V5 System 2000 MTU/MTU-A User Guide

Version 1.8 June 2007

Instrument firmware version 3112F

PHOENIX GEOPHYSICS

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Chapter 1

Overview

This chapter provides general information on MT and AMT applications and the use of Phoenix equipment. This chapter provides information on:

- Phoenix System 2000 equipment and methods.
- Steps in a typical survey.
- Techniques for ensuring quality data.
- Requirements (tools, equipment, software, etc.) for a survey.

Introduction to the Phoenix SSMT 2000 System

The Phoenix V5 System 2000™ is the world's leading 4-D electromagnetic system for geophysical applications. The family of products includes a variety of rugged, lightweight multi-channel instruments and a suite of software applications for processing, editing, and viewing the data. The instruments can acquire two channels of telluric data from porous pot electrodes, and/or two or three channels of magnetic data from coil sensors or a wire loop sensor. The instruments synchronize to Co-ordinated Universal Time (UTC) via signals from Global Positioning System (GPS) satellites.

The system was introduced in the late 1990s for the Magnetotelluric (MT) technique; its capabilities have since been expanded to include Audio Magnetotelluric (AMT) and Induced Polarization (IP) techniques. New capabilities and features, such as wireless data transfer, Internet Protocol (TCP/IP) networking support, and infrared connectivity with Palm OS® handheld devices, are continually being developed.

Fig. 1-1: Phoenix V5 System 2000 hardware components.

System applications

Geophysicists use the Phoenix V5 System 2000 for many industrial and scientific applications. MT techniques are valuable in exploration for:

- Oil and gas
- Diamonds (kimberlites)
- Base and precious metals (as deep as 2000 m)

- Groundwater
- Geothermal reservoirs
- Industrial minerals

…and for monitoring of:

- Hazardous waste sites
- Tailings ponds
- Hydrocarbon reservoirs
- Geothermal reservoirs
- Landslide zones
- Dams and dikes
- Karst terrains
- Active faults and earthquake zones
- Nationally strategic sites

MT techniques are also commonly used in pure research applications, such as deep crustal study.

Phoenix System 2000 advantages

Phoenix Geophysics has been at the forefront of MT system development since the introduction of the MT-16 in 1980, representing the third generation of MT technology.

First-generation systems had appeared in the 1950s when Cagniard in France and Tikhonov in Russia developed the MT method and began using analog instruments, processing their data largely by hand. Second-generation equipment introduced in the mid-1960s included minicomputers, tape recorders, and truck-mounted AC generators. Since Phoenix's entry into the market, successive generations of equipment have added more and more sophisticated computing capability, increased numbers of channels and functions, battery power, remote reference capability, and the locating and synchronizing functions of the Global Positioning System. At the same time, Phoenix has been able to continuously reduce both the capital and operating costs associated with MT surveys.

The System 2000 equipment and software available today leads the fifth generation of MT instrumentation. The low power, 24-bit acquisition units are small, lightweight, simple to operate, and highly flexible. Far more data is collected than ever before, with twice as

many frequencies analyzed, providing the highest quality data. System 2000 is the only system on the market that does not require cable connections among multiple instruments.

The field configuration and spacing of the instruments is completely flexible, to suit the requirements of the application. Because no cable links are required between the instruments, System 2000 has an important advantage in areas with rugged topography, lakes, water courses, or other access difficulties. The GPS synchronization means that sites even very remote from the survey can be used to acquire low-noise reference data, vastly improving the quality and reliability of the survey results.

The instruments are normally configured to use removable CompactFlash™ cards as the data storage medium. These small, re-usable cards are now available with enough memory to capture several days of uninterrupted MT data.

In customized installations with permanent power sources and data communications facilities, Phoenix System 2000 systems are also serving as completely automatic monitoring stations. For economical 4-D interpretation over a wide area, a number of permanent sites can be supplemented by a series of temporary soundings taken periodically.

How to get further information and support

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Web site: www.phoenix-geophysics.com

Customers are encouraged to register for a log-in ID and password on our Web site. After registering, you can use the Contact Us link in your private area of the site to request technical support or report problems.

AMT and MT techniques

AMT and MT techniques are essentially the same, differing only in the frequency range captured. The lower the frequency, the greater the depth of investigation possible at a given site. MT techniques acquire data in frequencies ranging from about 400 Hz to 0.0000129 Hz (a period of about 21.5 h), and are suitable for deeper investigations. AMT techniques acquire data in the frequency range of about 1000 Hz to 10 000 Hz (roughly the range of human hearing, hence the audio designation). AMT is suited to shallower depths of investigation.

Throughout this guide, the term MTU/MTU-A is used to indicate that the information applies to both types of data and instruments.

Duration of soundings

The length of time it takes to acquire quality data depends on the frequencies to be studied. During data processing, a number of waveforms at each analyzed frequency are stacked. The more waveforms available, the better the data quality. Many cycles of high frequencies can be acquired in a very short time, so an AMT sounding can take as little as five minutes in a low-noise area or perhaps an hour in an area affected by cultural noise. To acquire many cycles of MT frequencies, however, takes several hours (or several days, for the lowest frequencies).

An MTU can acquire only MT data, but an MTU-A can acquire either AMT or MT data, if equipped with the corresponding sensors (MTC-50 coils for MT, AMTC-30 coils for AMT). This capability permits an efficient sounding across the entire MT and AMT spectrum. You can acquire AMT data for a short period as soon as you set up each site, and then change the sensors and reconfigure the MTU-A to acquire MT data overnight.

Local, Remote, and Far Remote stations

Although an MTU/MTU-A can be used alone, best results are achieved when a remote or far remote site is available for noise-reduction techniques.

Apart from the 50 Hz or 60 Hz grid frequency, electrical noise from human activities tends to vary considerably over distance. The natural magnetic signal, though, tends to be the same over large distances—the lower the frequency, the less variation. The Phoenix system takes advantage of these characteristics by collecting data simultaneously at the survey ("local") sites and at one or more reference ("remote" or "far remote") sites. For MT data, a far remote site could be as much as 1000 km from the survey area; for AMT data, 50 km is a reasonable distance. Because all instruments are synchronized to UTC, data from two or even three sites can be processed in combination to greatly reduce the effects of local noise.

In some cases, it is practical to simply use two local survey sites together, with each acting as the remote reference for the other. However, in most surveys, a single, electrically quiet site is chosen, and an MTU/MTU-A with five channels is installed and left in place as the reference for the duration of the survey. Part of the daily routine of retrieving and redeploying survey sites is to visit the reference site to replace the battery, verify the installation integrity, and collect the previous night's data.

It is also possible to set up a more permanent reference site, solar-powered or grid-powered and equipped with automatic dial-up or satellite communication facilities. Such an installation is typical in monitoring applications or when a long-term far remote site is required.

Because it is chosen for its low noise characteristics, the reference site also makes a good location for the calibration of all equipment before the survey begins.

Telluric vs. magnetic deployments

The characteristics of the earth's magnetic and electric fields make it practical to acquire magnetic data at

relatively fewer sites and telluric data at relatively more sites. This strategy keeps capital costs low because fewer 5-channel instruments have to be purchased. It also reduces operating costs, because telluric-only sites take less time to install and retrieve. The basis for this strategy is explained in the next section, Station spacing guidelines.

Table 1-1: Phoenix System 2000 instruments

Instrument	Data type	Telluric channels	Magnetic channels
MTU-2E	MT	2	—
MTU-2EA	AMT, MT	2	—
MTU-3H	MT	—	3
MTU-3HA	AMT, MT	—	3
MTU-5	MT	2	3
MTU-5A	AMT, MT	2	3

The flexibility of the Phoenix System 2000 makes it easy to implement this strategy: choose the combination of instruments best suited to the application. The most common approach is to use a few 5-channel instruments with several 2-channel instruments. Table 1-1 shows the range of MTU/MTU-A instruments available.

Station spacing guidelines

For proper survey planning, it is necessary to know what distance is appropriate between stations. It is also important to know what distance is appropriate between stations that acquire magnetic data and those that do not.

Overall station spacing. The determination of station spacing overall is affected by many factors: purpose of the survey, geological structure, depth of investigation, area of investigation, topology and access, and financial resources. Typical station spacing might vary from 1000m or more for a large-scale survey to only 50m for a highly detailed follow-up study.

For guidance on suitable overall spacing for a given set of circumstances, customers are invited to contact Phoenix.

Magnetic vs. telluric-only station spacing. This section provides explanations and guidelines concerning the distance between stations that acquire magnetic data and those that do not.

For simplicity in this section, regardless of the instrument used, the term 3H refers to any site that acquires magnetic data; 2E refers to any site that does not acquire magnetic data.

Magnetic field variation. It is known that the spatial (lateral) variation of the magnetic field is much less than the spatial variation of the electric field.

Spatial variability is greatest at high frequencies and decreases as frequency decreases.

Spatial variability also depends on the underlying resistivity structure. The magnetic field at a specific frequency does not vary laterally over a purely 1-D, simple layered-earth resistivity structure. The magnetic field can only vary when the actual resisitivity structure is 2-D or 3-D.

For any given frequency, then, spatial variation is greater with greater resistivity contrasts and is greater over complex resistivity structures than over simple resistivity structures.

Number of 3H stations. The use of multiple 3H stations has several advantages.

If at least two 3H units are used on the survey grid, then 3H data is still available even if one unit fails. A second unit also provides backup in case one 3H unit is by chance located in an unfavourable position such as atop a high-contrast boundary.

During data processing, if two 3H units have been used, then the user can check the variation of the magnetic field. Resistivity at one production 2E site can be calculated twice, using data from each of the two 3H sites. If the resistivity is significantly different between the two calculations, then the magnetic field at the two 3H sites must also be significantly different.

Finally, in low-noise environments (only), the suitability of the 2E–3H spacing can be verified. If the E–H coherency is >0.7 at the highest frequency used, then the distance between 2E and 3H is satisfactory. (In environments with strong coherent noise, high coherency between 2E and 3H is not a reliable indicator.)

Mining applications. In the mining exploration environment (usually "hard-rock"), resistivity structures tend to be complex, with high contrasts. Spatial variability is therefore relatively high.

As a working rule, in mining surveys with at least a thin layer of overburden, Phoenix recommends using at least two 3H units on the survey grid, with no more than 500m separating a 2E site from a 3H site.

Hydrocarbon applications. In the hydrocarbon exploration environment (usually sedimentary or "soft-rock"), resistivity structures tend to approximate a 1-D, layered earth. Spatial variability is therefore relatively low.

As a working rule, in hydrocarbon surveys in a sedimentary rock environment, Phoenix recommends using at least two 3H units on the survey grid, with no more than 1000m separating a 2E site from a 3H site.

Best practices. Phoenix recommends a maximum 2E:3H ratio of 10:1, and a maximum 2E–3H distance of <1000m, even in the most favourable environments.

Further reading. A useful guide with objective calculations of the spatial variability of the magnetic field is provided by "Geological Mapping Using VLF Radio Fields" by J. McNeill and V. Labson, in Electromagnetic Methods in Applied Geophysics, Vol. 2 Parts A and B (Society of Exploration Geophysicists, Tulsa USA, 1991).

Steps in a typical survey

Every survey is unique, but the general sequence of steps remains the same. The survey is planned so that work crews can set up one or more sites each day, allow the equipment to acquire data for a period of

time, then retrieve the equipment to redeploy it at another site. In AMT surveys, or in higher-frequency MT surveys (periods shorter than 300s), the crew may stay with the equipment while the sounding is taken, because acquisition times are shorter. In full-spectrum MT surveys, the equipment is usually left to acquire data overnight.

This section explains the steps in chronological order:

- Planning
- Calibrating the equipment
- Setting up the survey sites
- Processing the data
- Exporting and interpreting the data

After reading this chapter to learn the high-level concepts, continue with Chapter 2 on page 27 for detailed instructions on installing equipment in the field.

Planning

When a survey area and objectives have been defined, the first step is to plan how the survey will be carried out. Consider the following when making your plans:

Choose the sites. Consider if the survey should be carried out along one or more lines, or on a grid. Also decide if you will orient your sites to True North, Magnetic North, or an arbitrary azimuth on a grid plan. In all cases, you will need to know the magnetic declination of your survey area. (See Appendix D on page 149 for Internet resources.)

Mark all the proposed sites with unique numbers on a topographical map.

Identify one or more remote sites that will be in quiet areas, yet close enough to be maintained daily, and add them to the map.

In the field, evaluate the proposed sites for noise sources, security of the equipment, and physical access or permission limitations. Livestock, wild animals, hikers, industrial or transport activity, power lines or

electric fences, and local laws can all interfere with survey work, equipment, or data. Even vegetation, under windy conditions, can induce micro-vibrations that will add noise to the data.

Modify the plan as necessary and mark the final version on the map.

Allocate and schedule the equipment. Decide how your equipment will be allocated, that is, the type of instrument and sensors to be used at each site.

Estimate the number of sites you'll be able to sound each day. This number will depend on the type of data to be collected (MT, AMT, or both) as well as on the factors affecting installation.

An experienced crew can install a 2-channel site in about 15 minutes; a 5-channel site in difficult conditions might take an hour. Retrieving equipment from a site usually takes about 15 to 30 minutes. Travel time must also be taken into account. Plan a progression from site to site for the most efficient use of resources.

Obtain permissions. In most cases, the land you want to survey is owned by a third party. Be sure that you allow sufficient time to contact the landowners to obtain permission to conduct your work. It is often helpful to write an explanatory note that you can give to the landowner. You might include:

- The purpose and benefits of your survey.
- Personal and institutional credentials.
- The anticipated schedule.
- An explanation that the equipment is a passive receiver and does not emit any radiation or noise.
- An outline of the physical impact on the land—vehicle access, shallow holes and/or trenches for the electrodes and sensors.
- A commitment to leave the area as undisturbed as possible.

Create a standard set of parameters. Although you can connect a PC to configure the MTU⁄MTU-A individually at each installation, it is much more efficient to put all the common information into a binary file and use it repeatedly.

A single file, called STARTUP.TBL, can be created and saved on a PC for transfer to all the instruments of the same type used in the survey. The file contains instructions to the instrument such as when to start and stop acquiring data, what frequency ranges to sample at what intervals, and so on. It also contains text that becomes part of the record, such as the names of your company and Layout Chief.

As long as the file is in the DATA folder on the MTU⁄MTU-A's CompactFlash card, the instrument will use it automatically.

Calibrating the equipment

The first task in the field is to calibrate the instruments and sensors. Calibration should take place at the beginning of every survey, and may have to be repeated during a survey if equipment problems arise (damaged cables, for instance).

Usually, the reference site is the best location for calibration, because you've chosen it for its low noise characteristics and you have permission to use it for a longer period of time. Alternatively, you can calibrate each set of equipment when you install it for the first time in the survey. In this case, you can perform the calibration either before (preferably) or after acquiring data.

Calibration of an MTU⁄MTU-A instrument takes about 10 minutes. Calibration of magnetic sensors requires a calibrated MTU⁄MTU-A instrument and takes at least an hour. The requirements of the physical layout are not as rigorous as for data acquisition—you don't have to carefully orient or level the coils, for example.

Setting up the survey sites

Once the equipment is calibrated, the actual survey work can begin. This section describes the general principles of setting up a successful survey site.

Form a 3-person crew. Experience in the field has shown that the ideal crew consists of a Layout Chief and two assistants. The Layout Chief stays at the centre of the site, using a compass to orient the assistants as they place the electrodes and sensors.

While the assistants install the electrodes and sensors, the Layout Chief can set up the MTU/MTU-A itself, take electrical measurements, and write the site record on a Layout Sheet.

More or fewer people can form the crew, but productivity may not be as high.

Keep records throughout. It is important to keep careful written records of each survey site. Information from these records must be included when processing the data. The record also helps track down any technician errors or equipment problems that may arise.

Use a standard Layout Sheet and Equipment Checklist, like those shown in Appendices A and B. The sample Layout Sheet highlights in red the records that are essential—serial numbers, measurements, a sketch of the layout, etc. Optional records are printed in black.

Conduct an inventory and inspection. Before you set out each day, make sure you have all the tools and equipment you need (see the sample Equipment Checklist in Appendix B.) and check that it's all in good condition. If the survey is just beginning, make sure there is a properly prepared CompactFlash card in every MTU/MTU-A. (During the survey, you will exchange cards daily as you retrieve the equipment.)

Verify the location. When you arrive at a site, ensure you are at the right site number and location as defined on the plan map. Use a handheld GPS locator or other reliable method to be sure of your location.

Determine the centre and place the MTU/MTU-A. The MTU/MTU-A instrument is usually (but not necessarily) placed exactly at the site centre, where the dipoles cross. (Variations from the usual layout are discussed later in this chapter.) Because there is extra length in the cables connecting the electrodes to the MTU/MTU-A, the instrument itself can be placed a metre or two off centre if necessary.

Choose a dry spot that will not pool water if there is rain. Stay away from noise sources such as power lines and roads, and avoid overhead obstructions that might block GPS signals. Try to find a spot that allows easy access in all four directions to where you'll place the electrodes and/or sensors.

