transmission is running
3. When the transmitter is confirmed to be transmitting, receiver crews start recording data.
    - If a receiver crew has time, it moves to the next location and performs a recording at new stations while the transmitter is still working.
4. At a certain point, the receiver crews stop recording and pack up.
5. Only when all receivers have stopped recording, the transmitter is turned off.

Recording CSAMT Data - Transmitter setup

Setup the motor generator (MG)
Use a 3-phase MG, and connect the provided cables (x3) to the TXU-30

Setup the TXU-30 panel
Ensure the output switch is **OFF** and set the Voltage Range switch to the maximum output mode desired:

- Low: 500 V mode
- Hi: 1000 V mode

Turn on the equipment, in the following order

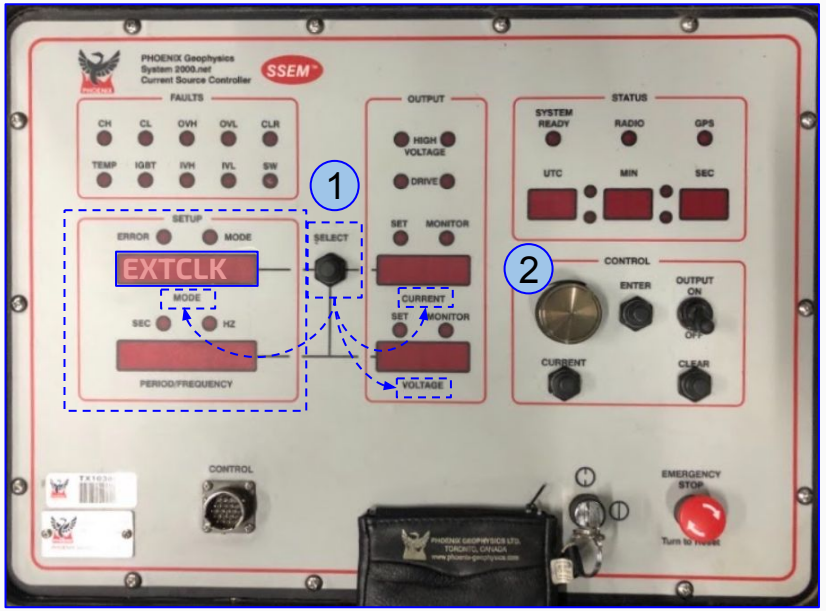
A) TXD-1 Transmitter Driver **C)** TXU-30
B) Motor generator **D)** Remote Controller

Setup the Remote Controller

- Push Select (1) until MODE is flashing
- Turn the wheel (2) to set MODE to “EXTCLK”
- Push Select (1) until CURRENT is flashing
- Turn the wheel (2) to set CURRENT to the desired value
- Push Select (1) until VOLTAGE is flashing
- Turn the wheel (2) to set VOLTAGE to the desired value

  Note: TXU-30 automatically sets the voltage depending on the desired CURRENT value

Transmitter crew installs transmitter and starts transmitting high power signal



Before start, check the contact resistance of the Tx dipole to ensure that there are no connection problems

Recording CSAMT Data - Starting transmission

Generating and recording a frequency waveform

- Start the waveform generation and current recording by pressing the power button of the TXD-1 Transmitter Driver when both of its LEDs are solid blue
- When both LEDs are flashing blue, the TXD-1 Transmitter Driver is generating a waveform and recording the transmitter current, you can now proceed to turn on the output of the transmitter

Turning on the high power output

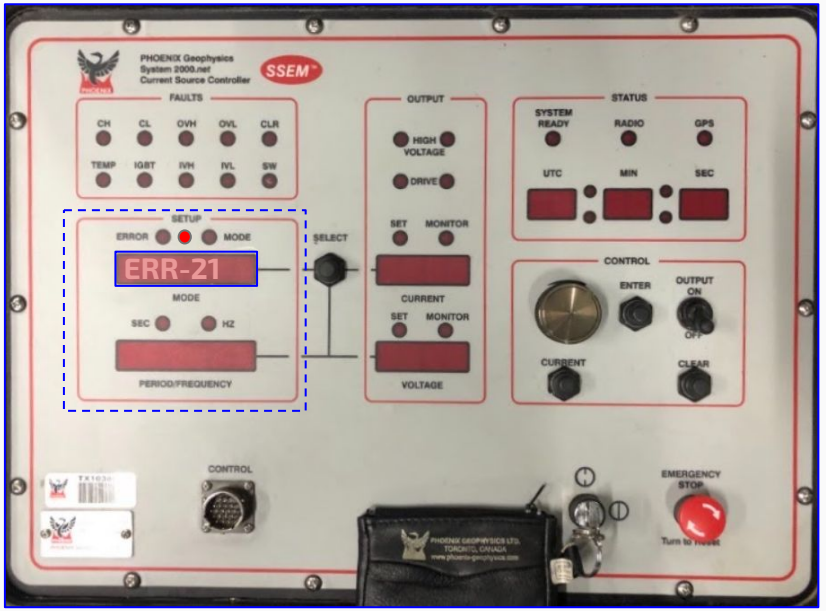
- Set the **OUTPUT** switch of the Remote Controller to the **ON** position to start transmitting
  - Be extremely cautious at that point with the Tx E-dipole, DO NOT TOUCH any steel stakes or plates while injecting current
  - The Remote Controller will display the actual output current and voltage
    - *The actual value might be different than desired value due to limitations imposed by the load*
    - *In case of receiving an error in the TXU-30 remote when turning on the power, consult your TXU-30 user manual to understand how to deal with it.*

Troubleshooting TXU-30 - Error 21

This error indicates that the voltage at the output of the TXU-30 is too high *(>550V for 500V mode, or >1100V for 1000V mode).*

This is usually caused by transmitting high current at high frequencies. Depending on the wire type, length and layout used for the transmitting dipole, the dipole may present high impedance at high frequencies, casing energy reflections that can cause the TXU-30 to trip with “ERROR-21”.

The best way to solve this problem is to reduce any undesired reactance in the transmitting dipole. Ensure that the dipole is laid out only with the necessary amount of wire, so that there is no excess wire coiled up. A coiled up segment of wire will increase significantly the impedance at high frequencies. Even a large segment of wire laid out in S-shapes will cause an increase in inductance, so it is advisable to use just the length of wire necessary to set up the transmitting dipole, only allowing for some slack. Using a thicker wire might also help to reduce the impedance.