Tip In livestock farming areas, electric fences are a common source of noise. Sites must be located well away from these fences, although if the ground is very conductive, a distance of only 100m can be enough.

Set up the telluric lines. All MTU/MTU-A instruments except the MTU-3H accept two dipoles to acquire telluric data. Each dipole consists of two lead-chloride porous pot electrodes buried about 25cm deep in salty mud, connected to the MTU/MTU-A by cables (commonly called E-lines). The dipoles form a right angle cross, with the MTU/MTU-A near the centre.

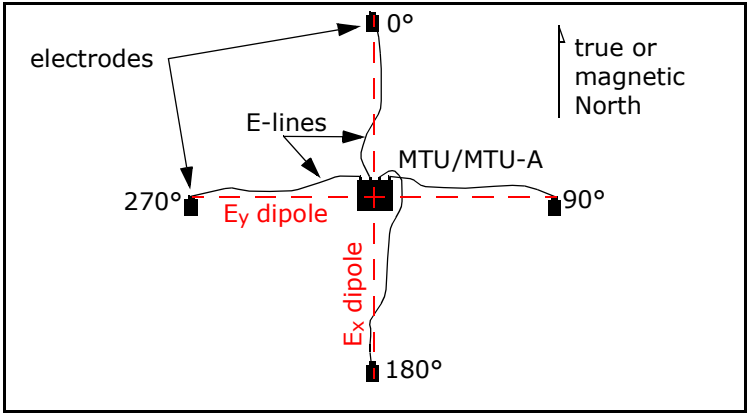


Fig. 1-2: Standard site layout.

Typically, each E-line is from 25 to 100m long, making two equal-length dipoles 50 to 200m long. The longer the dipole, the better the signal-to-noise ratio but the greater the AC voltage induced by the local power grid. A high AC voltage can result in unusable data ("saturated records") when the dynamic range of the system is exceeded.

The north-south dipole is referred to as E_X and the east-west dipole is referred to as E_Y.

Tip Because maps place North at the top, it is tempting to think of a north-south line as similar to a graph's vertical y-axis, and an east-west line as similar to its horizontal x-axis. With MT techniques, though, the opposite is true: the north-south dipole is E_x, not E_y.

It's also tempting to think of the E-line cables as forming the dipole. However, the dipoles are *imaginary* straight lines measured between the electrodes; they are not the same thing as the physical cables. Always measure and orient the layout from where the imaginary dipole lines cross, not where the cables connect to the MTU/MTU-A.

Adjust for E-line difficulties. Local conditions—boulders, trees, hills, water bodies, etc.—can often make it difficult or impossible to keep to a standard layout. E-lines may have to be longer or shorter than normal, or a dipole may have to be oriented other than to true or magnetic north.

Obstructed dipoles. If an obstruction in the area means that one E-line has to be shortened, the other can be lengthened to compensate. For example, if a 100m dipole is planned but the north E-line can only be 30m long, you can extend the south E-line to 70m.

In some cases, the two dipoles may have to be of unequal lengths. Although not ideal, this layout is still viable.

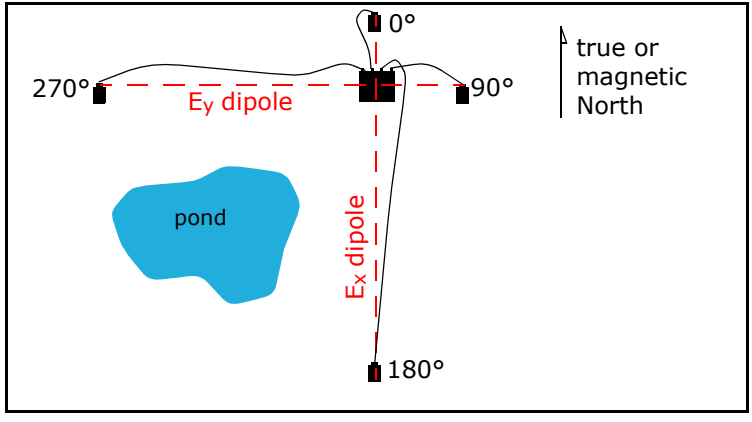


Fig. 1-3: E-line lengths adjusted to avoid an obstruction.

Occasionally you won't be able to orient the dipoles along the north-south and east-west azimuths you have planned. In this situation, you can "rotate the site"—orient the dipoles as much as ±44° away from the planned azimuth, *while keeping their right-angle relationship*. As long as the azimuth is entered

accurately during data processing, the rotation of the site will not degrade data quality. (This is another example of the importance of keeping accurate records on the Layout Sheet.)

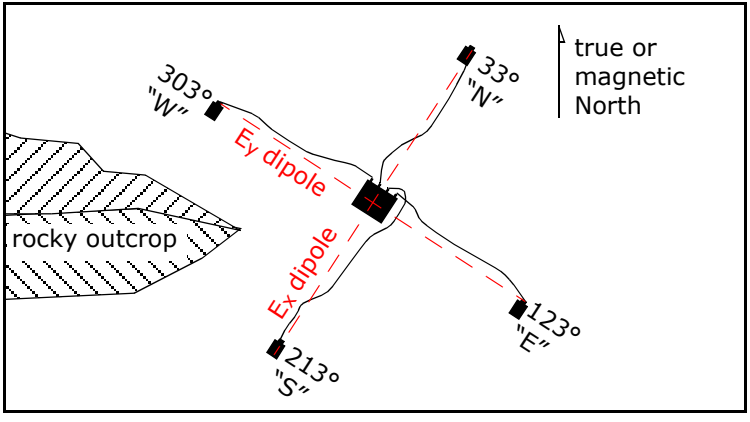


Fig. 1-4: Site rotated to avoid an obstruction.

Note A site rotation, when corrected for magnetic declination, must not exceed ±44°. If you find that this angle is exceeded, either rotate to a smaller angle or rotate in the opposite direction.

Excess cable. In order to allow E-lines to be extended as described earlier, the cables are usually cut in lengths significantly greater than half the dipole length. Always lay excess cable in elongated S-shapes, no closer than 5m from the ends. If you coil the excess instead, you will create an induction loop that will distort the signal.

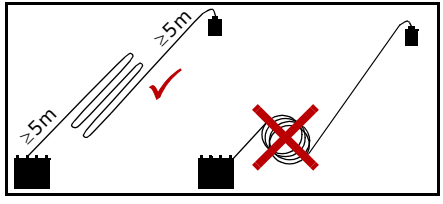


Fig. 1-5: Lay excess cable in S-shapes, not coils.

Slope. E-lines laid out down a steep slope can also create a problem: the measured distance between the electrodes no longer equals the actual horizontal length of the dipole. Instead, the measured distance is a vector resulting from both horizontal and vertical displacement.

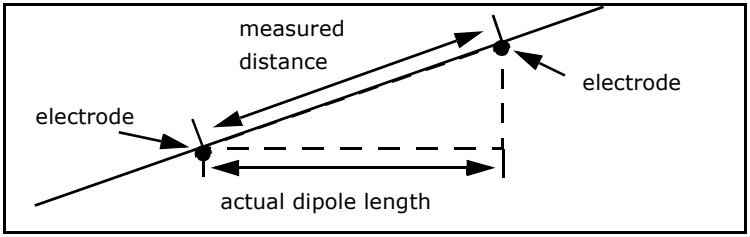


Fig. 1-6: Side view of a hill shows the effect of slope on dipole length.

If you encounter inclines ≥20°, you must compensate using trigonometry. One way is to calculate how much to lengthen the E-lines when laying out the site so that the horizontal component of the vector is the desired dipole length. Alternatively, you can make no compensation in the field, and instead calculate the actual horizontal dipole length before processing the data.

Wind. Try to avoid setting up close to tall trees or other vegetation that could propagate wind-induced vibrations through the roots. Always lay the cables flat on the ground, not draped over branches or rocks. You may also need to restrain the E-lines to limit wind-induced noise. Use the materials at hand, such as rocks, broken branches, or mounds of dirt or snow to hold down the cables every metre or so.

Traffic. In general, avoid areas subject to vehicle, pedestrian, or animal traffic. If you must run an E-line across a pathway, bury the cable completely to prevent disturbance. If you must run a cable across a road, look for drainage pipes crossing underneath that could be used to pass the E-lines through. Otherwise, use a commercial wire-protection cover designed for the purpose. Be aware that data quality will be greatly reduced by passing vehicles.

Set up the magnetic sensors. The MTU-3H, MTU-5 and MTU-5A instruments acquire the natural magnetic signal using coil or loop sensors. Three kinds of sensors are available:

- MTC-50 coils, for MT soundings.
- AMTC-30 coils, for AMT soundings.
- AL-100 air-loops, used in place of vertical coils.

Usually, two sensors are placed horizontally and one vertically. However, depending on the application, the vertical sensor may be omitted.

Placement. Because all system components carry electric current, they all generate magnetic fields that can degrade the data. Therefore, component separation is important. Whenever possible, you should place each sensor in a different quadrant formed by the dipoles, as far from the MTU/MTU-A as the connecting cable allows. In any case, the instrument and each of the sensors must be separated from the others by at least 5m.

The horizontal coils are normally aligned with the telluric dipoles, as carefully oriented and level as possible, buried in shallow trenches. The coil placed with its free end pointing north is referred to as H_x. The coil with its free end pointing east is H_y.

The third coil, H_z, should be set as precisely vertical as possible in a hole deep enough that the entire coil can be buried (although you can bury it partially and then mound earth over the top if necessary). This vertical coil is the sensor most susceptible to electrical coupling with the E-lines, so place it as far from the other components as possible.

Substitute an air-loop if necessary. In terrain where a hole cannot be dug deep enough to even partially bury the vertical coil, you can substitute an air-loop sensor. The loop is laid out flat on the ground in a square, restrained by rocks or other weights, or shallowly buried. Unlike coil sensors, an air-loop is not shielded, and is therefore more affected by cultural noise than coils are.

Identify and orient correctly. *It is critically important to identify and orient the sensors correctly.* Coil sensors must be aligned so that the free end of H_x points north (connector points south), and the free end of H_y points east (connector points west). This alignment is intuitive when the coils are placed north and east of the MTU/MTU-A because the connectors face the instrument and the cables run directly to it. However, if the coils are placed south or west of the instrument, the connector must face *away* from the instrument, so the cables loop back to it. (See Figure 1-7.)

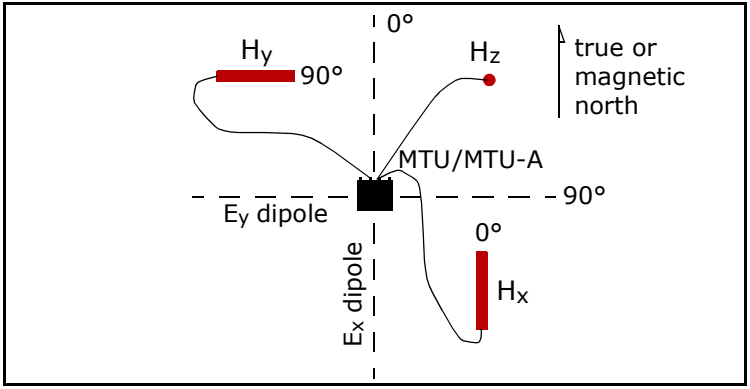


Fig. 1-7: Example layout with three coils correctly oriented (not to scale).

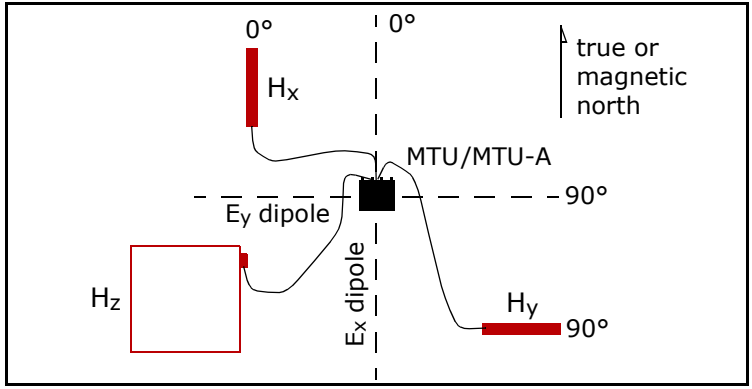


Fig. 1-8: Example layout with two coils and an air-loop correctly oriented (not to scale).

If an air-loop is used for the H_z channel, it must be oriented so that, when viewed from *inside the loop*, the cable exits from the pre-amplifier *toward the right*. (See Figure 1-8 on page 19.)

In all cases, you *must* note the serial numbers of the coils before burying them, and record on the Layout Sheet which sensor is used as H_x, H_y, and H_z. Without this information, you cannot reliably process the data, because there is no way to associate the correct sensor calibration files with the magnetic channels.

Some errors in laying out H_x and H_y coils can be corrected using advanced techniques in data processing; however, it is better to lay out the site

correctly to begin with. Errors in laying out an air-loop cannot be corrected during data processing.

Adjust for sensor difficulties. Use the same techniques as for E-line difficulties to deal with excess cable, wind, and traffic. You can usually avoid obstructions by placing the sensor in a different quadrant.

Submersion in rain water is a further consideration with sensors. Although they can withstand moisture, it is better to position them on higher ground where possible.

Measure and record electrode resistance and dipole voltages. When all the connections have been made to the MTU⁄MTU-A but before turning on the power, take measurements of the electrical characteristics of the site.

Dipole voltages. Start by recording the AC and DC potentials on the dipoles. These measurements will help you choose the best setting for gain when you program the MTU⁄MTU-A.

When measuring dipole voltages, use a digital voltmeter. Analog meters are not sensitive enough to measure accurately in the 200 mV range encountered in MT surveys.

Measure each type of voltage on the N-S and E-W dipoles. Again, lower values are better. Values ≥150 mV AC may indicate the presence of power lines or other electromagnetic noise sources close to the site.

High DC potentials can also mean a faulty electrode. Test for this condition by measuring the voltage from the MTU⁄MTU-A ground terminal to each of the E-line terminals. Significantly higher potential on one electrode indicates that it should be replaced.

Unfortunately, apart from relocating the entire site, there is no way to improve high readings caused by noise.

Electrode contact resistance. When measuring contact resistance, use an analog ohmmeter. An analog meter produces more current than a digital meter (mA versus μA), and is therefore more accurate in the presence of self-potential on the E-lines.

The higher current from an analog meter is also the reason to measure dipole voltages (with a digital meter) first. The analog meter could leave a residual charge on the electrodes, causing errors if the digital readings are taken afterwards.

Measure the resistance of each E-line and each dipole, and record the values on the Layout Sheet. In other words, measure from the MTU⁄MTU-A ground terminal to each of the E-line terminals, and again between each N-S and E-W pair of E-line terminals. A significant difference between the dipole resistance and the sum of the corresponding E-line resistances indicates a problem with the layout or a faulty measurement.

Note To accurately measure contact resistance ≥2000Ω, you must disconnect the E-lines from the MTU⁄MTU-A. Measure from the ground terminal to each E-line end, and between the two E-line ends of each dipole.

In general, the lower the contact resistance, the better. High contact resistance limits the upper range of frequencies that can be acquired. If you encounter resistance ≥2000Ω, you may be able to reduce it using one of these methods:

- Lift the electrode, add more salt water to the mud, and rebury the electrode.
- Move the electrode to a new hole a short distance away. There may have been a large rock directly under the first hole.
- Replace the dirt in the hole with a mixture of salt water and either Bentonite (driller's mud) or "kitty litter"—granulated clay for litter boxes.

Start up and verify operation of the MTU⁄MTU-A. Once the site is properly laid out and tested, the MTU⁄MTU-A can be powered on.

If you did not load a standard STARTUP.TBL file on the CompactFlash card, you will have to set up the parameters for your data acquisition using a PC running the WinHost program.

It is important at this stage to verify that the instrument has acquired "GPS lock"—contact with at least four GPS satellites. Data acquisition cannot begin unless GPS lock has been achieved (even if only

briefly). You can verify GPS lock either by watching signals from the LED indicator or by monitoring the instrument with a PC, as explained in Chapter 2.

It can take anywhere from 30 s to 30 min for GPS lock to be achieved, depending on factors such as limited direct view of the sky, or distance from the last site where the instrument was used.

Usually, lock is achieved within 10 min. If it takes longer, try relocating the antenna or substituting another antenna or cable.

Tip If equipment has been shipped a long distance (for instance, on initial delivery from Phoenix), GPS lock can take a long time. To speed up the process, use the WinHost program to reset the GPS receiver.

Protect the equipment. Before leaving the site, take steps to protect the equipment as required. You should always protect the MTU/MTU-A with a tarpaulin or sunshade. Wrap the tarpaulin tightly to protect from snow, rain and condensation, or loosely (ventilated) to protect from the heat of the sun. In very hot climates, take the instrument out of its carrying case and erect a sunshade over it to provide maximum ventilation and protection from direct sun. In some circumstances, it may also be necessary to post a guard at the site.

Warning In hot climates, failure to protect the instrument from direct sunlight may result in equipment damage. (This warning applies whether the instrument is powered or not.)

Complete the layout sheet. Verify that all mandatory information has been entered on the Layout Sheet, and add any optional information you want to record. (The sample Layout Sheet in Appendix A shows mandatory information in red, optional records in black. Supplies of these Layout Sheets printed on waterproof, tearproof paper can be ordered from Phoenix.)

Acquire data. Once the site setup and records are complete, the crew can move on to set up the next survey site. The MTU/MTU-A will automatically acquire data according to the programmed schedule.

Retrieve the equipment. At the end of the data acquisition period, the crew retrieves the equipment. In AMT surveys, retrieval might happen several times in a

day. In MT surveys, retrieval usually happens the next morning. The crew returns to the site to verify that it is undisturbed and to pick up the equipment. If there are problems, it's easier to repair the installation and take a second sounding than to remove the equipment and have to return later.

The retrieval routine includes a check of the LED on the MTU/MTU-A, which indicates if acquisition ended normally, and measurement of contact resistance and battery voltage. These measurements can help identify potential equipment problems.

After you shut down the MTU/MTU-A and remove all the equipment connections, replace the CompactFlash card with one prepared for the next site. Then gather up all the equipment and tools, restoring the site as you committed to the landowner. Finally, move to the next site to retrieve more equipment or to set up for a new sounding.

Processing the data

Each evening, you should copy the newly acquired data to a PC and to CDs or DVDs for long-term storage. Then use the suite of Phoenix software programs to process and perhaps edit the data, to judge the success of the soundings. Nightly processing allows you to identify sites that need to be repeated, and schedule them efficiently.

Exporting and interpreting the data

The final step in the survey is to carefully edit and then export the processed data (usually in EDI format) to your choice of interpretation software.

Refer to the *Data Processing User Guide* for instructions on using the suite of software programs.

Ensuring quality data

Phoenix instruments are designed to acquire the highest quality data possible, but many factors outside the instrument can affect quality. This section highlights ways that you can maximize the results you get from your Phoenix equipment.

Storage and handling

- To keep cables tangle-free, gather them carefully into figure-8 shapes after use. Inspect cables frequently for breaks in the insulation.
- Always store electrodes in salt water to prolong their life and reduce contact resistance.
- Keep electrodes out of direct sun when possible.

Warning Electrodes contain small amounts of toxic lead-chloride that gradually seeps through the porous ceramic base. Avoid touching the bottom surface of the electrodes, and wash hands thoroughly if there is any possibility of contamination. Dispose of depleted electrodes according to local hazardous waste guidelines.

- Make sure batteries are fully charged before use and before storage.
- Disconnect *all* cables before storage and transport, to prevent damage to connectors.
- Keep protective caps in place on connectors, or joined to each other when cables are connected.
- Before powering an MTU/MTU-A that has no electrodes connected (during calibration or testing, for example), ground the four input terminals by connecting them to the GND terminal. Failure to ground the terminals may damage the instrument.

Maintenance

- Monitor the DC potential measured on the electrodes. The lead-chloride gradually leaches out of the electrodes, and they must be refurbished or replaced after about a year of regular use. Consistently high potentials indicate a problem. To test the electrodes, put them in a container with a few centimeters of salt water and measure the resistance between any pair. Resistance should be $<100\Omega$. Also measure the DC potential between the

pair. Self-potential should be <10mV (<2mV when new).
- Test your batteries after each use. If a battery's reading falls to 10V, it should probably be replaced.
- Test your batteries after each charge, allowing at least two minutes after disconnecting from the charger before taking the measurement. The minimum acceptable reading is 12.75V.

Operations

- After calibration, allow time to acquire simultaneous baseline data from all the instruments at the calibration site. Compare results to ensure all the equipment is performing properly. (This process also helps to develop a model of the data characteristics you can expect during the rest of the survey.)
- Test all hand-held GPS receivers to ensure uniformity of readings within acceptable variance. Be aware that map grids may contain errors or distortions, but the graphics themselves are created accurately from photographs. Therefore, test your receivers with reference to natural landmarks when possible.
- When using a compass, keep the area clear of local sources of magnetic distortion such as vehicles, belt buckles, shovels, sensor coils, etc.
- During sensor calibration, avoid movement of local sources of magnetic distortion.
- Take compass readings twice, from opposite directions (two crew members can do this simultaneously).
- Have at least two people record and check the information on the Layout Sheet, and initial it as correct.

Survey requirements

Ensure that you have all the required tools and equipment before beginning your work:

- Equipment Checklist and Layout Sheets.
- MTU/MTU-As, sensors, cables, etc. per checklist.
- Tools per checklist.

- PC with parallel cable, CompactFlash card reader.
- Setup and Monitoring software (WinHost or WinTabEd Off-line Editor).
- Processing software (SSMT2000, SyncTSV, MTEdit, MTPlot).
- A supply of CD-R or DVD disks for archiving data.

Chapter 2

Field operations

This chapter contains task-oriented procedures for field operations. Explanatory material has been kept to a minimum because that has been provided in Chapter 1.

Instructions are provided for:

- making equipment connections.
- programming and monitoring the MTU⁄MTU-A.
- calibrating the equipment.
- setting up a survey site.
- retrieving the equipment from a survey site.

General techniques

Most of the tasks in this chapter start with the same series of procedures—connecting various cables to attach the GPS antenna, the battery, the sensors, and perhaps a PC. The next few pages explain these procedures in detail, so as to simplify the instructions later in the chapter. Read this section to become familiar with the techniques, and refer back to it as needed.

Warning In hot climates, protect the instrument from direct sunlight at all times. Failure to protect the instrument from direct sunlight may result in equipment damage. (This warning applies whether the instrument is powered or not.)

Handling locking-ring connectors

The PC connection and all magnetic sensor connections are made with military-grade cylindrical bayonet-lock connectors equipped with protective caps or locking rings. Most of these caps can be joined together in pairs to keep them clean while the equipment is in use.

Fig. 2-1: Military-grade cylindrical connector and cap.

The GPS antenna and battery connections are made with similar but smaller locking connectors; the MTU⁄MTU-A terminals have caps, but the cable ends do not.

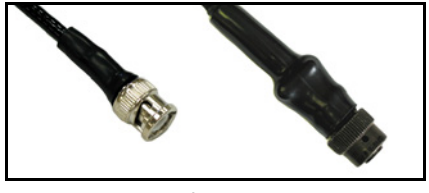


Fig. 2-2: GPS and Battery connectors.

To remove a protective cap:

- On an MTU/MTU-A or a magnetic sensor, push on the cap and turn it counterclockwise.
- On a cable end, hold the cap in one hand and with the other hand, push the locking ring toward the cap and turn the ring counterclockwise.

To make cable connections:

- Fit the cable end to the receiving connector and turn the locking ring clockwise until it locks in place.

To disconnect a cable:

- Push the locking ring toward the connection and turn the ring counterclockwise.

To keep connectors clean:

1. When a connection is made, always join the two loose protective caps and lock them to each other. (See Fig. 2-3 and 2-4.)
2. When disconnecting equipment, always replace the protective caps immediately and lock them in place.

Fig. 2-3: Cables joined with military-grade cylindrical connectors and connector caps joined for protection from dirt.

Warning Never pull a coil sensor out of the ground by pulling on the cable. Damage to the cable or connector can result. Either dig the sensor out completely, or tie a short length of rope around the coil before burying it, to help in retrieval.

Fig. 2-4: Sensor connector caps joined for protection before burial.

Connecting a PC

An MTU⁄MTU-A that is properly prepared with a startup table on its CompactFlash card can acquire data without the need for a PC. However, you must connect a PC in order to:

- Calibrate the instrument or sensors.
- Establish the parameters when a startup table is not on the CompactFlash card.
- Change parameters.
- Monitor data acquisition.

A special cable is supplied to connect the PC parallel port to the MTU⁄MTU-A.

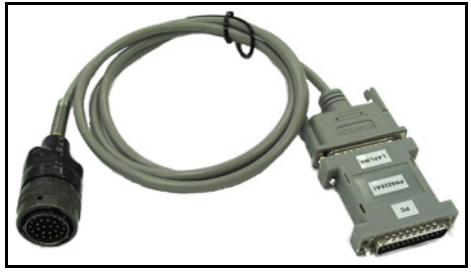


Fig. 2-5: MTU⁄MTU-A to PC parallel port cable.

To connect a PC:

1. Fit the PC cable to the parallel port on your computer.

2. Fit the other end of the cable to the PARALLEL I/O connector of the MTU/MTU-A as described on page 28.

Tip To prevent damage to the PC because of accidental polarity reversal, start up the PC and the MTU/MTU-A independently and verify their proper operation before connecting the two together.

Connecting the GPS antenna

The global positioning system (GPS) antenna must always be connected to the MTU/MTU-A when operating or calibrating the equipment, because the satellites provide the necessary time signals. The cable has two connectors: one with slots for quick connection to the MTU/MTU-A box, and one with threads for connection to the antenna.

To connect the GPS antenna:

1. Screw the threaded connector of the antenna cable to the underside of the antenna head. (See Fig. 2-6.)
2. Fit the slotted connector to the GPS ANT connector on the MTU/MTU-A as described on page 28.
3. Open the antenna tripod and position the GPS antenna so that it is level, stable, and has unobstructed sight lines to as much of the sky as possible. If necessary, tape the antenna tripod to another object (e.g., a stake, post, or larger tripod) so that it is raised above tall grass or shrubs.

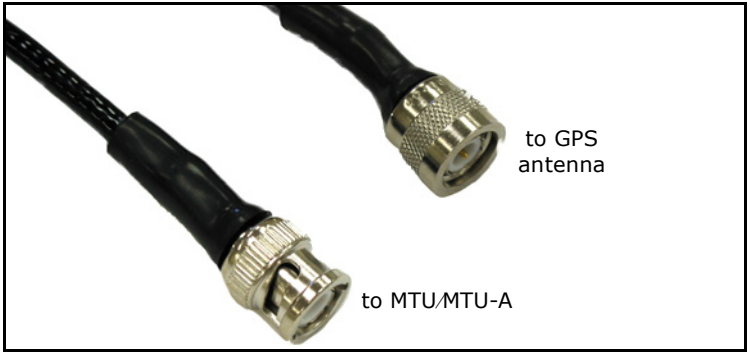


Fig. 2-6: GPS antenna cable connectors.

Tip In many cases, the antenna tripod can be left unopened, propped up in the side pocket of the MTU/MTU-A canvas case. The antenna can receive satellite signals even if the MTU/MTU-A is wrapped in a tarpaulin. (Just make sure the top of the antenna remains level.)

If you must stretch the cable in order to position the antenna, prevent damage to the connectors by providing strain relief at each cable end. Tape the cable to the tripod and the instrument handle so that there is some slack at each connector.

Connecting electrodes

All MTU/MTU-A versions use at least one cable for the ground electrode; two- and five-component versions use four more cables for the telluric dipoles (E-lines). The terminals are marked W, N, S, E, and GND.

Warning To prevent damage to the instrument, always connect the ground electrode to the GND terminal first, before making any other connections.

To connect ground and telluric cables at the MTU/MTU-A:

1. If necessary, remove 2–2.5cm of insulation from the end of the cable, and twist the strands tightly together.
2. Wrap the exposed end of the coaxial shield with two or three layers of electrician's tape.

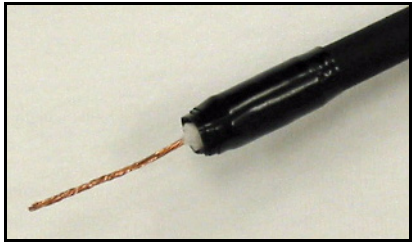


Fig. 2-7: An E-line cable stripped and wrapped with electrician's tape.

3. Unscrew the terminal on the MTU/MTU-A until it stops. (The terminals cannot be unscrewed completely.)
4. Thread the twisted strands of the cable through the hole in the shaft of the terminal, and wrap the free

end clockwise around the shaft. If your cable is very thick, you may have to cut some of the strands at the insulation in order to fit the wire through the hole in the shaft.

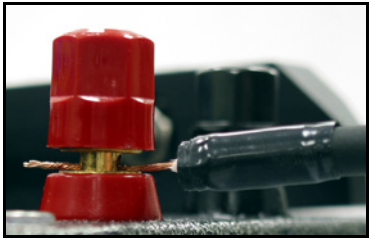


Fig. 2-8: E-line cable threaded through the MTU terminal shaft. Wrap the free end around the shaft before tightening the terminal.

5. Tighten the electrode terminal securely.
6. Make sure that there are no loose strands that could touch other wires or the MTU/MTU-A case.

Connecting sensors

Three- and five-component MTU/MTU-As are supplied with a short 3-way cable to connect the magnetic sensors. The pigtails of the 3-way cable are marked with rings of coloured tape: one ring for H_x, two rings for H_y, and three rings for H_z. It is critical to ensure that each sensor is connected to the correct pigtail.

Fig. 2-9: Three-way sensor connector cable.

To connect sensors:

1. Fit the single connector of the 3-way cable to the MAG INPUT terminal of the MTU/MTU-A and lock it in place.
2. Fit the sensor cables to the the pigtails of the 3-way cable and to the sensors, and lock all the connections. **Be sure that the H_x, H_y, and H_z sensors**

are connected to the correct H_x, H_y, and H_z pigtails.

3. Join the pairs of loose caps to keep them clean.

Installing and removing the CompactFlash card

The MTU⁄MTU-A stores its parameters and data on a CompactFlash (CF) card. The CF card fits into a slot in the front of the MTU⁄MTU-A, protected by a small watertight cover.

Note CF cards must be formatted as FAT (not FAT32 or NTFS), using the Windows™ formatting utility (*not* the SanDisk utility). Refer to the *Data Processing User Guide* for details.

If only one CF card is available, then each day's data will have to be transferred from the CF card to a PC (equipped with a CF card-reader or the WinHost program) brought into the field. It is more convenient to use two CF cards for each. One CF card is left in the instrument to acquire data, while the other is taken back to survey headquarters. There, a CF card-reader is used to transfer the data from the CF card to the PC. Nightly processing of the data confirms whether each site was successfully sounded.

CF cards are expensive and contain your valuable data. Protect them from damage by storing them in plastic or fabric cases when they are not in use.

Fig. 2-10: CompactFlash cards in protective case.

Tip To avoid loss of data, use the Windows ScanDisk utility periodically to check the condition of your CompactFlash cards.

Warning Never insert or remove a CompactFlash card when the MTU/MTU-A is powered! Serious damage to the unit may result.

To access the CompactFlash card slot:

1. Locate the card slot on the front of the unit. If the MTU/MTU-A is inside its canvas case, peel back the flap that covers the card slot.

Fig. 2-11: Canvas case flap opened, showing card slot cover.

2. Unlock the card slot cover by lifting the ring on the handle and turning it 90° counterclockwise.
3. Lift the slot cover away from the MTU/MTU-A.

To insert the CompactFlash card:

1. Ensure that the MTU/MTU-A is powered off.
2. Hold the CompactFlash card by the bottom corners, with the back of the card facing the SSMT logo on the MTU/MTU-A.
3. Slide the card gently into the slot and press it into place.

Fig. 2-12: Inserting the CompactFlash card.

To remove the CompactFlash card:

1. Ensure that the MTU/MTU-A is powered off.

2. Eject the card partially by pressing the small square button beside it.

Fig. 2-13: CompactFlash card eject button.

3. Hold the card by the two corners and withdraw it from the slot.

To replace the card slot cover:

1. Align the ring of the slot cover at right angles to the length of the cover.
2. Place the bevelled edge of the cover against the MTU/MTU-A case and push the cover handle fully into the case.
3. Turn the cover handle one-quarter turn clockwise to lock.

Warning Never operate the MTU/MTU-A without a CompactFlash card installed and the card slot cover locked in place.

Connecting the battery

The MTU/MTU-A is powered by one or two 12V DC batteries, which should be fully charged prior to use. (Follow the instructions provided on the Battery Charging Quick Reference Guide.) Usually, two batteries are needed for each MTU/MTU-A. One battery powers the instrument during data acquisition while the other is being recharged. For long soundings, two batteries can power the instrument at the same time, connected using a special cable.

Two-component instruments use the BTU-24/12 battery; five-component instruments require the larger BTU-45/12 battery. Either type may use the optional light-weight lithium ion battery.

If you are providing your own batteries, ensure that they have the capacity to power an instrument for your planned acquisition durations. For 24 hours of run-time, an MTU-2E(A) requires 20Ah; a 5-component instrument requires either 30Ah (with AMTC-30 sensors) or 45Ah (with MTC-50 sensors).

Ensure that you have the correct batteries for your application.

Newer Phoenix BTU-type batteries are shipped with the cable ends bolted to the battery terminals; older batteries were shipped with the cable unattached.

Note Make all other connections, and always a ground connection, before connecting a battery to the MTU/MTU-A.