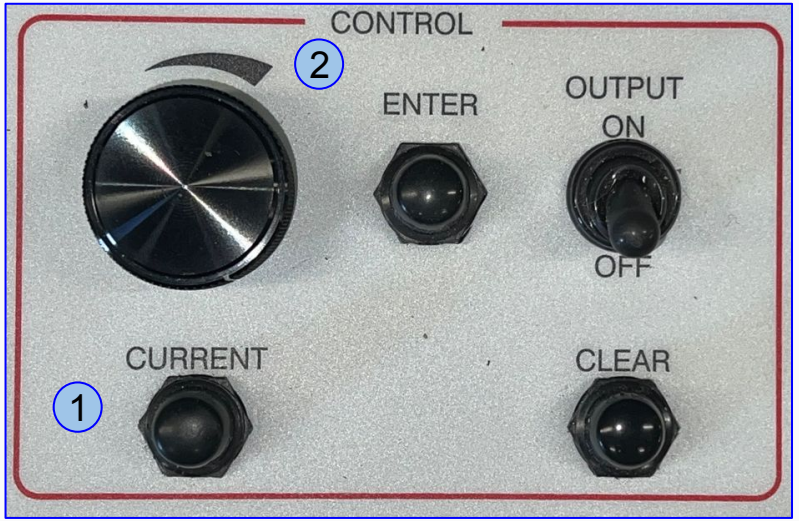


Troubleshooting TXU-30 - Error 21 - Continued

If your dipole is already using an optimal length of wire, to prevent Error 21 from happening, the current can be manually reduced before reaching the high frequencies which cause the TXU-30 to report ERROR 21 by using the following procedure:

1. During transmission observe the frequency being transmitted in the remote controller. When the schedule approaches higher frequencies push and hold the current button
2. Reduce the current using the dial
3. After the frequencies that cause tripping have passed in the transmission cycle (as seen in the remote controller), increase the transmitted current to the desired value by following steps **1** and **2** above

TXU-30 Remote control panel

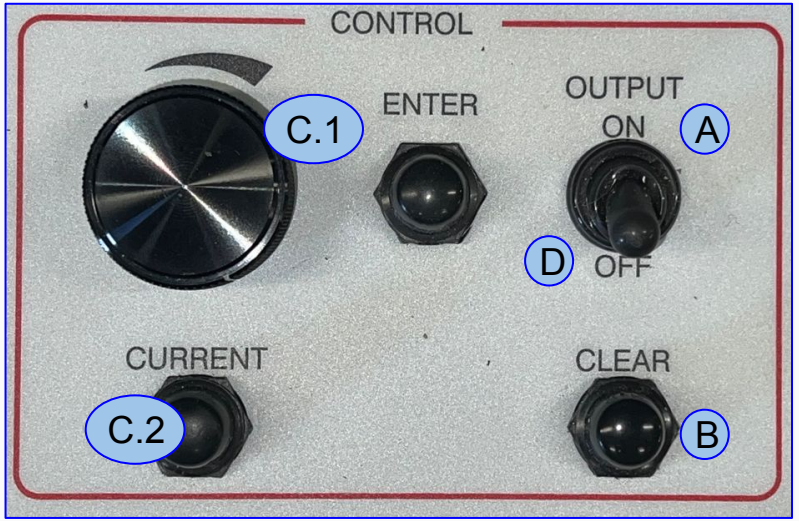


Troubleshooting TXU-30 - Error 21 - Continued

If you have attempted the solutions previously provided, and this problem keeps occurring, you can attempt resetting the error 21 manually every cycle. To do this:

- **A.** As soon as the error appears during a transmission, toggle the output switch from the the Remote Control to OFF
- **B.** Press the CLEAR button (In older units the button will read RESET instead)
- **C.** Reduce the requested current as explained in steps **1** and **2** in the previous slide
- **D.** Toggle OUTPUT switch back ON to start transmitting as soon as the next frequency comes up in the display.

TXU-30 Remote control panel



Recording CSAMT Data - Receiver operations

Once the transmitter is confirmed to be transmitting, the crews will start the receiver installation

1. Install the receiver
   - Consult section “Connection options for receiver electrode”
   - Insert the SD Card
2. Turn on the **receiver**
3. Start recording data by pressing the power button after both LEDs are solid blue
4. Complete the full frequency cycle *(CSAMT recording in progress)*
   - Full frequency cycle is ~30 min (4 frequency per octave)
     **It will depend on the frequency range and number of frequencies per octave*
   - Recording additional cycles will increase the number of clean stacks for noisy areas

1

2 **Turn on the receiver**

3 **Recording Process**

The current reported in the TXD screen will be "peak" current as opposed to RMS or other measurement techniques. This is indicated in the receiver screen by "pk" after the current measurement. For certain frequencies, there can be an inductive/aliasing effect. The reported current will be slightly different than the current reported in the TXU controller due to this effect.

** Note that in some cases the current and reported on the screen may be delayed by approximately 20-30 seconds because of the calculation routines that the TXD uses.*

Stop the receiver(s) recording before turning off the transmitter.

Recording CSAMT Data - Receiver operations

5. Stop the recording after the acquisition is complete by pressing the power button

6. Move the sites and repeat steps 1 to 5 at the next location. During the procedure, it is not necessary to turn off the transmitter.

- Use a small battery in the side pouch of the instrument's bag, and hang the GPS antenna on the other pouch. This allows keeping the receiver ON while moving the receiver to a new location, and start recording without having to wait for GPS

7. At the end of the day, after stopping the last recording, turn off the receiver by pressing the power button for more than 3 seconds

5 **Stop Recording**

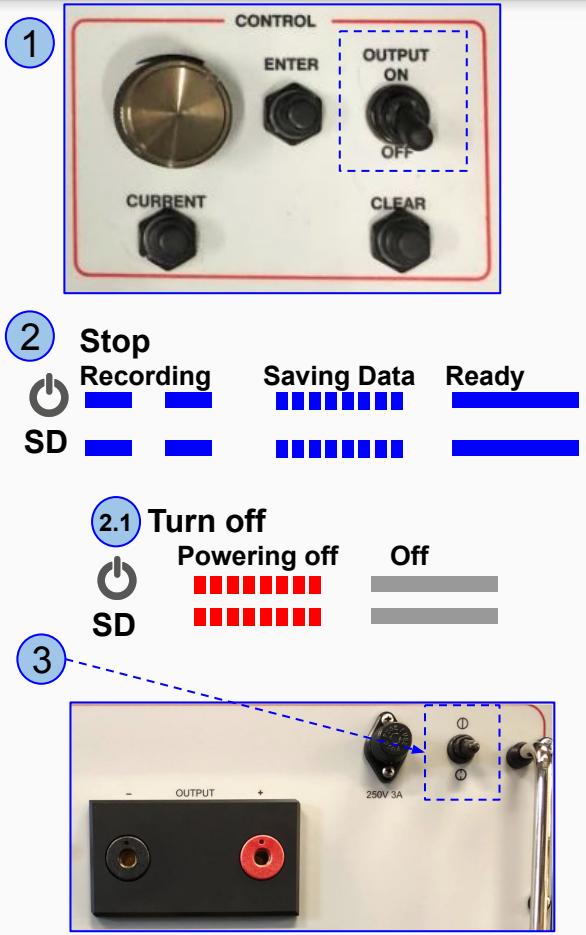
6

7 **Turn off the receiver**

Stopping High power transmission - Transmitter side

At the end of the day, and after confirming that all receiver crews have stopped recording, follow this process to correctly turn off the transmitting equipment:

1. Set the **OUTPUT** switch of the **Remote Controller** to the **OFF** position to stop the high power output of the **Transmitter**.
2. Stop the **TXD-1** transmitter Driver recording by pushing the power button briefly
   - **2.1.** Turn off the transmitter by pressing the power button
3. Turn off the **TXU-30** by setting the output switch in the TXU-30 panel to OFF
   - Wait until the TXU-30 cools down *(when fans stop)*
4. Turn off the **Motor Generator**

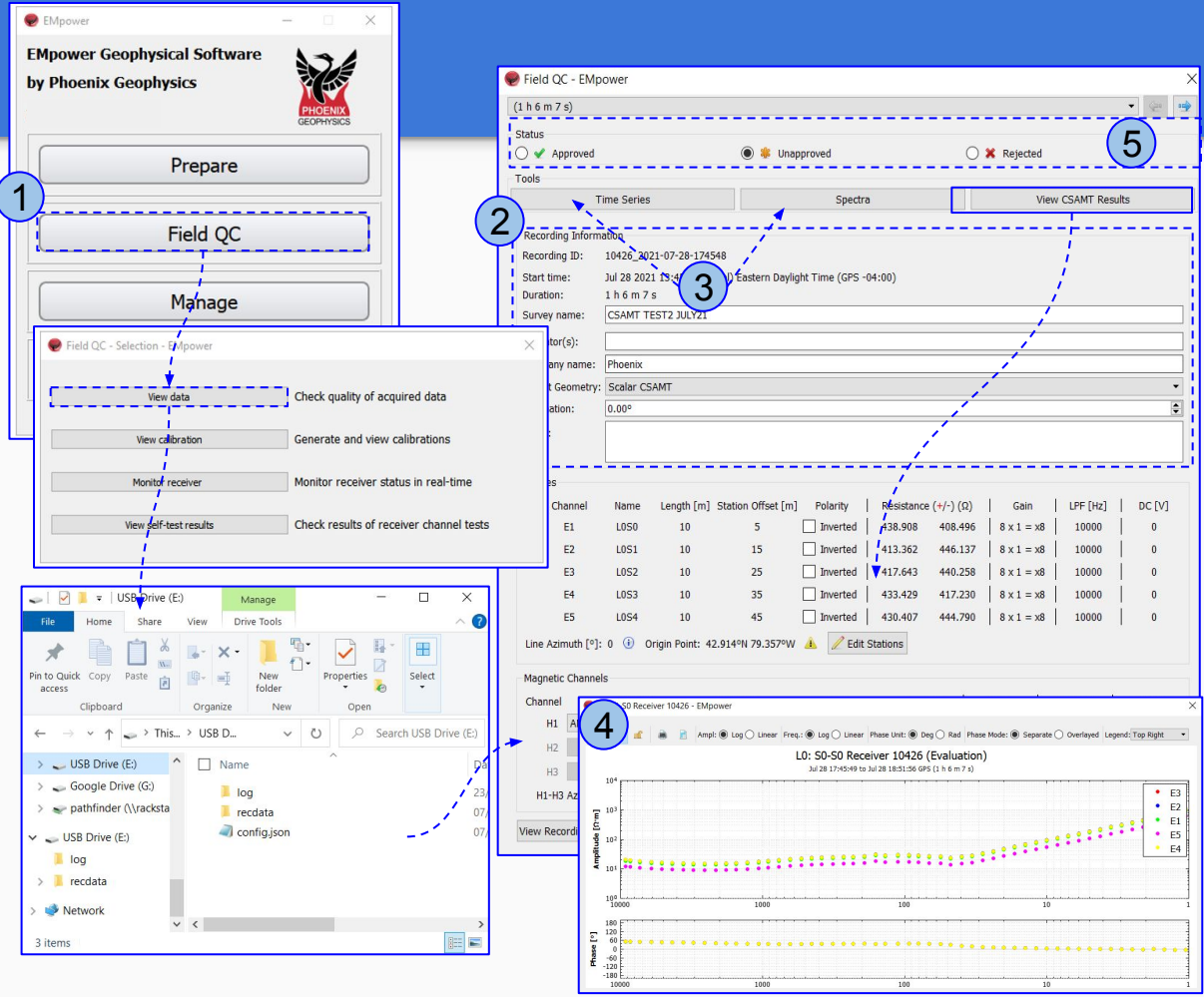


Viewing and Managing CSAMT Data

Field QC

Use **Field QC** to quickly check the results obtained in the field

1. From **Field QC**, click **View Data** button and select the recording from SD Card or from data directory
2. Review the Recording Information and edit the station layout if necessary *(as per next page)*
3. Review the curves on **Time Series** and **Spectra**
4. Review the results by clicking the **View CSAMT Results** button
5. To keep track of the quality of the recording as observed in the field, it is recommended to either set the recording **Status** as as accepted or rejected



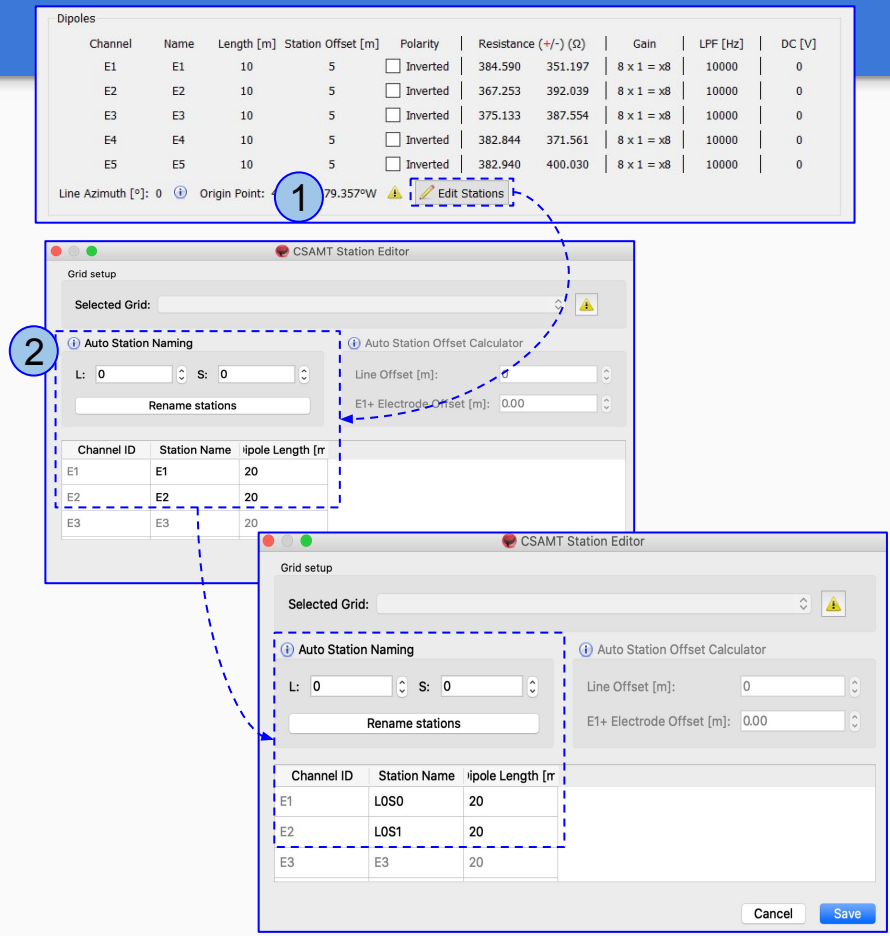
Field QC - Edit Station *(Station Naming)*

To keep the data organized and fully reflecting the actual station names, Phoenix recommends reviewing and **Editing Station's** Name and actual dipole length in the **Field QC** module after each acquisition.

1. Use the **Edit Station** button in Field QC to rename stations
2. **Auto Station Naming**
   Used to rename stations to the standard *"L<line#>S<station#>"*, where the number in the **S** field corresponds to the first channel in the table

Note: *After importing data to EMpower project, EMpower will show CSAMT Stations on the map at their correct name as edited in the Field QC module.*

For Mac users, after editing any fields hit the "enter/return key" on the Keyboard before clicking on the Save button of the ***CSAMT Station Editor*** *window in order to save changes.*



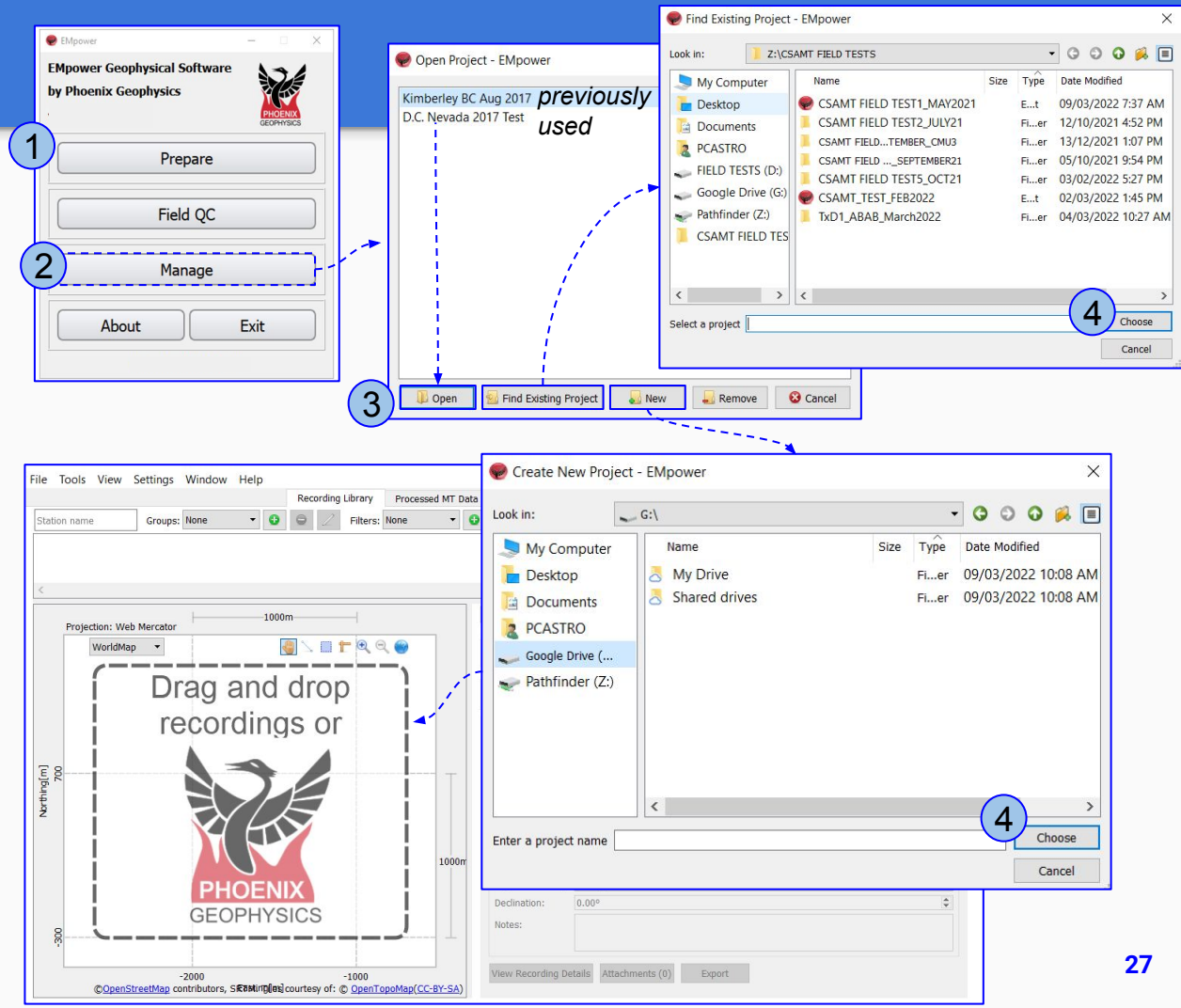
Managing a CSAMT survey

The Manage section of EMpower can be used to aggregate and manage the data of all stations in a survey project through easy-to-use visual tools. To open a project, follow these steps:

1. Start **EMpower**
2. Click **Manage** module
3. Open or Create a Project

   Existing Project
   - Select from the list *(previously used)* and click ***Open***
     Or
   - Click **Find Existing Project**
   - Select the Project

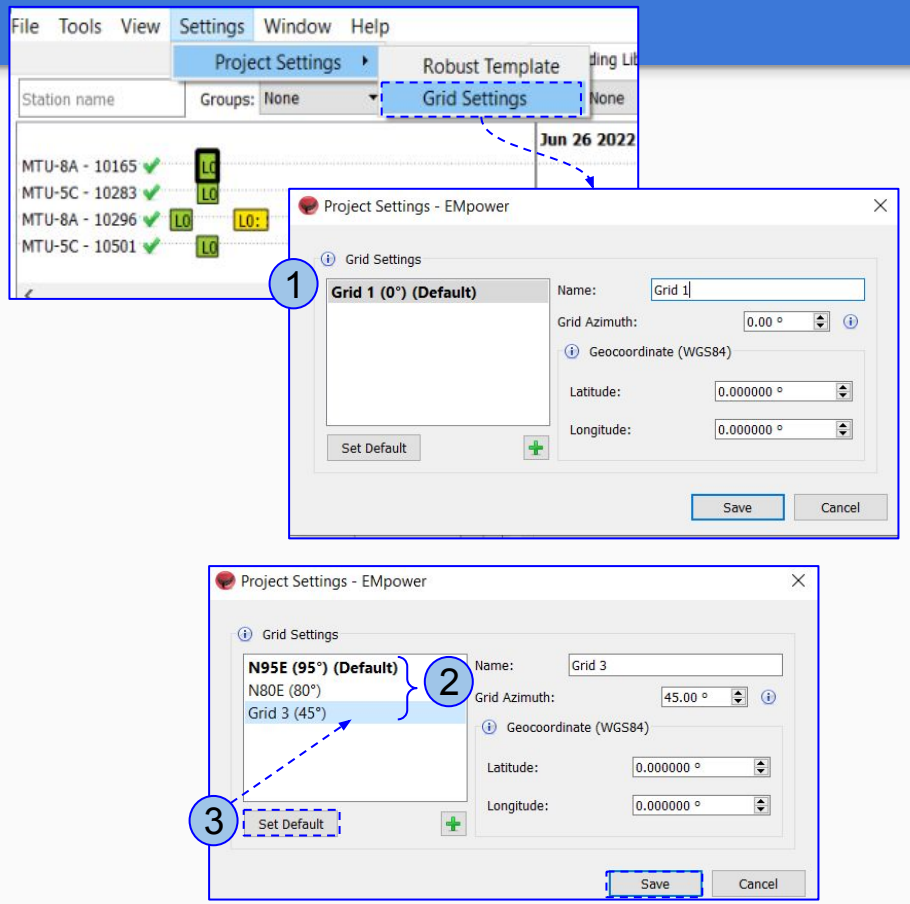
   New Project
   - Click **New**
   - Type the Project Name
4. Click **Choose**