To connect a BTU-type battery:

1. Examine the battery terminals and clean off any corrosion that might prevent a good electrical connection. (Use sandpaper, emory cloth, or a knife blade to carefully clean the terminals.)
2. If the cable ends are not bolted to the battery terminals, attach the alligator clamps to the terminals (red clamp to the positive [+] terminal, black clamp to the negative [–] terminal). **Ensure that the connection is secure and of correct polarity.**

Tip On batteries with spade terminals, attach the alligator clamps so that they grip the edges rather than the flat surfaces of the terminals. The greater tension from the clamp springs helps ensure a good connection.

3. Fit the slotted connector to the EXT BATT terminal on the MTU/MTU-A as described on page 28.

To connect a lithium ion battery:

1. Place the battery in the canvas case so that the mini jack is uppermost and the LED Fuel Gauge is visible through the vinyl window. (See Fig. 2-14.)

Fig. 2-14: Li-ion battery LED Fuel Gauge.

2. Plug the cable into the battery mini-jack.

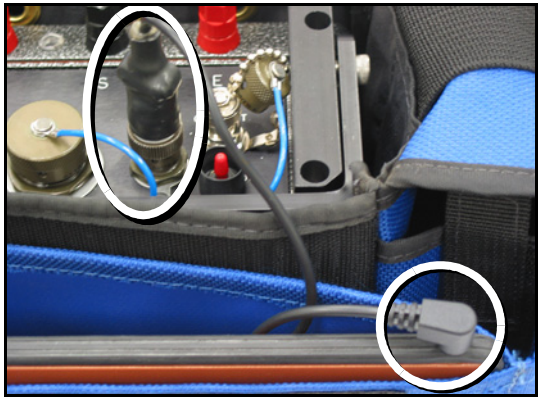


Fig. 2-15: Li-ion battery cable connections.

3. Fit the other end of the cable to the EXT BATT terminal on the MTU/MTU-A as described on page 28.

Note The mini-jack plug on the battery cable should be protected from physical damage or shock.

Understanding LED indications

The LED indicator between the N and S terminals provides an indication of the MTU/MTU-A status.

Fig. 2-16: Instrument LED indicator.

Original indication sequence

On instruments with firmware prior to 3112F, for most indications, the LED blinks in a specific pattern that repeats every 12s.

System startup.

- During system startup, the LED blinks once, then lights steadily for about 30s.

Initial satellite lock. To synchronize with UTC and begin data acquisition or calibration, the MTU/MTU-A must receive signals from at least four GPS satellites. Under normal conditions, this takes less than 10min. A longer delay may indicate poor antenna positioning or a faulty antenna or cable.

- Before acquisition, the LED pattern is 1s on, 1s off, for each satellite acquired, for up to four satellites.

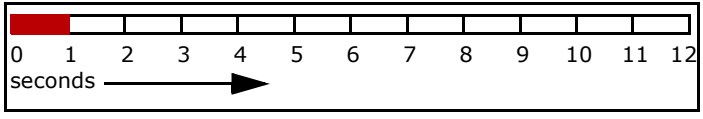


Fig. 2-17: Before data acquisition, one satellite acquired.

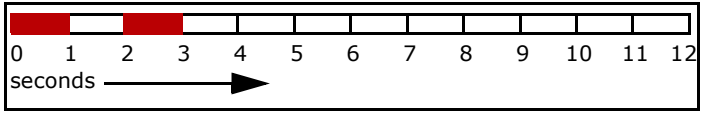


Fig. 2-18: Before data acquisition, two satellites acquired.

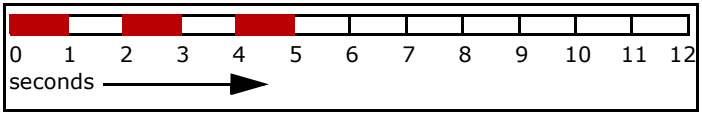


Fig. 2-19: Before data acquisition, three satellites acquired.

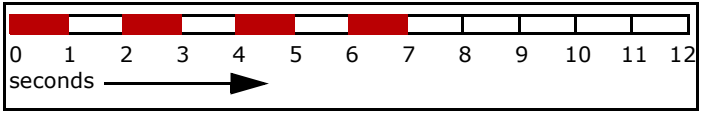


Fig. 2-20: Before data acquisition, satellite lock achieved (four or more satellites acquired).

During data acquisition. The MTU/MTU-A can acquire site or calibration data any time after the initial four-satellite lock has been achieved. It is not necessary for satellite lock to continue uninterrupted, because the MTU/MTU-A internal clock stays synchronized with UTC for several hours even if satellite lock is temporarily lost.

- During data acquisition, the LED blinks in a pattern of one second on, two seconds off, for each satellite acquired, to a maximum of four satellites.

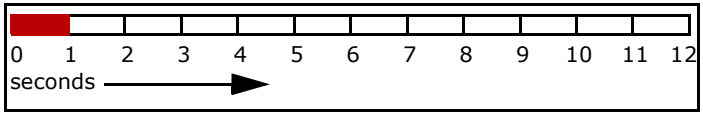


Fig. 2-21: During data acquisition, one satellite acquired.

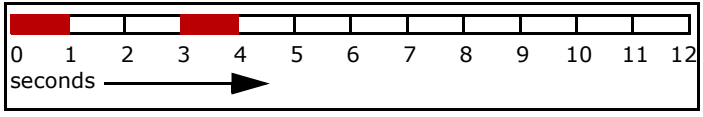


Fig. 2-22: During data acquisition, two satellites acquired.

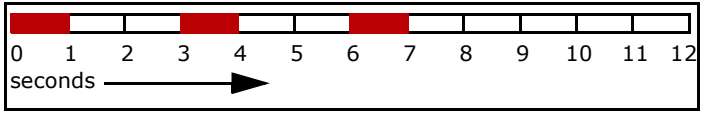


Fig. 2-23: During data acquisition, three satellites acquired.

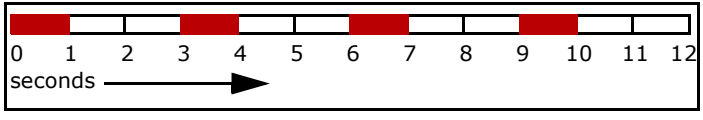


Fig. 2-24: During data acquisition, four or more satellites acquired.

Tip If a PC is connected to the MTU/MTU-A and the WinHost program is running, you can learn the exact number of acquired satellites by clicking MTU Status and examining the **GPS Status** pane in the **Information Parameters** dialog. The number may vary from 0 to 8.

After data acquisition. The MTU/MTU-A can be programmed to continue operating at idle or to shut down at the end of site data acquisition. It will idle after calibration data acquisition.

- If the MTU/MTU-A shuts down, the LED will go out.
- If the MTU/MTU-A is idling, the LED will blink in a pattern of one second on, 5 seconds off.

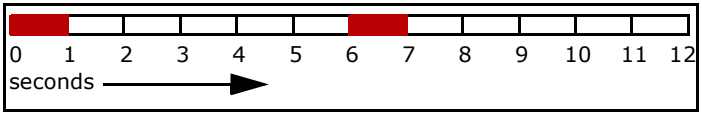


Fig. 2-25: Idling after site or calibration data acquisition.

New indication sequence

Beginning with firmware version 3112F, for most indications the LED flashes in a sequence that repeats every 15s. Seven seconds are used to indicate the status of the instrument, including warning and error messages. Two seconds are used to indicate the status of satellite lock. The satellite indication is aligned with UTC seconds :00, :15, :30, and :45. Two seconds are used to indicate the status of the on-board clock, and four seconds are used to indicate the instrument mode.

System startup and shutdown.

- During system startup, the LED flashes once, then again, then lights steadily for about 30s. This pattern is the same as in previous firmware versions.
- During system shutdown, the LED lights steadily until shutdown is complete. Do not disconnect battery power until the LED goes out.

Instrument status. Seven seconds of the sequence are used to indicate either that the instrument is performing normally or that there is an error or a potential error, such as overheating or low battery voltage.

- If the instrument is performing normally, the LED is off for one second, then lights steadily for 5 seconds, then goes off for one second.

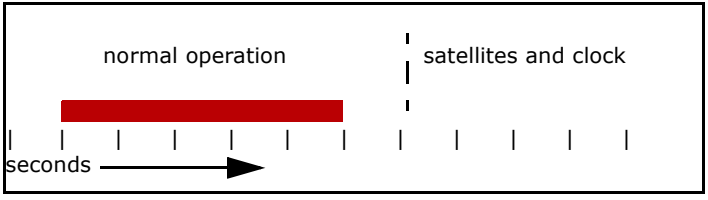


Fig. 2-26: Indication of normal operation.

- If an abnormal condition exists, the LED will flicker rapidly for 350ms as an alert, and will then flash from one to seven times, 50ms on, 350ms off (see Fig. 2-27). Table 2-1 explains the meaning of the number of flashes.

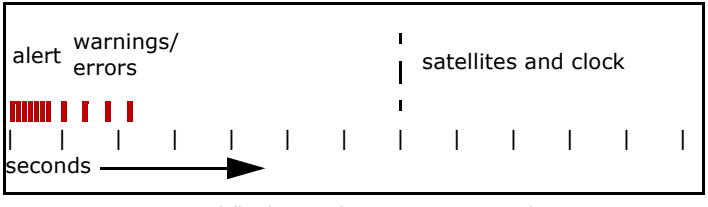


Fig. 2-27: Pattern of flashes indicating errors and warnings.

Table 2-1: Error and warning LED indications

Flashes	Message type	Meaning
1	Warning	Battery voltage is less than 11V.
2	Error	CompactFlash card is not installed.
3	Warning	Instrument internal temperature exceeds 60°C.
4	Warning	Instrument is in record mode but disk space is <50MB (AMT), <10MB (MT), or <2MB. The 50MB and 10MB warnings appear for 5 minutes only. The 2MB warning is continuous.
5	Warning	The number of saturated records has increased.
6	—	Measured electrode resistance exceeds acceptable maximum.
7	Error	Calibration failed.
8–14	—	Reserved for future use.

System error. In some circumstances, the instrument may not be able to start up normally. This problem can be caused by damaged circuit boards or corrupt firmware files, for example.

- In the case of a fatal system error, the LED flashes constantly, 100 ms on, 100 ms off (see Fig. 2-28).

Fig. 2-28: Pattern of flashes indicating system error.

If the instrument displays this indication, contact Phoenix technical support.

Satellite lock. To synchronize with UTC and begin data acquisition, transmitter control, or calibration, the instrument must receive signals from at least four GPS satellites. (The instrument may actually acquire up to eight satellites, but only indicates the first four.) Under normal conditions, satellite lock takes less than 10 min. A longer delay may indicate poor antenna positioning or a faulty antenna or cable.

- After the 7-second instrument status indication, the LED pattern is 250 ms on, 250 ms off, for each satellite acquired, for up to four satellites (see Fig. 2-29). If no satellites have been acquired, the pattern is 1.9 s on, 0.1 s off (see Fig. 2-30).

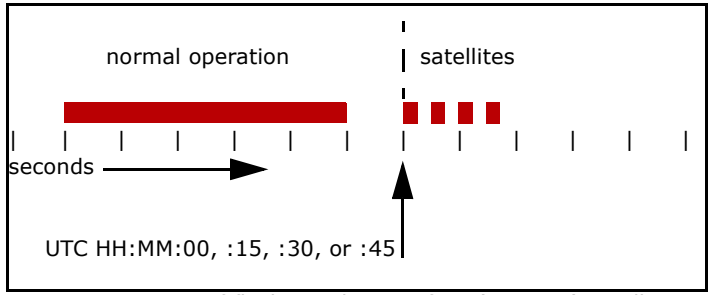


Fig. 2-29: Pattern of flashes indicating four (or more) satellites acquired.

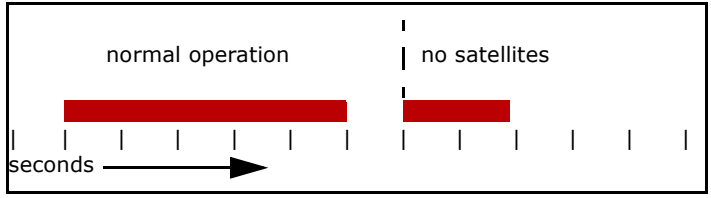


Fig. 2-30: A single long flash indicates zero satellites acquired.

Clock status. Once the instrument acquires the minimum number of satellites, the on-board clock synchronizes to GPS time. Within the following 12.5min, the satellites send a correction message and the on-board clock synchronizes to UTC. (The difference between GPS time and UTC is the number of UTC leap seconds, which are not incorporated in GPS time.) If satellite lock is subsequently lost, accurate time is maintained by an oven-controlled crystal oscillator (OCXO). Recording of site data or calibration data cannot begin unless the clock is synchronized to either satellites or OCXO.

- After the satellite indication, the LED pattern is 250ms on, 250ms off, from zero to four times (see Fig. 2-31). Table 2-2 explains the meaning of the number of flashes.

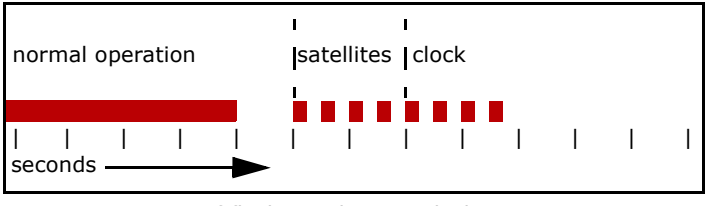


Fig. 2-31: Pattern of flashes indicating clock status.

Table 2-2: Clock status LED indications

Flashes	Meaning
0	Clock is not yet initialized.
1	Clock is synchronized to CPU real-time clock.
2	GPS synchronization is in progress.
3	Clock is synchronized to OCXO.
4	Clock is synchronized to GPS or UTC.

A complete pattern of eight equally spaced flashes indicates both satellite lock and clock synchronization to GPS or UTC. The instrument is ready to record site data or calibration data.

Instrument mode. The next four seconds of the sequence indicate whether or not the instrument is measuring electrode resistance or recording site data or calibration data. The possible instrument modes are: setup, standby, measuring resistance or recording data, or idling after recording.

- In these four seconds of the sequence, the LED pattern is 900ms on, 100ms off, from one to four

times (see Fig. 2-32). Table 2-3 explains the meaning of the number of flashes.

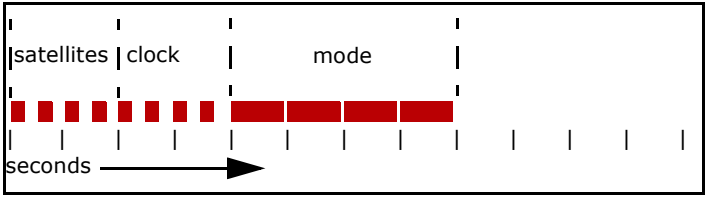


Fig. 2-32: Pattern of flashes indicating instrument mode.

Table 2-3: Instrument mode LED indications

Flashes	Meaning
1	Instrument is in Setup mode.
2	Instrument is standing by before recording or calibrating.
3	Instrument is measuring electrode resistance or recording site data or calibration data.
4	Instrument is idling after measuring electrode resistance or recording site data or calibration data.

Summary of complete sequence. Figure 2-33 shows the complete 15s indication sequence. In summary:

- Constant rapid, equally spaced flashes indicate a fatal system error.
- A fast flicker followed by very short flashes indicates an error or warning.
- A steady 5-second light indicates normal operation; be prepared to read the satellite count and clock status after this light goes off.
- A steady 1.9s light indicates no satellites acquired
- Short, equally spaced flashes indicate satellite and clock status; eight flashes in a row means the instrument is fully synchronized and ready to record.
- Longer flashes with a short space between them indicate setup or recording mode.