Grid settings - The default grid

A new CSAMT project will require one or more grids to locate the stations imported into the map.

1. All stations imported to the project will be automatically assigned to the active default grid. The first grid created will automatically become the default Grid.
   - All recordings that are not yet assigned to a grid, will get assigned to the default one as soon as it is created
   - Consult page 6 for more details about the Grid Azimuth and Grid Geocoordinate origin conventions
2. When there is more than one grid in the project, the default grid has to be explicitly set, to ensure that new recordings get assigned to the desired grid
3. The default grid can be changed at any time. This will assign any recording imported from there on into the new default grid
   - To set the active default grid, select the desired grid, click “Set Default” and save.



*Note that each recording can be manually switched from one grid to another whenever needed. The location of a recording in the map is set using the **CSAMT Station Editor**.*

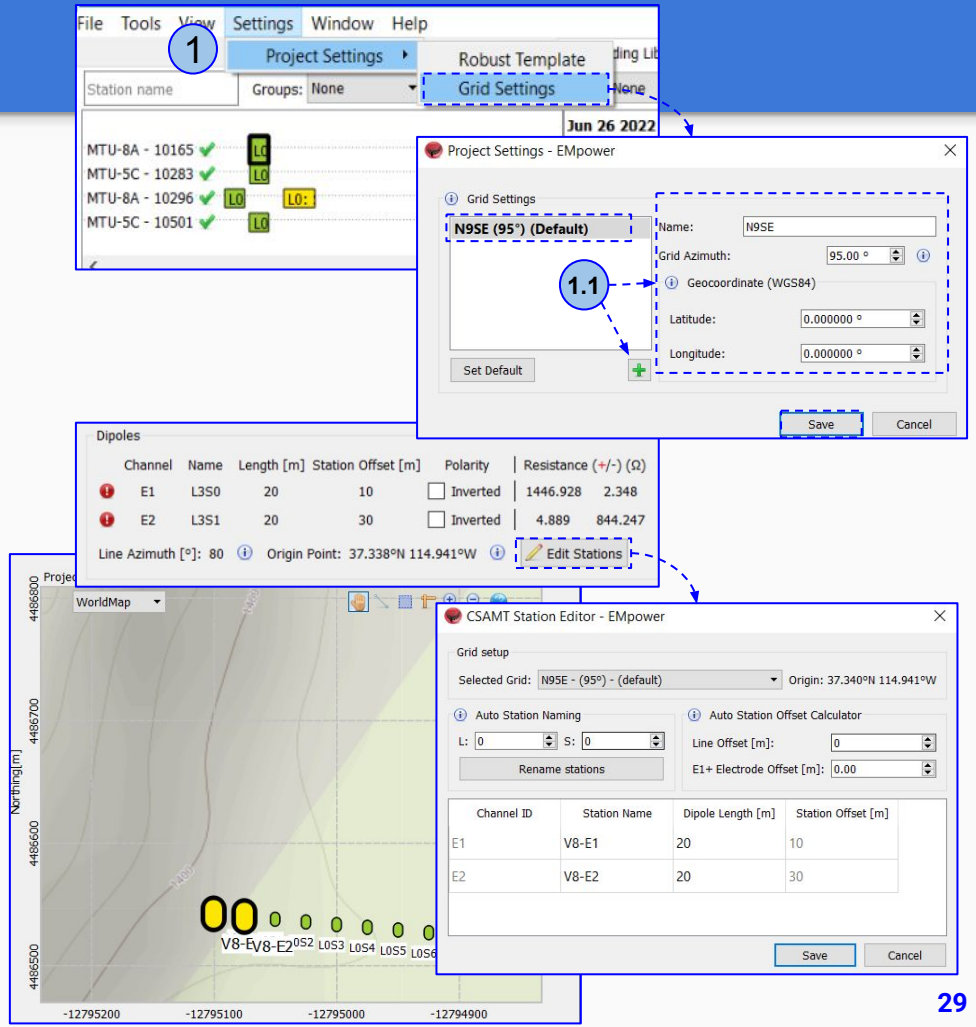
Grid settings - Single grid

Optimal when the stations are all installed in lines that are parallel to each other

1. In the main menu of the Manage section select *Project Settings / Grid Settings*
   - **1.1.** To add a grid, click the ➕ icon, type the **Name** to identify that particular grid, type the **Grid Azimuth** and the **Geocoordinate** of the origin of the grid *(see slide 6)*, and **Save**

Note: The first grid created will be the Default Grid to locate all recordings imported to the project

**If there is a line with a different orientation, users need to create a new grid using a new grid origin and line azimuth as described in the following slides.*



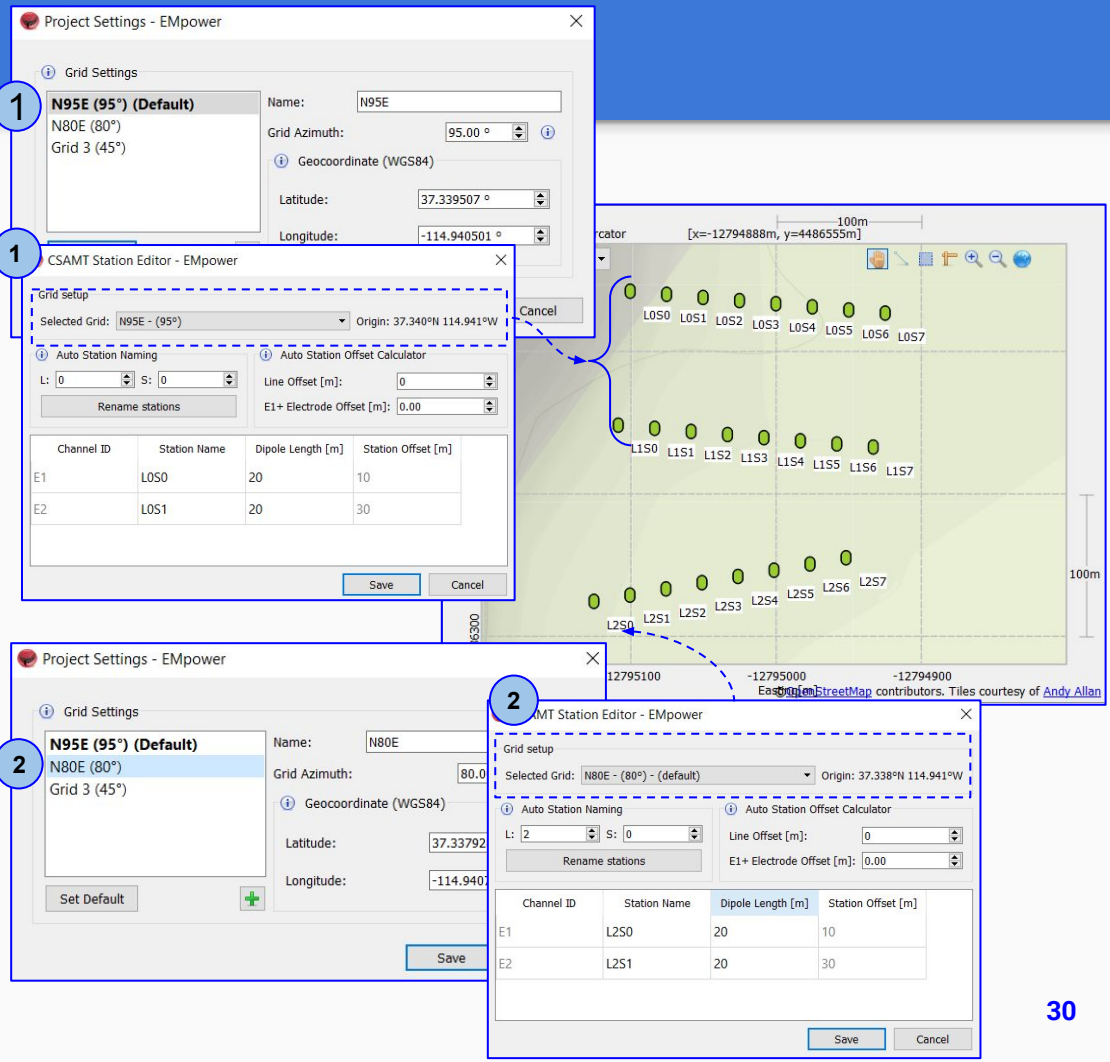
Grid settings - Multiple grids

Multiple grids can be used for different advanced mapping purposes:

- Mapping stations in projects that have lines with different azimuths.
- Mapping projects that have stations installed in several separate geographical locations.
- Also, one grid can be used per line if that makes mapping easier.

Example of lines with different azimuths:

1. The map shows stations in lines L0 and L1 positioned using a grid with a 95° azimuth, with origin coinciding with L0S0
2. The stations in line L2 use a second grid that has an 80° azimuth, with its origin coinciding with L2S0



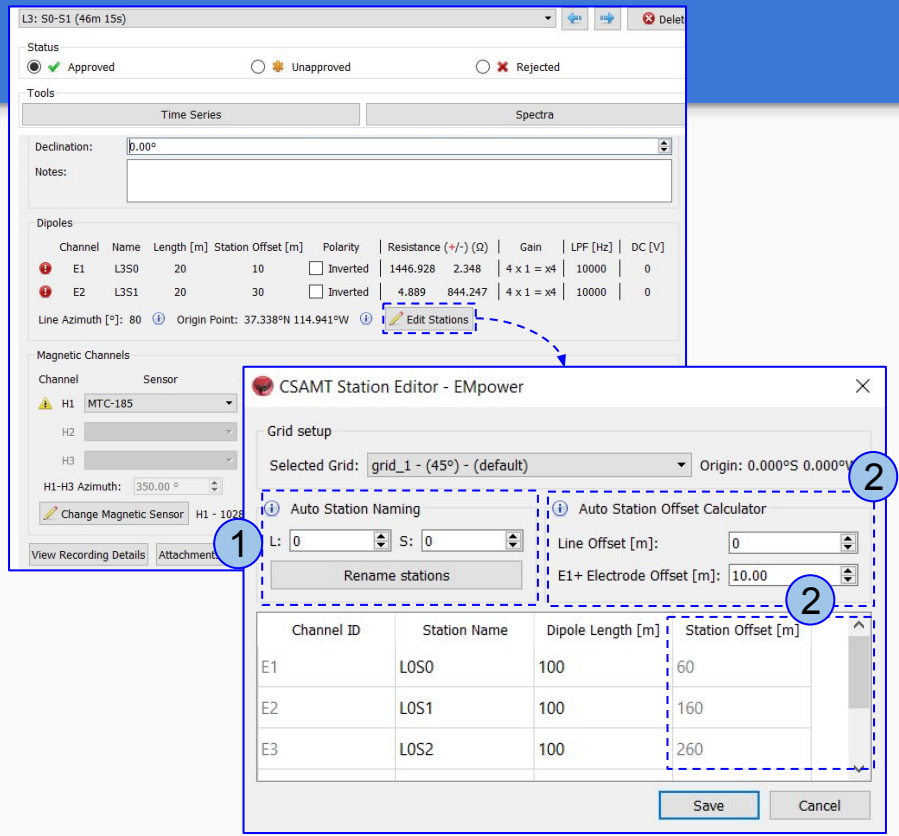
CSAMT Station Editor

The CSAMT **Edit Stations** button opens the **CSAMT Station Editor**. This editor allows setting an ID for the recorded stations, and offers mechanisms for mapping such stations within a grid, based on the dipole lengths used in the field.

To facilitate these tasks, the station editor offers different automated tools

1. **Auto Station Naming** *(see pages 30)*
2. **Auto Station Offset Calculator** *(see pages 32)*

Note: *After importing data to EMpower project, EMpower will show CSAMT Stations on the map, either at their recording GPS location if no grid has been selected, or at their position as defined by the grid and the Offset Calculator.*



*For Mac users, after editing any fields, hit the "enter/return key" on the Keyboard before clicking on the Save button of the **Edit Station** window in order to save changes.*

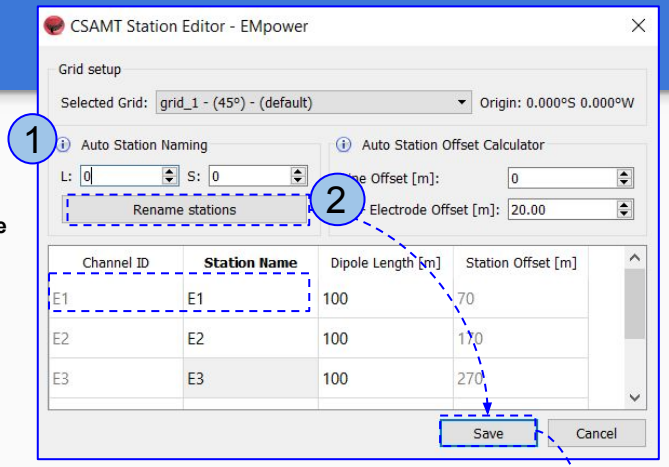
CSAMT Station Editor - Auto Station Naming