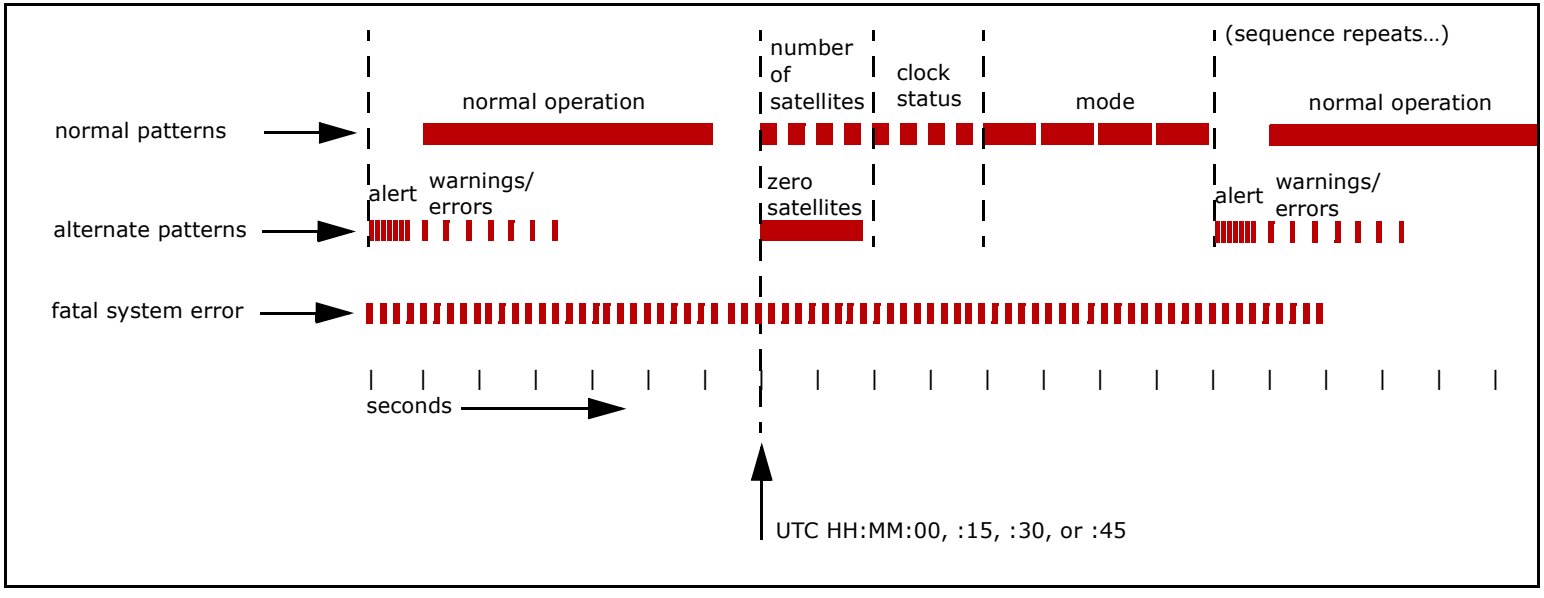


Fig. 2-33: Complete new indication sequence.

Examples. The following figures show examples of LED indications under various conditions.

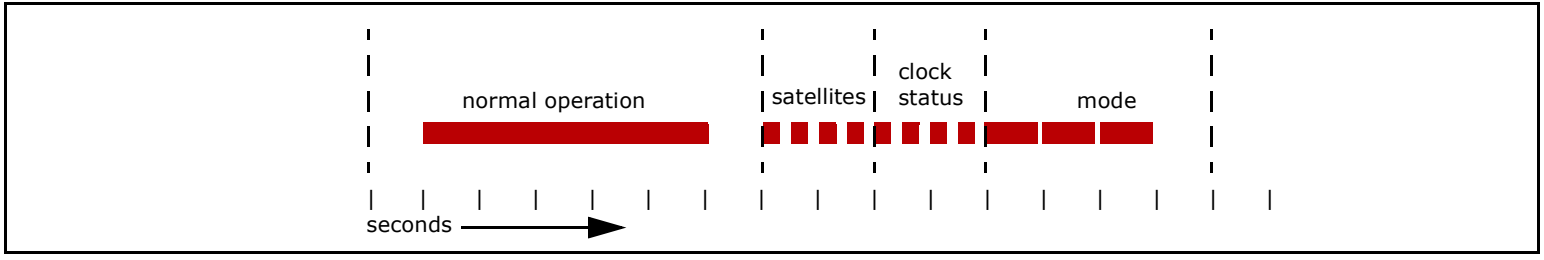


Fig. 2-34: Example of normal operation in record mode (site data or calibration data), or measuring electrode resistance.

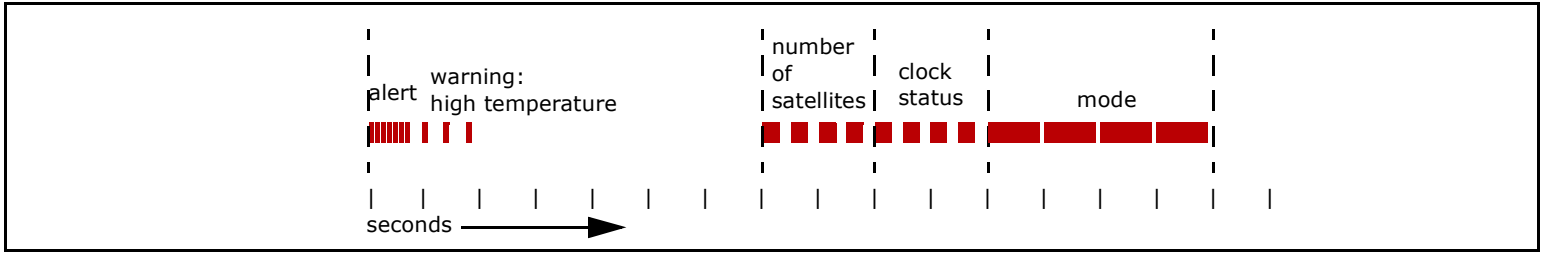


Fig. 2-35: Example of idling after acquisition with internal temperature exceeding 60°C.

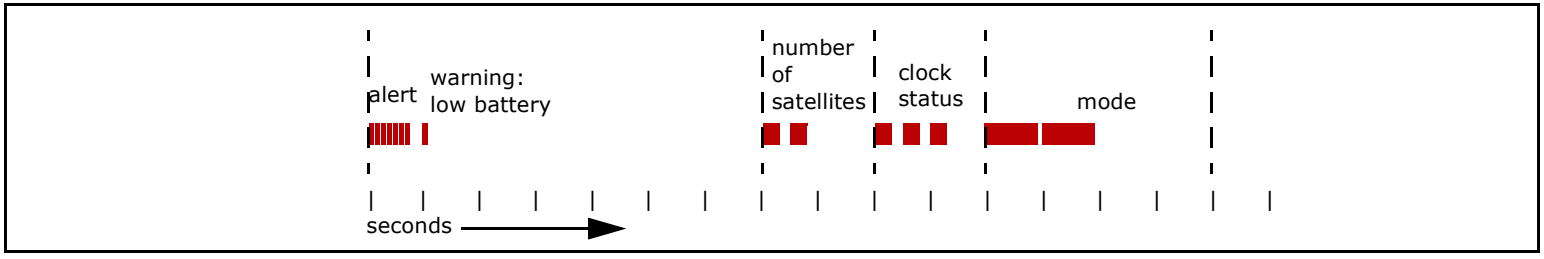


Fig. 2-36: Example of operation in standby mode when synchronized to OCXO, with a low battery warning.

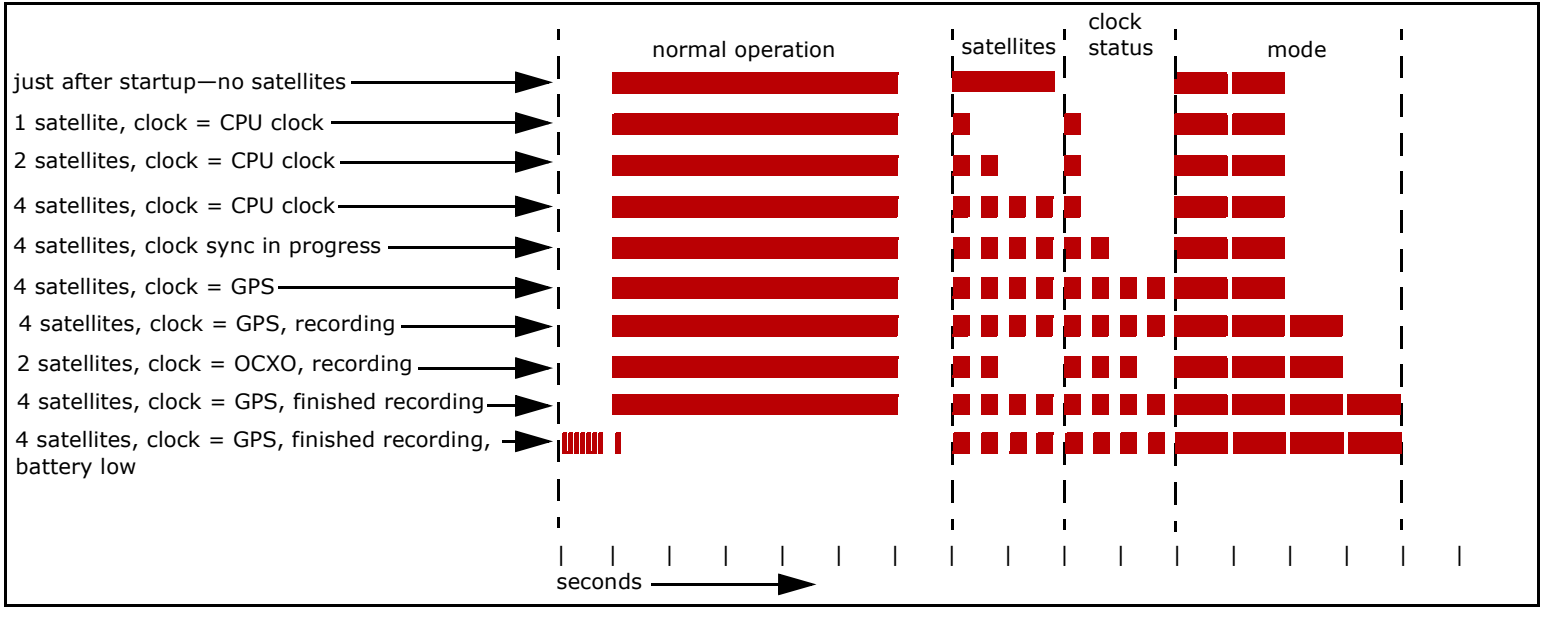


Fig. 2-37: Example of how the pattern might change during a normal sounding. At first there are no satellites acquired, then 1 satellite, then 2, then 4 or more. As satellites are acquired, the clock synchronizes first with the CPU, then with GPS/UTC. At the programmed start time, the mode changes from standby to record mode. Satellites may be lost temporarily, leaving the clock synchronized to the OCXO while recording continues. Recording stops at the programmed time and the instrument idles, possibly draining the battery below 11V.

Using the new indication sequence

If you have a PC connected to the instrument, you can use WinHost to learn the details of GPS synchronization, instrument mode, and so on. However, the LED indications give you a quick way to learn if everything is operating as expected, without needing a PC in the field.

The most important indication is the steady 5-second light. This light tells you that the instrument is operating normally. If you see an alert and warning or error indication instead, take immediate steps to correct the cause.

If the 5-second light indicates normal operation, then watch the following flashes to learn the satellite and clock status. For several minutes after powering on, you should expect to see the 1.9s zero-satellite indication and a clock indication of zero flashes. After a few minutes the satellite indication will change to show the number of satellites acquired and the clock indication will show one or two flashes to indicate progress in synchronizing.

Once the satellite indication reaches four flashes, you should see the clock indicator also change to four flashes. Taken together, these eight identical flashes indicate full GPS and clock synchronization.

After the clock is synchronized, you may see the number of satellites drop to less than four; at that point, the clock status will change to three flashes to indicate synchronization to the crystal oscillator. This is also a normal condition.

Finally, check the longer flashes of the mode indication. If you are recording or calibrating, you should see three flashes. When calibration is complete or data recording has ended according to a schedule, you will see four flashes. If you have scheduled the instrument to record automatically at a later time, you should see two flashes.

If the LED indications are not what you expect to see, use the WinHost program to find out where the problem lies.

Programming and monitoring an MTU/MTU-A

An MTU/MTU-A can be controlled and monitored in real time using the PC program, WinHost. Alternatively, the instrument can be programmed to operate automatically, by using the PC program WinTabEd to save parameters in a file (STARTUP.TBL).

The easiest way to prepare for a survey of multiple sites is to use WinTabEd to create generic STARTUP.TBL file. Otherwise, you will have to take a PC into the field and set up parameters individually at every site.

Be sure that you use the correct version of WinHost and WinTabEd for the instrument you are programming and for the type of data you want to acquire. See Chapters 3 and 4 for instructions on how to use the software. Refer to the *Data Processing User Guide* for instructions on installing the software and setting up the PC parallel port to communicate with the MTU/MTU-A.

Calibrating the equipment

Before each survey begins, all the MTU/MTU-As and sensors must be calibrated. Once the equipment is set up, the process takes about 10 minutes for an MTU/MTU-A and one hour or more (in half-hour increments) for sensors. Each calibration must be completed in a single session; it cannot be interrupted and resumed.

The usual practice is to calibrate the MTU/MTU-A and then the sensors immediately after, usually at the survey remote reference site. However, an MTU/MTU-A can be calibrated on its own, even indoors if GPS signals can be received.

No additional calibration equipment is needed except a PC for control and monitoring and copying the resulting files.

Calibrating the MTU/MTU-A

MTU/MTU-As must be calibrated before acquiring data or calibrating sensors. Because calibration requires GPS satellite lock, it is usually done outdoors. However, if the GPS antenna can be positioned outdoors and connected to the MTU/MTU-A with an extended cable, then the calibration can be done indoors.

Note For best results, the instrument should be at operating temperature when you start the calibration. In normal ambient conditions, the MTU/MTU-A will reach a stable operating temperature 10–15 minutes after it is powered on. In cold weather, allow more time before you start the calibration.

The MTU/MTU-A stores the resulting calibration file in the `\CAL` directory on its internal disk. The file is named `ssss.CLB`, where `ssss` is the serial number of the instrument. Do not rename, move, or delete the directory or the calibration file.

Tip If you intend to calibrate an MTU/MTU-A and magnetic sensors in the same session, plan for enough time and choose an outdoor location suitable for both. See "Calibrating coil sensors (MTC-30/50)" on page 54 and "Calibrating air-loop sensors" on page 60 for requirements. To work efficiently, begin the layout of the sensors while the MTU/MTU-A calibration is in progress.

Tools and equipment required:

- MTU/MTU-A to be calibrated
- Battery and cable
- GPS antenna and cable
- PC with WinHost On-Line Interface software and cable

To calibrate an MTU/MTU-A:

1. Connect the GPS antenna to the MTU/MTU-A as described on page 31.
2. Connect the battery to the MTU/MTU-A as described on page 32.

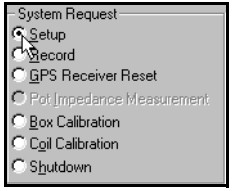
3. Ground the input terminals by running a length of bare wire from one terminal to the next, ending at the GND terminal.

Warning Failure to ground the input terminals may result in damage to the instrument.

4. Power up the MTU/MTU-A by pushing the red POWER switch up to the ON position and releasing it.

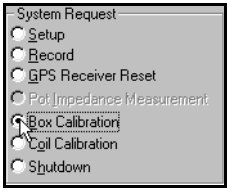
   After a brief delay, the LED indicator between the North and South E-line terminals will light steadily for about 30s, then start blinking.

5. Turn on the PC.
6. Connect the PC to the MTU/MTU-A as described on page 30.
7. On the PC, click **Start** and point to **Programs**, then to **Phoenix Geophysics MTU Host software** or **MTU-AMT Host software** (according to the type of MTU/MTU-A you are calibrating), and click **Winhost—Online**.
8. If necessary, wait for the MTU/MTU-A to achieve satellite lock. (See "Initial satellite lock" on page 39.)
9. In the **System Request** area at the top left of the Winhost main window, select **Setup**:



   The MTU/MTU-A restarts as soon as you select the option.

10. Verify that the MTU/MTU-A has again achieved satellite lock.
11. Set the **Power Line Filter** to the frequency of the commercial power grid in your area.
12. O an MTU, set the **Sampling Schedule** to V5-2000.
13. In the **System Request** area at the top left of the main window, select **Box Calibration**:



Calibration begins as soon as you select the option.

14. From the command buttons on the right of the main window, click MTU Status.

    The **Information Parameters** dialog appears.

15. Monitor the calibration in the **Calibration Status** pane in the lower right.

    When a successful calibration is complete in about 10 minutes, the **Calibration Status** pane will contain the message, "Box calibration file on disk." The MTU⁄MTU-A LED will indicate idle mode.

    If the calibration is not successful, see "Interpreting calibration results" on page 63.

16. Close the **Information Parameters** dialog box.

17. If you want to calibrate sensors, continue with the next procedure; otherwise, copy the calibration file to the PC.

18. If you are not continuing with sensor calibration, shut down the MTU⁄MTU-A as described on page 82.

Warning Disconnecting battery power before shutting down the MTU⁄MTU-A may result in damage to the equipment and/or loss of data.

Calibrating coil sensors (MTC-30/50)

Magnetic sensors must be calibrated (using a calibrated MTU⁄MTU-A with magnetic channels) before acquiring data. Sensors can only be calibrated outdoors, although the layout requirements for calibration are not as rigorous as for data acquisition. Sensor calibration takes at least one hour, and can be extended in increments of half an hour. The noisier the area, the more time is needed to ensure a quality calibration.

Electrical noise, physical vibration, and temperature variation all contribute to poor calibration data.

Although the sensors do not have to be buried to be calibrated, do choose a location protected from wind and sunlight, and away from sources of electrical noise and vehicle or pedestrian traffic. If these conditions cannot be met, plan to bury the coils. (If sunlight is the only potential problem, plan to cover each sensor with a tarpaulin.)