To use the standardized station naming convention in EMpower, follow these steps:

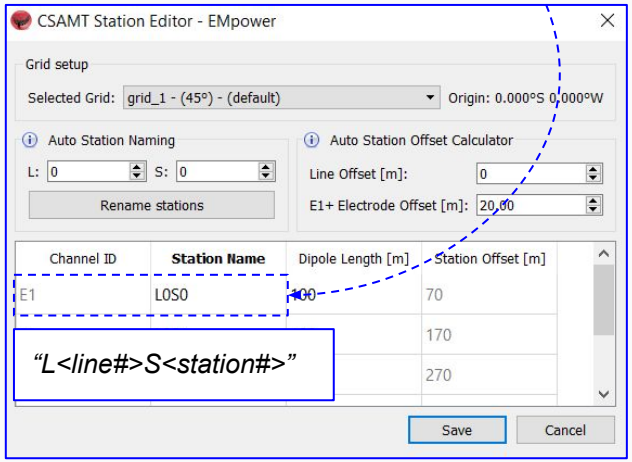
1. On top of the table, type the **L** (line) and **S** (station) numbers that correspond to the first dipole in the recording *(i.e. E1)*.
2. Click **Rename stations** to rename all stations in the format *"L<line#>S<station#>"* and then click **Save.**

Note: *The processed CSAMT data tab will reflect changes done by the auto-naming tool automatically.*

Before



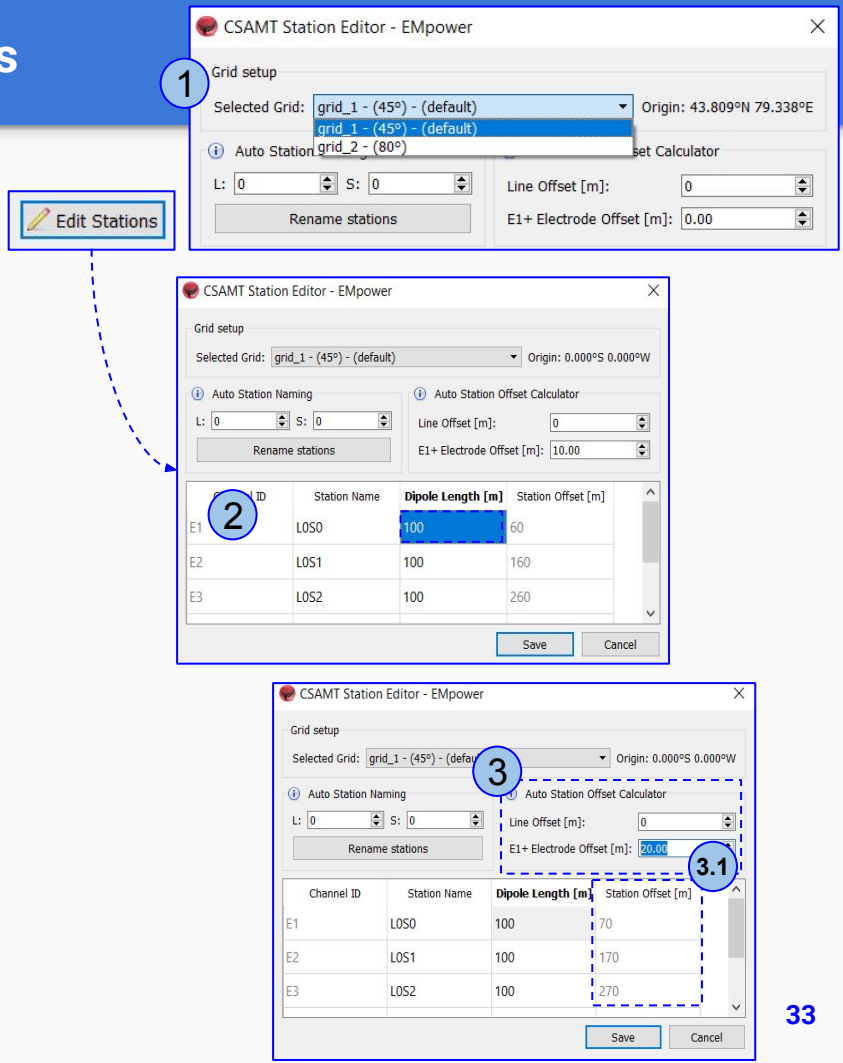
After



CSAMT Station Editor - Editing Station Locations

To correctly locate each dipole in the map grid, use the **Edit Stations** button *(Recording Information / Recording library)*

1. Select the Grid that this recording belongs to
   **To create a new Grid, see pages 25-27*
2. Ensure that all dipole lengths in the table match the lengths used during the survey. If the lengths differ, double click on the **Dipole Length** cell of the station(s) that need to be updated and change the length
3. Type the **Line Offset** of the line of the dipole, measured from the ***S*** axis in the direction of the ***L*** axis
   - **3.1.** Type the **E1+ Electrode Offset,** which is the offset to the positive electrode of the first station in this recording (i.e. the one recorded by channel E1) in the direction of the line.
4. Click **Save**