Tip The remote reference site to be used in a survey is often the best place to perform calibrations, because it is chosen for its low-noise characteristics.

The MTU⁄MTU-A stores the resulting calibration files in the `\CAL` directory on its internal disk. The file names are entered by the operator in the WinHost main window, and must include the serial numbers of the sensors. The MTU⁄MTU-A will add the extension `CLC` to each file name. Do not rename, move, or delete the `\CAL` directory.

Note The instrument that is used to calibrate sensors must already be calibrated itself. (The instrument calibration file (`*.CLB`) must be in the `\CAL` directory.)

Tools and equipment required:

- Sensors to be calibrated and a cable for each
- 3-way splitter cable
- Calibrated MTU⁄MTU-A with magnetic channels
- Battery and cable
- GPS antenna and cable
- PC with WinHost On-Line Interface software and cable
- A ground electrode and cable
- Salt water (50g/L)
- A shovel
- Optionally, tarpaulins for covering the sensors

To lay out a site for coil calibration:

1. Choose a location for the coils and position the MTU⁄MTU-A about 10m away. (See Fig. 2-38.)
2. Bury the ground electrode (see "Installing porous pot electrodes" on page 67) and connect it to the `GND` connector on the MTU⁄MTU-A.
3. Ten meters away, lay the coils parallel, flat on the ground about 3m apart, with all the connectors oriented toward the MTU⁄MTU-A.

4. If you are going to bury the coils, dig a trench alongside each, about 30cm deep and slightly longer than the coil.
5. On a Layout Sheet, note the serial number of each coil and designate it as either H_x, H_y, or H_z.
6. Connect the sensors to the MTU/MTU-A (see "Connecting sensors" on page 33).
7. To minimize wind-induced noise, ensure that the sensor cables lie flat on the ground. (Place weights on them every metre or so if necessary.)
8. If you are burying the coils, cover them with the earth removed from the trenches.
9. Complete the Layout Sheet for the site.

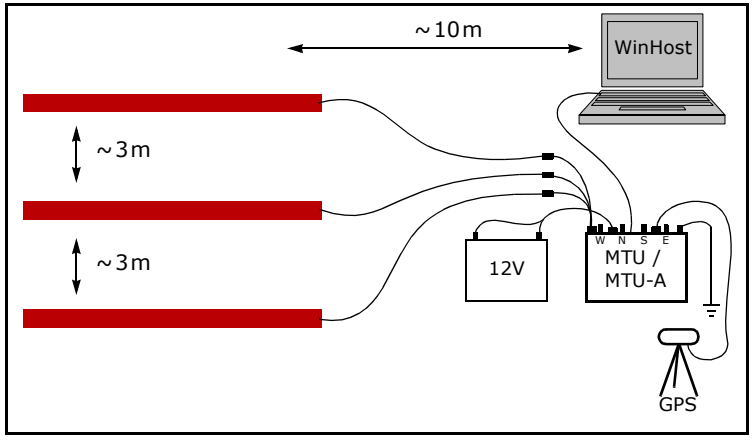


Fig. 2-38: Coil calibration layout.

To calibrate coil sensors:

1. If you are not continuing in the same session after calibrating an MTU/MTU-A, then set up a calibrated MTU/MTU-A by following steps 1 through 10 on page 52.
2. In the lower right of the WinHost screen, for each **Coil Serial #** (MTU) or **Sensor Serial #**, type in the 8-character file name to be used for the sensor's

calibration. Use the formats `COILssss` for MTC-50 coils and `AMTCssss` for MTC-30 coils, where `ssss` is the serial number of the coil. If no coil is connected to any of the H_x, H_y, or H_z channels, leave the **Serial #** blank for that channel.

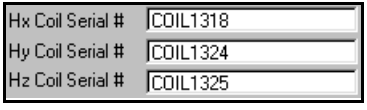


Fig. 2-39: Coil calibration file names (MTU).

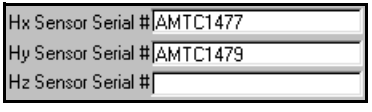


Fig. 2-40: Sensor calibration file names (MTU-A)—two sensors in use.

Note Be certain that the serial numbers are correct and are correctly identified as being H_x, H_y, or H_z as you noted when you laid out the coils. An error here means that all data acquired with the affected sensor(s) will be invalid—a potentially costly mistake.

3. Set the **Coil Cal. Multiplier** (MTU) or **Sensor Cal. Duration** (MTU-A) to at least 2 to ensure quality calibration data. (Each increment of this parameter adds 30 min to the duration of calibration data acquisition.) If you know that the area is electrically noisy, set this parameter to a higher number.
4. If you are using an MTU-A, choose the type of sensor from the **Sensor Type** list.

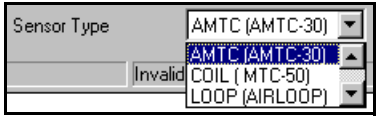
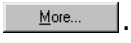
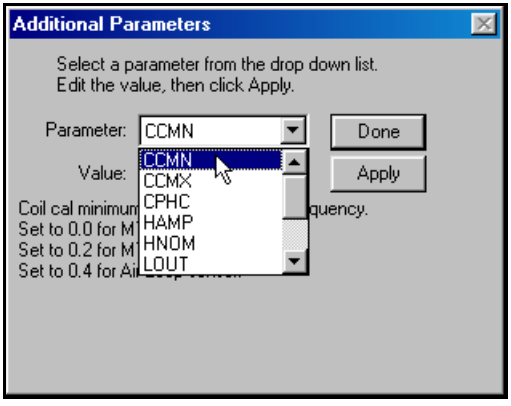


Fig. 2-41: The **Sensor Type** dropdown list.

Choosing the sensor type from this list automatically sets the values of five parameters that are used in the calibration process.

5. If you are using an MTU-A, skip to step 10. If you are using an MTU, then from the command buttons on the right of the main window, click 

.
6. In the **Parameter** list, select **CCMN**:



7. Follow the instructions in the dialog box to change the parameter value according to the type of sensor in use. (Be sure to click Apply after the change.)

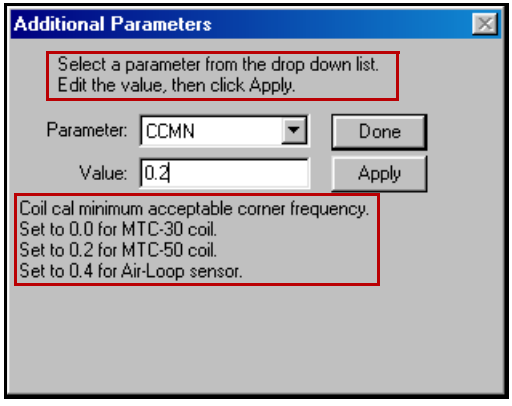
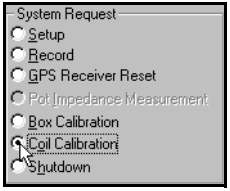


Fig. 2-42: Instructions in the **Additional Parameters** dialog box.

8. Repeat step 7 after selecting each of the following parameters:
   - **CCMX**
   - **CPHC**
   - **HAMP**
   - **HNOM**
9. Click Done to return to the main window.

10. In the System Request area at the top left of the main window, select **Coil Calibration**:

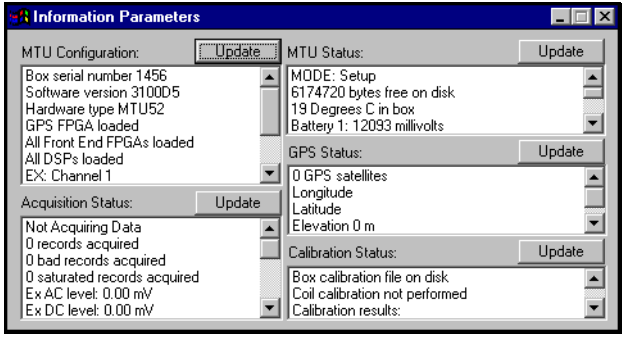


Calibration begins as soon as you select the option.

To monitor calibration progress:

1. From the command buttons on the right of the main window, click MTU Status.

The **Information Parameters** dialog box appears:



2. Monitor the calibration in the **Calibration Status** pane in the lower right.

   When calibration is complete in about one hour, the **Calibration Status** pane will contain the messages, "Coil calibration files on disk" and "Calibration results: IINNN" ("I" for Incomplete on unused channels and one "N" for each magnetic channel having a Normal result).

   If the calibration is not successful, see "Interpreting calibration results" on page 63.

3. Close the **Information Parameters** dialog box.
4. Copy the calibration files to the PC.

5. When you have finished calibrating equipment, shut down the MTU/MTU-A as described on page 82.

Warning Disconnecting battery power before shutting down the MTU/MTU-A may result in damage to the equipment and/or loss of data.

Calibrating air-loop sensors

An air-loop sensor is used for the H_Z channel in place of a coil sensor when ground conditions make it impossible to dig a hole deep enough to bury the coil vertically. Calibration of an air-loop is identical to calibration of coils except for the layout and the use of an excitation loop as the signal source. (See Fig. 2-43.)

Please read "Calibrating coil sensors (MTC-30/50)" on page 54 to gain a general understanding of the process and requirements.

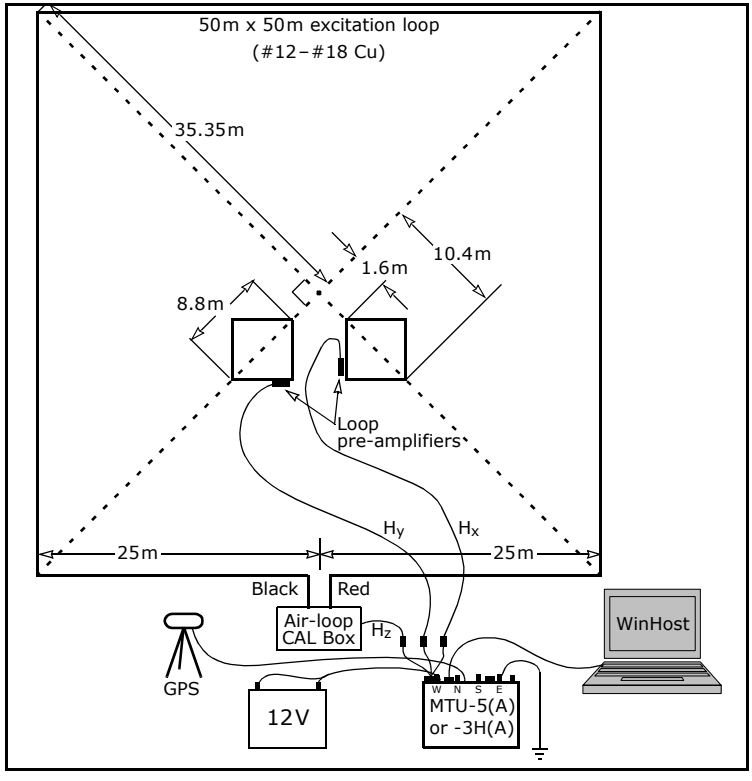


Fig. 2-43: Air-loop sensor calibration.

Tools and equipment required:

- Sensors to be calibrated and a cable for each
- 3-way splitter cable
- Air-loop "CAL Box" and cable
- Calibrated MTU/MTU-A with magnetic channels
- Battery and cable
- GPS antenna and cable
- A ground electrode and cable
- Salt water (50g/L)
- PC with WinHost On-Line Interface software and cable
- 250m of #12–#18 gauge copper wire for the excitation loop
- Measuring tape (≥50m)
- A shovel
- Marking stakes
- A compass and tripod

To lay out the excitation loop:

1. Review the diagram on page 60.
2. Prepare the wire for the excitation loop by marking it with coloured tape at 25m, 75m, 125m, 175m, and 200m. The tape will mark the corners and the end of the loop. Wind the wire onto a portable spool.
3. Set up a compass on a tripod where you plan the centre of the loop.
4. Sight from the compass toward one of the planned corners and have an assistant place a stake to mark 1.6m, 10.4m, and 35.35m. These stakes mark two corners of the AL-100 loop, and one corner of the excitation loop.
5. If more than one AL-100 loop is to be calibrated, repeat step 4, sighting at a 90° angle to the first corner.
6. Stake the remaining corners of the excitation loop by sighting at 90° increments and measuring 35.35m.
7. Starting at the midpoint between two corners, walk the perimeter of the loop, unwinding the copper wire from the portable spool as you go. Align the tape markings at the corners to verify your compass sightings and measurements.

8. Connect the the excitation loop ends to the Air-loop CAL Box.

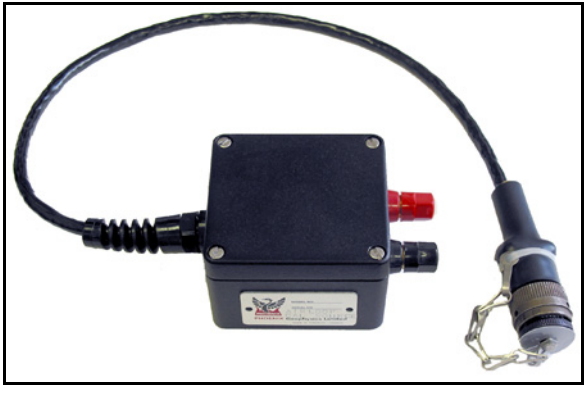


Fig. 2-44: Air-loop CAL Box.

To lay out the AL-100 air-loop:

1. Using the stakes at the 1.6m and 10.4m measurements, position two opposite air-loop corners as shown in the diagram. (The four corners of the AL-100 loop are marked with tape and a preamplifier.)
2. Gently pull the remaining two corners into position.
3. Verify that:
   - The air-loop sides are parallel to the excitation loop sides.
   - The air-loop forms a perfect square. (Opposite corners are 8.8m apart.)
   - The pre-amplifier is at one corner of the air-loop.
   - The cable to the MTU⁄MTU-A exits the pre-amplifier *toward the right* when viewed from within the air-loop.

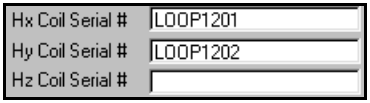
To connect the MTU⁄MTU-A:

1. Position the calibrated MTU⁄MTU-A near the Air-loop CAL Box.
2. Bury the ground electrode (see "Installing porous pot electrodes" on page 67) and connect it to the GND connector on the MTU⁄MTU-A.
3. On a Layout Sheet, note the serial number(s) of the air-loop(s) and connect their cable(s) to the MTU⁄MTU-A as H_x or H_y. (See "Connecting sensors" on page 33.)

4. Connect the Air-loop CAL Box to the MTU/MTU-A as H_z.
5. Complete the Layout Sheet.

To calibrate air-loop sensors:

1. If you are not continuing in the same session after calibrating an MTU/MTU-A, then set up a calibrated MTU/MTU-A by following steps 1 through 10 on page 52.
2. In the lower right of the WinHost main window, for the **H_x** and/or **H_y Coil Serial #**, type in the file name to be used for the air-loop calibration(s). Use the format `LOOPssss`, where `ssss` is the serial number of the air-loop. If no loop is connected to either the H_x or H_y channel, leave the **Serial #** blank for that channel:

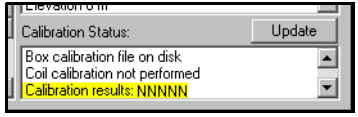


Note Be certain that the serial numbers are correct and are correctly identified as being H_x or H_y, as you noted when you connected the air-loop cables. An error here means that all data acquired with the affected sensor(s) will be invalid—a potentially costly mistake.

3. The rest of the procedure is identical to that for coil sensors: follow steps 3 through 10 on page 57 (being sure to use the values for Air-Loop in the **Additional Parameters** dialog box) and monitor the calibration as described on page 59.

Interpreting calibration results

When an instrument or sensor calibration ends, the coded results appear in the **Calibration Status** pane of the **Information Parameters** dialog box:



For each channel of the instrument, a single alphabetic character indicates the calibration result. Channels

appear in the order E_x, E_y, H_x, H_y, H_z. Table 2-4 explains the meaning of the codes.

Table 2-4: Calibration result codes

Code	Meaning
N	Normal completion.
C	Corner frequency out of range.
H	Corner frequency out of range.
G	Gain out of range.
L	(MTU only) Gains factory-set to Low series.
I	Incomplete or Inapplicable (in the case of sensor calibration where a channel was unused).

Setting up a survey site

The next sections explain how to install and connect the various parts of the SSMT 2000 system to acquire data at a survey site.

Tip
A three-person crew can work very efficiently if the crew leader handles operations at the MTU⁄MTU-A while the two field workers install the E-lines and sensors. The crew leader orients the field workers as they position the E-lines. While the workers install the electrodes and sensors, the leader can install the ground electrode and make other connections and measurements at the MTU⁄MTU-A.

Verifying your location

Ensure that you are at the right site number and location as defined on the survey map. Use a handheld GPS locator or other reliable method to be sure of your location.

Choosing the site centre

Scan the general area to locate the best place for the MTU⁄MTU-A, at the centre of the site.

To centre the site:

1. Take a quick sighting with a handheld compass and allow enough room to the north, south, east, and west to lay out the E-lines and/or sensors. (Remember that if there is a slope ≥20°, you may want to extend an E-line to compensate.)
2. Choose a dry spot that will stay dry if it rains.
3. Stay clear of noise sources (power lines, roads and paths, railways, etc.) and overhead obstructions.
4. Spread out a 1m by 2m tarpaulin at the chosen centre and set the MTU/MTU-A and battery on it near one short edge. Align the W terminal of the MTU/MTU-A toward the west, to simplify cable connections later.

Note In all cases, allow enough room to keep the MTU/MTU-A at least 1m away from the dipole electrodes, and the sensors 5m away from the E-lines, to avoid electromagnetic interference.

Fig. 2-45: Instrument and battery positioned on tarpaulin.

Setting up telluric dipoles (E-lines)

Except at magnetic-only sites, the next step is to set up the dipoles, or E-lines. Although experienced crews

often orient the dipoles using a handheld compass, for greatest accuracy, you should use a compass on a tripod.

Tip To save time in the field, use coloured adhesive tape to mark the length of half the desired dipole on precut E-line cables. As the field worker pulls the cable end away from the site centre, the crew leader can pay out the cable and call a halt when the tape marker is reached. With this method, the workers only have to use a tape measure when the standard layout can't be followed.

To set up the dipoles:

1. Have a field worker gather up:
   - an electrode
   - a shovel
   - a container of salt water (50g/L)
   - a handheld compass
   - one end of an E-line
   - (a tape measure, if the layout is non-standard or the E-lines cables are not pre-marked)
2. If you are keeping track of equipment deployment, then record the electrode number and/or cable number on the Layout Sheet.
3. Sighting with the compass at the site centre, guide the field worker while the worker pulls the E-line (and tape measure if necessary) in the direction of the dipole.

Tip If you can pick out a landmark in the distance that aligns well with the dipole, you can simply direct the worker to walk straight toward it.

Be sure that no metal objects such as belt buckles, vehicles, or shovels are close enough to distort compass readings.

4. If you are working as a 3-person crew, save time by having the second field worker simultaneously pull the second E-line in the opposite direction, keeping aligned with the site centre and the first worker.
5. When the workers arrive at the measured distance, carefully fine-tune their positions.
6. Have the workers install the electrodes as described in the next procedure.

7. Lay out excess cable in S-shapes. In windy areas, have the workers weight down the cables with rocks or dirt every metre or so as they return to the centre.
8. Repeat this procedure for the second dipole.

Tip If you decide to use a handheld compass at the site centre, it's good practice to scuff a mark in the soil under each foot as you orient the first half of each dipole. When you turn to orient the other half, don't simply swivel around on one foot—you'll be about a metre off centre. Instead, make sure to place your feet back in the two scuff marks after you turn.

Also, have the assistants use their compasses to verify the accuracy of the dipole orientation by sighting from each end of the dipole to the other, through the site centre.

Installing porous pot electrodes

All MTU/MTU-As require at least one porous pot electrode to provide an electrical ground. All units except MTU-3H or MTU-3HA also require four electrodes to form the telluric dipoles.

It is important that the MTU/MTU-A be grounded before any other connections are made, and that all the electrodes have the lowest contact resistance possible.

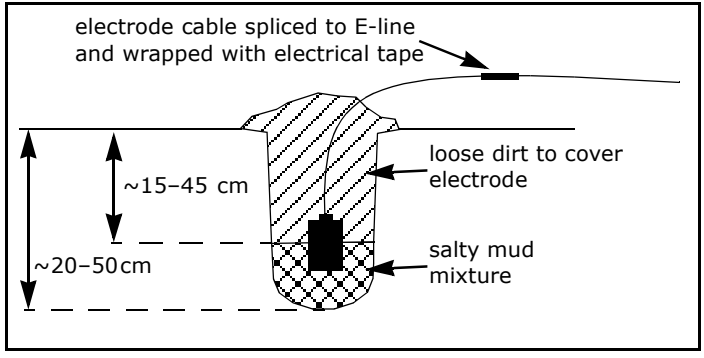


Fig. 2-46: Electrode installation.

To install an electrode:

1. Determine the electrode position as described in the previous section. For the ground electrode, choose a spot less than 1 m from the MTU/MTU-A.
2. At the chosen position, dig a small hole about 20–50 cm deep, removing any sizeable rocks.

3. Loosen the dirt at the bottom of the hole, or replace a bit of the loose dirt just removed.
4. Pour in at least 1 L of salt water and mix it with the dirt to form a uniform mud. In porous or sandy soil and in hot weather, use more salt water—enough to keep the electrode damp for the duration of the sounding.
5. Place the electrode upright in the hole, rotating it back and forth to position it solidly in the mud, leaving the electrode cable extended outside the hole.
6. Cover the electrode completely by filling the hole with loose dirt.
7. Connect the electrode cable to the E-line cable or the MTU/MTU-A GND terminal, as described in the next section.

To connect E-lines to the electrodes:

1. Remove 2–2.5 cm of insulation from the ends of the cables.
2. Hold the E-line and the electrode cables side by side with the ends pointing in the same direction.
3. Divide the strands of the electrode cable in half, twist one half tightly around the bare end of the E-line, and then twist the remaining half over top of the first half. This assures a good electrical connection.
4. Wrap the joined wires with two or three layers of electrician's tape.
5. Tie an overhand knot near the splice, treating the two cables as if they were one. (The splice can remain connected for the duration of the survey. This knot prevents the splice from being pulled apart when the electrodes are retrieved and reinstalled at other sites.)

Tip Other than in monitoring applications, cable splices will be temporary—they'll have to be separated when you retrieve the equipment after the last sounding. To save time, when you wrap a splice, always leave the free end of the electrician's tape doubled back or twisted onto itself. When you retrieve the equipment, the loose end of tape will be easy to grasp and unwrap, even when wearing gloves.

Connecting electrodes to the MTU/MTU-A

This task can be done by the crew leader after burying the ground electrode, and while the workers are setting up the dipoles and/or sensors.

To connect the electrodes:

1. Make sure the MTU/MTU-A is aligned so that the W terminal faces west and E terminal faces east. This alignment helps to avoid layout errors by keeping the E-lines organized.
2. Connect the ground electrode to the GND terminal first.
3. Connect the four E-lines to their appropriate terminals.
4. Double check that the correct electrode is connected to each terminal: west to W, north to N, south to S, and east to E.

Tip To identify the dipole electrodes, tie a loose single overhand knot about 40 cm from the end of the North E-line cable before connecting it to the N terminal. Tie two overhand knots in the East cable, three in the South cable, and four in the West cable. With this method, even if the lines become disorganized around the MTU/MTU-A, it will be easy to verify that the cables are connected to the correct terminals.

Measuring electrical characteristics

For proper data processing and as a check on the condition of the equipment and the installation, you must measure and record several electrical characteristics of the site. At sites with magnetic channels, the crew leader can make these electrical measurements while the workers are installing the sensors (see “Setting up magnetic sensors” on page 72).

For best results, use a digital voltmeter and an analog ohmmeter, in that order.

Tip To improve accuracy when using the ohmmeter and voltmeter, take every measurement twice, reversing the polarity the second time. Record the average of the two values.

To measure AC and DC potentials:

1. Using a digital voltmeter at the MTU/MTU-A, measure the AC potential in mV between the N and S terminals and between the E and W terminals, recording each measurement on the Layout Sheet.
2. Measure and record the DC potentials (in mV) in the same way.

   If AC potential approaches 150 mV or higher, there may be a strong noise source nearby. A DC potential in the same range may indicate a faulty electrode. Little can be done about a noise source, but you can test for faulty electrodes.

To test for faulty electrodes:

1. Using a digital voltmeter at the MTU/MTU-A, measure the AC or DC potential in mV between the GND terminal and each of the two terminals forming the dipole that has the high reading.
2. If the total potential of the dipole is significantly different from the sum of the potentials of its two electrodes, the electrode with the higher potential is probably faulty. Replace it with a different electrode and repeat all electrical measurements.

To measure contact resistance:

1. Using an analog ohmmeter at the MTU/MTU-A, measure the resistance in kΩ between the GND terminal and each of the W, N, S, and E terminals, recording each measurement on the Layout Sheet.
2. If any of the electrodes has a resistance >2000 Ω, consider taking steps to reduce the contact resistance (add more salt water or driller's mud, relocate the electrode).

Note To accurately measure contact resistance ≥2000 Ω, you must disconnect the E-lines from the MTU/MTU-A. Measure from the ground terminal to each E-line end, and between the two E-line ends of each dipole.

3. Measure and record the resistance between the N and S terminals.

4. Measure and record the resistance between the E and W terminals.
5. If the total resistance of either dipole is significantly different from the resistance to ground of each of its electrodes, there is a problem with the installation—usually the ground electrode is at fault. Double check all cables and connections, test the electrodes as just described, and repeat the resistance measurements.

E-line checklist

Use this checklist to verify that your set-up is correct.

- Are the dipole orientations correct?
- Are the dipole lengths correct?
- Have cable splices been waterproofed with electrician's tape?
- Are the cable ends correctly identified with knots and connected to the right terminals?
- Has excess cable been laid in S-shapes, no closer than 5m from the ends?
- Do the cables lie flat on the ground?
- Are the cables restrained with rocks or dirt (in windy areas)?
- Are cables that cross pathways completely buried?
- Have you accounted for excessive slope?
- Have you made all the necessary electrical measurements?

Setting up magnetic sensors

MTU⁄MTU-A's with magnetic channels accept two or three sensors. Normally, all sensors are coil-type, but if the vertical component (H_Z) is required and the ground is too rocky for a coil to be buried, an air-loop sensor can be substituted.

Choosing sensor locations

Except in the case of instruments designated -2H and -3H, which acquire only magnetic channels, you will already have laid out two dipoles. The dipoles form four quadrants with the MTU⁄MTU-A at the intersection.

Use the dipole quadrants as a guide, and place each magnetic sensor in a separate quadrant whenever possible.

If you are using -2H or -3H instruments, simply keep the sensors widely separated.

To choose sensor locations:

1. Use the length of the connecting cables as a guide, and plan to place each sensor as far as possible from the MTU⁄MTU-A, from other sensors, and from the dipoles. However, stay clear of noise sources (power lines, roads and paths, railways, etc.).
2. If you must place more than one sensor in a quadrant to avoid noise or difficult terrain, keep the sensors, dipoles, and the MTU⁄MTU-A separated by at least 5m.
3. For each sensor, try to choose a dry spot, preferably one that will stay dry if it rains.

Installing coil sensors

Correct identification, careful levelling, and accurate orientation are crucial to obtain good sensor data.

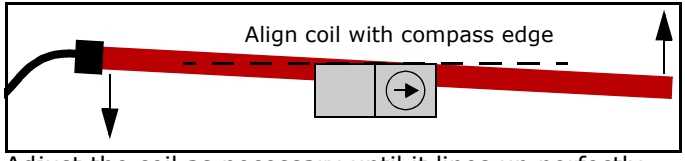
Tip Be sure that no metal objects such as belt buckles, vehicles, or shovels are close enough to distort compass readings.

If you tie a short piece of rope around the coil before burying it, you'll be able to pull the coil free of the ground more easily when retrieving the equipment.

To position and orient a horizontal coil sensor:

1. Designate the sensor as H_X or H_Y and record its serial number on the Layout Sheet.
2. If you are keeping track of equipment deployment, then also record the identifying number of the sensor cable to be used.
3. Gather up:
   - the sensor
   - one end of the sensor cable
   - a shovel
   - a spirit level
   - a handheld compass
4. Carry the equipment to the location chosen for that sensor, pulling the sensor cable as you go.
5. Lay the sensor on the ground and use the compass to orient it reasonably accurately. *Be certain that the free end is to the north for H_X, or to the east for H_Y.*

Tip To orient a coil easily, open the handheld compass fully and rotate the housing to the desired azimuth. Then hold it at waist level directly over the coil and align the compass North marking with the needle. Sight past the long edge of the compass to the side of the coil to judge its alignment.



Adjust the coil as necessary until it lines up perfectly with the long edge of the compass.

To bury a horizontal coil sensor:

1. Use a shovel to mark the outline of a trench about 10–15cm beyond each end of the oriented sensor and the same distance from each side.

2. Move the sensor aside and dig the trench about 40cm deep, keeping the bottom smooth and level and piling the soil alongside the trench.
3. Connect the cable to the sensor.
4. Lay the sensor in the trench in the correct orientation, using the spirit level to place it as accurately level as possible. You may have to deepen or fill in the trench slightly to meet this requirement.
5. Use the compass to orient the sensor as accurately as possible.

Note If you adjust the sensor in any direction, *always recheck the accuracy of both orientation and level*.

6. Taking care not to disturb the sensor, replace the soil in the trench and pack it down gently. (Do not mound the soil over the coil, or you will increase wind noise.)
7. If there is excess cable, lay it out in S-shapes. In windy areas, weight down the cables with rocks or dirt every metre or so as you return to the site centre.

To install a vertical coil sensor:

1. On the Layout Sheet, record the H_z coil serial number.
2. If you are keeping track of equipment deployment, then also record the identifying number of the sensor cable.
3. Gather up:
   - the sensor
   - one end of the sensor cable
   - a shovel
   - a post-hole digger or an auger
   - a spirit level
4. Carry the equipment to the location chosen for the sensor, pulling the cable as you go.
5. Dig a narrow hole deep enough to completely bury the sensor. If this is too difficult, dig as deeply as possible and plan to mound additional soil over the top of the coil.
6. Connect the cable to the sensor.

7. Place the sensor in the hole and steady it by replacing about half the excavated soil.
8. Use the spirit level to position the coil vertically as accurately as possible, measuring at two places at right angles to each other on the side of the coil.
9. Taking care not to disturb the coil, replace the remaining soil. If necessary, build a gently-sloping mound of additional soil over the top until the coil is completely buried.
10. If there is excess cable, lay it out in S-shapes. In windy areas, weight down the cables with rocks or dirt every metre or so as you return to the site centre.

Installing an air-loop sensor

If the ground is too rocky to allow burial of a vertical coil, use an air-loop as the H_z sensor instead.

To install an air-loop sensor:

1. On the Layout Sheet, record the H_z air-loop serial number.
2. If you are keeping track of equipment deployment, then also record the identifying number of the sensor cable.
3. Gather up:
   - the sensor
   - one end of the sensor cable
   - a tape measure
4. Carry the equipment to the location chosen for the sensor, pulling the cable as you go.
5. Arrange the air-loop flat on the ground so that:
   - The air-loop forms a perfect square (opposite corners should be 8.8m apart).
   - The pre-amplifier is at one corner of the square.
   - The cable to the MTU/MTU-A exits the pre-amplifier *toward the right when viewed from within the air-loop*.

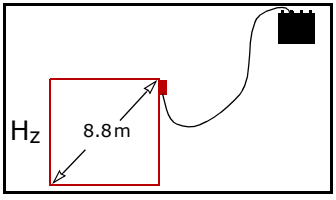


Fig. 2-47: Air-loop cable must exit the pre-amplifier toward the right when viewed from within the air-loop.

6. Weight down the air-loop and its cable with rocks or dirt every metre or so. If there is a risk of disturbance by humans or animals, consider burying the air-loop completely.

Connecting the sensors to the MTU/MTU-A

If you are using an instrument with magnetic channels only (MTU-2H, -3H, -2HA, -3HA), install a ground electrode before connecting sensors. (See "Installing porous pot electrodes" on page 67.) Then connect the sensors. (See "Connecting sensors" on page 33.)

Be sure that each sensor is connected to the correct pigtail of the 3-way cable. The cable is marked with one ring for H_x, two rings for H_y, and three rings for H_z. (See Fig. 2-48.)

Fig. 2-48: Three-way sensor connector cable.

Tip To identify the sensor cables, tie a loose single overhand knot about 40 cm from the end of the H_x cable before connecting it to the 3-way cable pigtail. Tie two overhand knots in the H_y cable, and three in the H_z cable. With this method, even if the lines become disorganized around the MTU/MTU-A, it will be easy to verify that the cables are connected to the correct pigtails.

Sensor checklist

Use this checklist to verify that your set-up is correct.

- Do the free ends of the horizontal coils point north or east, no matter which quadrant they are in?
- Were the coils perfectly level and not disturbed when buried?
- Have all metal objects been removed from the vicinity of the sensors?
- Is the H_Z coil exactly vertical and completely covered?
- Does the cable from the H_Z air-loop exit from the pre-amplifier to the right when viewed from inside the loop?
- Do the cables lie flat on the ground?
- Are the cables restrained with rocks or dirt (in windy areas)?
- Are cables that cross pathways completely buried?
- Have all serial numbers been correctly recorded?

Setting up the MTU/MTU-A instrument

Two final connections must be made to the MTU/MTU-A to complete the site setup: the battery and the GPS antenna.

To complete the MTU/MTU-A setup:

1. Connect the GPS antenna (see "Connecting the GPS antenna" on page 31).
2. Connect the battery (see "Connecting the battery" on page 36).