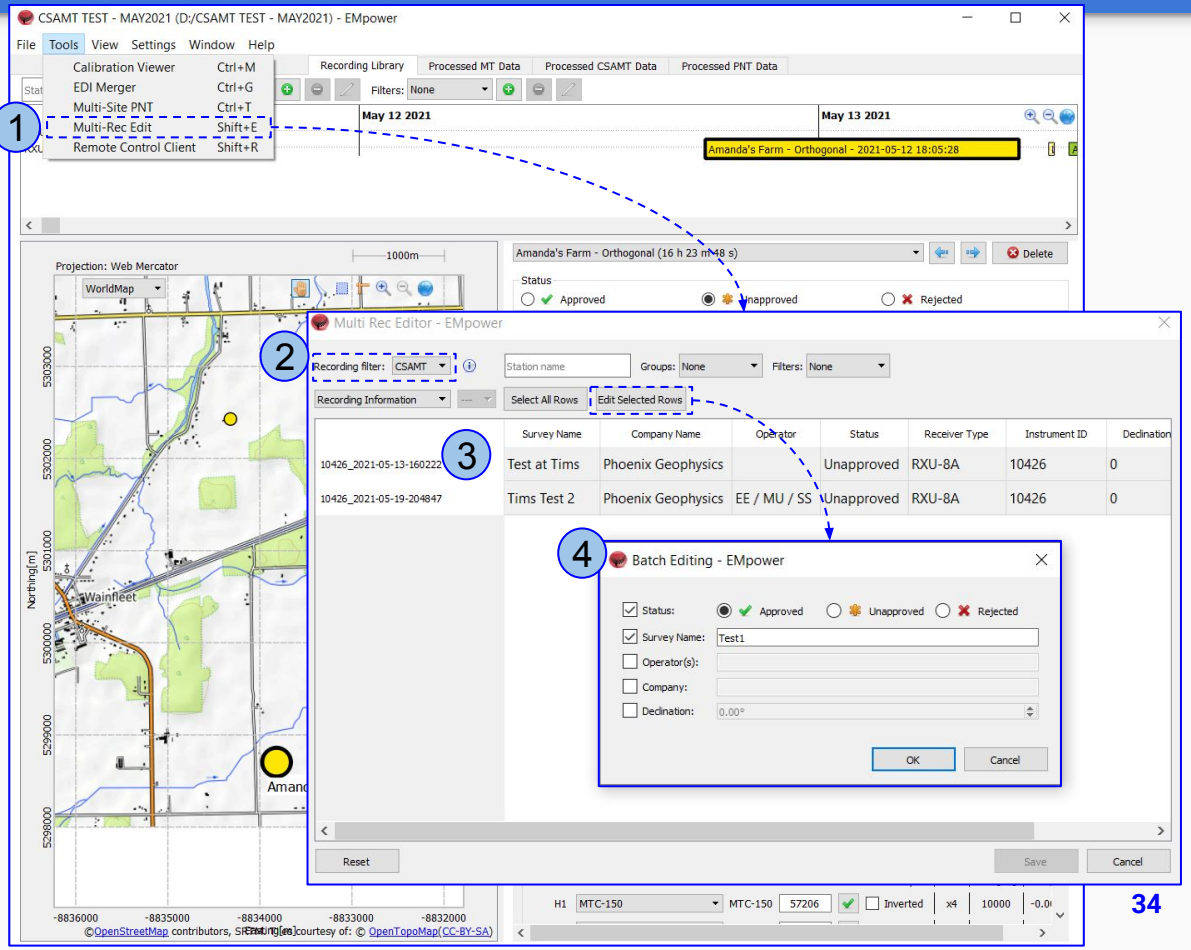


*Refer to pages 6 and 7 in this manual for more information about axes **S** and **L**, on locating a station within a grid using offsets, and the standard way of ordering receiver channels within a line.*

Editing Metadata for Multiple Recordings

Use the **Multi-Rec-Edit tool** to update or adjust the metadata of multiple recordings at once. To do so, follow these steps.

1. From the **Tools** menu select the **Multi-Rec Edit** option
2. Select the filter for **CSAMT** recordings
3. Select the recordings that need to be edited
   - Left-click on the first desired site on the list, press and hold the Shift key and left-click on the last desired site
     Or
   - Left-click on the metadata desired site on the list and hold Ctrl+left-click on any other stations desired
4. Edit the information as needed
   - Click **OK**



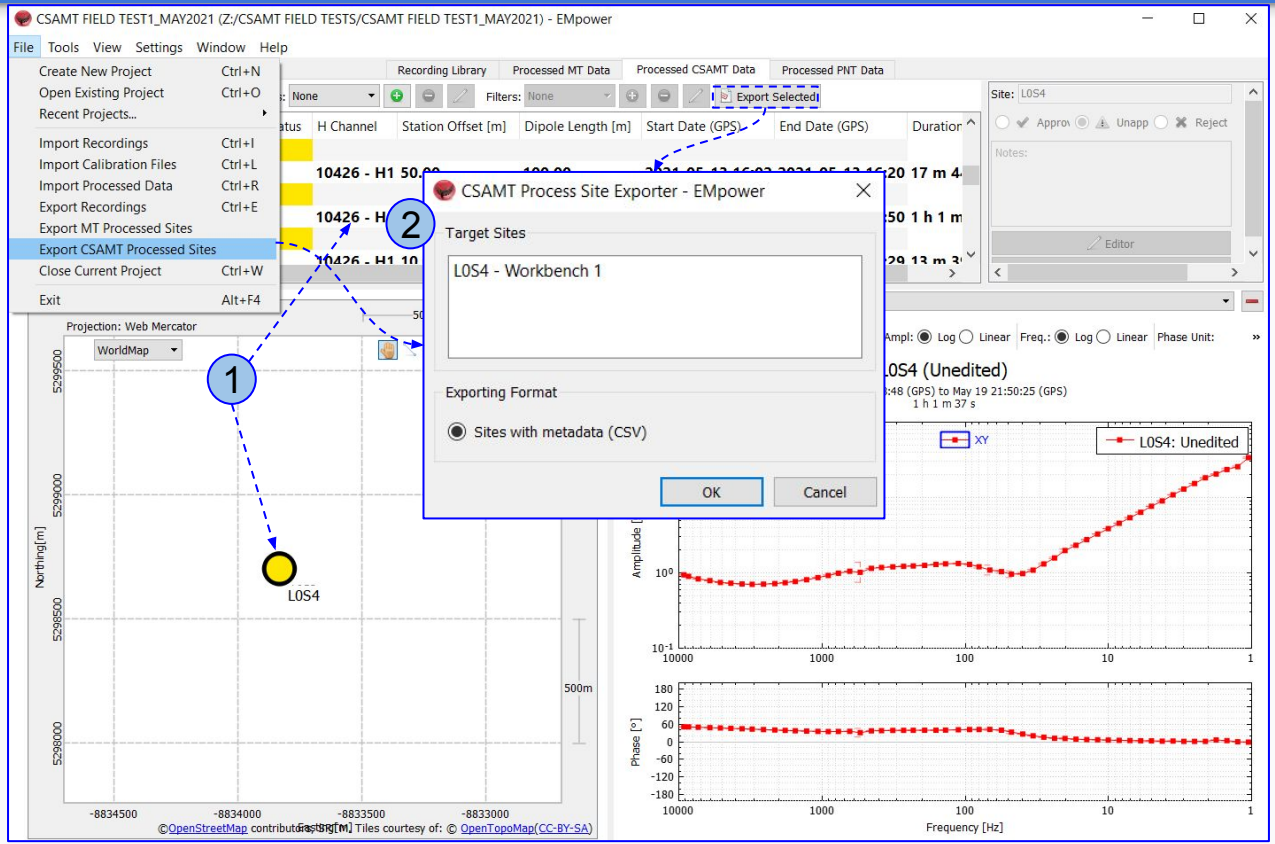
Stack rejection tool

The Stack editor is a tool designed to clean the data by removing the selected noisy stacks

1. Open the Processed CSAMT tab and select the sites, from the list or map and click **Editor** button
2. Create a new **Workbench** and define a name
3. Review the data and reject the stacks that are affecting the results by clicking **Reject Stack** button. Rejected stacks will appear in red
4. Review the results on the Amplitude/ phase plot
5. The stack can be restored using the **Accept Stack** button

CSAMT Processed Data Exporter

1. Select the **CSAMT** site
   - Choose the site from the list or map
     **EMpower is limited to exporting a single workbench per site*
2. Select the **Export CSAMT processed sites** from **File** menu or click **Export Selected** button
   - The information will be exported to CSV format



Contact support

Please check out the FAQs
https://phoenixgeophysics.freshdesk.com/
Or email us at: *support@phoenix-geophysics.com*