Powering up the MTU/MTU-A and acquiring data

Once all the components have been connected, the MTU/MTU-A can be powered on. The red LED indicator on top of the unit indicates its status.

To power up the MTU/MTU-A:

1. Push the red POWER switch up to the ON position and release it.

   The LED indicator between the North and South E-line terminals will blink once, and after a slight delay will light steadily.

Fig. 2-49: Instrument LED indicator.

2. After approximately 30s when the MTU/MTU-A has started up, watch for the LED indication of initial satellite lock. (See "Understanding LED indications" on page 39.)

Tip When preparing to leave a survey site, always ensure that the MTU/MTU-A has acquired the four-satellite minimum. Reposition the GPS antenna or replace the antenna and/or cable if necessary. If you leave the site without ensuring satellite lock, the MTU/MTU-A may not be able to acquire data, and the site will have to be resounded.

3. If you are not working with a pre-configured STARUP.TBL on a CF card, connect a PC and program the MTU/MTU-A as explained in Chapters 3 and 4. Disconnect the PC when you have finished.
4. Cover the MTU/MTU-A with the tarpaulin that you first laid out under it.
   - In warm weather, cover the instrument loosely for shade, weighting down the tarpaulin but leaving the sides open for ventilation. (See Fig. 2-50.)

Fig. 2-50: In warm weather, wrap the tarpaulin loosely.

- In wet or damp conditions, wrap the tarpaulin tightly, folding the ends under the instrument to hold the tarpaulin in place. (See Fig. 2-51.)

Fig. 2-51: In wet or damp conditions, wrap the tarpaulin tightly.

- In very hot weather (>35°C), take the instrument out of its carrying case, position it so the connectors face upward, shade it from the sun, and ensure there is good ventilation to prevent damage from overheating. A simple lean-to sunshade can be constructed from two wooden or metal poles, stakes, and a tarpaulin. (See Fig. 2-52.)

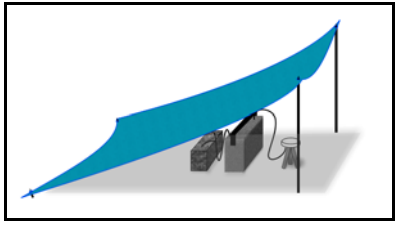


Fig. 2-52: In very hot weather, construct a sunshade and remove the instrument from its carrying case. To maximize the exposed surface area, keep the instrument upright, not lying on its side.

5. Take any other necessary precautions to protect the site, and leave the equipment to acquire data.

Final site checklist

Use this checklist to verify that your set-up is correct.

- Has GPS lock been achieved?
- Has the Layout Sheet been completed?
- Has the instrument been protected from the environment using a tarpaulin?
- Have you collected all installation tools?

Retrieving the equipment

Retrieving the equipment from a site is a fairly straightforward reversal of the steps taken to set up. When you arrive, check the site and the equipment for signs of disturbance. You many find cables chewed through by animals, for example, indicating that the site will likely have to be re-sounded.

If everything is in order, then retrieve the equipment using the following procedures.

Shutting down the MTU/MTU-A

Care must be taken that the MTU/MTU-A has shut down properly before battery power is disconnected. If the instrument has not been programmed to shut down automatically at the end of data acquisition, you must shut it down manually.

Warning Disconnecting battery power before shutting down the MTU/MTU-A may result in damage to the equipment and/or loss of data.

To shut down an MTU/MTU-A:

1. Push the red POWER switch down (toward the POWER label) and release it.
2. Wait approximately 30 seconds until the LED goes out.

Remeasuring electrical characteristics

For complete and accurate records, you should repeat the electrical measurements (contact resistance and AC and DC potentials) on the dipoles before disconnecting them. It is also good practice to check the battery voltage, because a reading below 10V may indicate a worn out battery that should be replaced.

Tip The recorded contact resistance is an important factor during data processing, but the resistance changes over time. The change is probably most rapid just after electrode installation, as the salt water disperses. Therefore, during data processing, you may want to use either the post-acquisition value alone, or an average of the pre- and post-acquisition values.

Use the back of the Layout Sheet to record the measurements.

Collecting the equipment

Once you have shut down the MTU/MTU-A and remeasured the electrical characteristics, you can disconnect all the equipment and pack it up for use at the next survey site.

To collect the equipment:

1. Disconnect each E-line and coil it in a large figure-8 shape. Wrap a few layers of electrician's tape through the top of the "8" to keep the lines tangle-free. (Twist the end of the tape back on itself to make it easy to take off later.)
2. Dig up the electrodes, clean off most of the dirt, and store them in a carrying case containing a few centimetres of salt water. (It is important not to let the electrodes dry out.)
3. Dig up and disconnect the sensors and/or air-loop. Coil their cables and secure them with a few wraps of electrician's tape.

Warning Never pull a coil sensor out of the ground by pulling on the cable. Damage to the cable or connector can result. Either dig the sensor out completely, or tie a short length of rope around the coil before burying it, to help in retrieval.

4. Remember to replace all the protective caps on cables and connectors, to protect them from dirt and moisture.

Tip When coiling sensor cables, avoid damage by letting the length of the cable rotate on its axis as you make each loop. Otherwise, the cable will become twisted and kinked, leading to internal breakage.

Charging the batteries

Ensure that all batteries needed for the following day are charged overnight. Refer to the instructions provided with the battery charger for connection and correct operation.

Chapter 3

Programming an MTU using WinHost and WinTabEd

Two PC programs are available to program and control an MTU/MTU-A: WinTabEd and WinHost. WinTabEd saves instructions to a file that the MTU/MTU-A loads when it is powered on, for automatic, unattended operation. WinHost allows you to control the instrument directly using a cable connection. This chapter explains how to use these two programs to set up an MTU for data acquisition. Chapter 4 explains how the settings differ for an MTU-A.

Because most parameters are similar for MTU and MTU-A instruments, you should read this chapter to become familiar with the programs, even if you are only using MTU-A instruments.

WinHost and WinTabEd

The WinHost and WinTabEd programs are very similar. WinHost controls an MTU in real time via a cable connection to the PC, whereas WinTabEd saves the control settings in a file for later transfer to the CompactFlash card of an MTU. The file, STARTUP.TBL, controls the operation of the MTU the next time it is powered on.

The information in this chapter applies to both programs except where noted.

Starting the programs

Different versions of WinTabEd and WinHost exist for use with MTU versus MTU-A instruments. The versions are identified on the Programs menu as Phoenix Geophysics MTU Host Software or Phoenix Geophysics MTU-AMT Host Software. Each program is compatible with only one instrument type. **Be sure that you use the correct program for your equipment.**

If you only want to create a STARTUP.TBL file, start WinTabEd.

If you want to control an MTU in real time, or if you want to create a STARTUP.TBL file based on the instrument's current settings, connect it to the PC as described on page 30 and power it on. Wait approximately 30 s while it initializes, then start WinHost.

Start the programs as you would any Windows program: either double-click a desktop shortcut, or from the **Start** menu, point to **Programs** and then to **Phoenix Geophysics Host Software**, and click the program name.

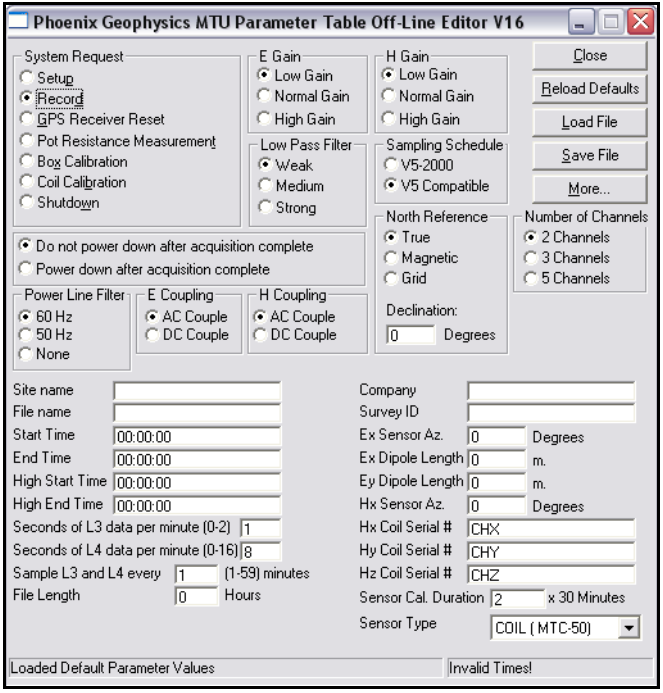


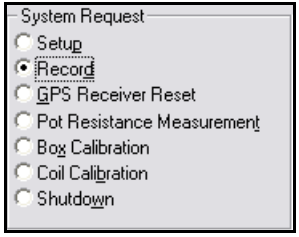
Fig. 3-1: WinTabEd main window.

Entering Setup mode (WinHost)

Before you change any parameters with WinHost, the MTU should be in Setup mode.

To enter Setup mode:

1. Examine the option buttons in the **System Request** area of the main window. If **Setup** is selected, the MTU is already in Setup mode, and no further action is required.



2. If any other option button is selected, click **Setup** and answer **Yes** in the confirmation dialog box.

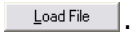
Loading an existing parameter file

You can use the system defaults as the basis for programming an MT instrument, or you can load the settings from a file saved on the PC (WinTabEd) or on the instrument (WinHost).

Loading a parameter file (WinTabEd)

Settings from any table file (`*.TBL`) on your PC can be loaded into WinTabEd to serve as a starting point.

To load an existing parameter file:

1. From the command buttons on the right of the main window, click 

.

   A standard Windows **Open** dialog box appears.

2. Navigate to the folder containing the file you want to use.

3. Select the file and click

.

   The settings contained in the file appear in the WinTabEd main window.

Loading a parameter file (WinHost)

The only parameter file that WinHost can load is the `STARTUP.TBL` file in the `\DATA` directory of the instrument, if that file exists.

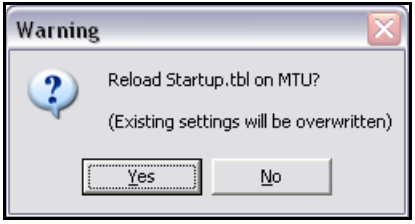
When WinHost starts, it automatically displays the current settings of the instrument. If the instrument has just been started, then these settings will be identical to those in the startup.tbl file, if it exists. However, after you make changes to the settings, you may decide you want to revert to the starting point. To do this, you can reload the `STARTUP.TBL` file from the instrument.

To reload the `STARTUP` file settings:

1. From the command buttons on the right of the main window, click

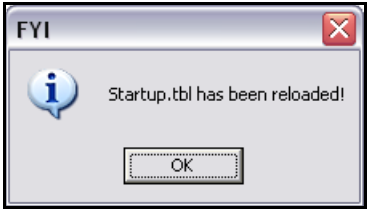
.

   A **Warning** dialog box appears:



2. To reload the startup settings, click **Yes**. To cancel, click **No**.

   If you click **Yes**, a confirmation dialog box appears:



3. Click **OK**.

Setting Record mode (WinTabEd)

If you are using WinTabEd to create a startup parameter file, you will want the MTU to enter Record mode when it is next powered on.

To set Record mode:

1. Examine the option buttons in the **System Request** area of the main window. If **Record** is selected, the MTU will start up in Record mode, and no further action is required.
2. If any other option button is selected, click **Record**.

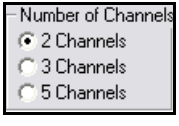
Note It is not advisable to select **Box Calibration** or **Coil Calibration** for a STARTUP file. The first operation in these modes is to erase any existing calibration files. This means that although a calibration could be carried out automatically using a STARTUP file, the calibration data would be erased the next time the instrument is powered on.

Setting the number of channels (WinTabEd)

Because the WinTabEd program has no connection to an MTU, the instrument cannot automatically report its type to the software. You must identify the number of channels to be recorded in order for the software to calculate the amount of storage required on the CompactFlash card. (This setting is not saved and has no effect on data acquisition. It is used only to calculate storage requirements.)

To set the number of channels:

- Select the appropriate option in the **Number of Channels** area:



Setting gain parameters

Three gain settings are available for each type of channel (magnetic and telluric). Table 3-1 shows the gain factor that is applied to the channel inputs for each setting.

The "correct" setting for E and H gain is dependent on local conditions of signal strength and noise. The objective is to set the gain as high as possible, without causing saturated records. As you build experience with your equipment in your locale, you will be able to judge the best settings to start with, and when to modify them.

The **Normal** setting should give good results in most cases. Use the **Low** settings in noisy areas (AC measured on the dipoles >100mV). Use the **High** E Gain only in low-noise, very low-resistivity areas.

Table 3-1: MTU Gain Factors

Setting	E Gain	H Gain
Low	10	3
Normal	40	12
High	160	48

To set E and H Gain:

1. Select **Normal Gain** for E channels and **High Gain** or **Normal Gain** for H channels:

2. If initial soundings contain many saturated records, reduce the settings by one level.
3. In very low resistivity areas with very low noise, select **High Gain** for E channels, but examine results carefully for excessive saturations.

Tip Even though the mid-level H Gain of 12 is labelled Normal, experience has shown that **High H Gain** gives good results in most cases, too. If your survey is not in a noisy area, consider using **High H Gain** as your usual setting.

Determining the number of saturated records

If gains are set too high, records will be saturated and data quality will be poor. To evaluate your gain settings, either monitor the instrument (see "Monitoring the MTU during acquisition (WinHost)" on page 105) or acquire some test data and examine the resulting Site Parameter File using the SSMT2000 program. The following procedure provides brief instructions on SSMT2000. Refer to the *Data Processing User Guide* for complete instructions.

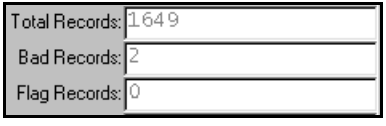
To determine the number of saturated records:

1. Start SSMT2000.

2. Locate and select the Site Parameter File for your test data.
3. Click

.
4. Click

.
5. Examine the **Total Records** and **Flag Records** values:



6. If **Flag Records** is more than 1–2% of **Total Records**, reduce the gain settings for future soundings.

Setting filter parameters

Two filters are applied to the E channel inputs: a low pass filter and a comb filter at the power line frequency.

Setting the low pass filter

The input low pass filter has three settings, **Weak**, **Medium**, and **Strong**. The choice of setting depends on the dipole contact resistance: the higher the resistance, the weaker the filter that should be used.

A filter setting that is too strong for the contact resistance will introduce phase shift error into the upper frequencies, and the plot of apparent resistivity will show a sharp rolloff at these frequencies. (This rolloff may be hard to recognize if near surface resistivity changes rapidly with depth.)

The low pass filter allows optimization over a range of electrode resistance. Using Figure 3-2 and Table 3-2 on page 91 as guides, set the filter to the weakest value that effectively reduces noise.

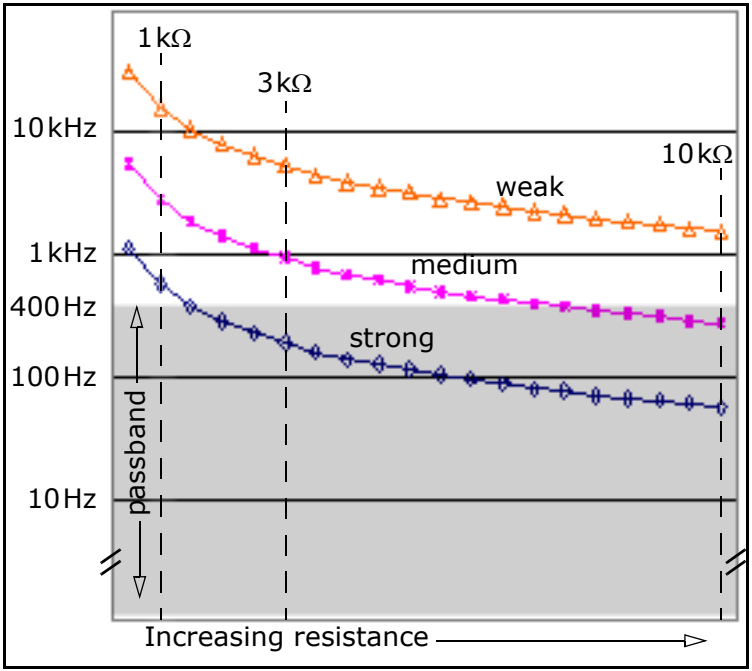


Fig. 3-2: Low pass filter corner frequencies versus contact resistance. The curves represent the frequencies at which response is attenuated by 50%.

Table 3-2: Low Pass Filter Settings

Contact Resistance	Maximum Filter Setting
<10kΩ	Weak
<3kΩ	Medium
<1kΩ	Strong

To set the low pass filter:

- Select either **Weak**, **Medium**, or **Strong** filtering, according to the electrode resistance:

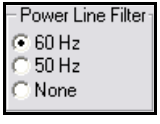
Note To accurately measure contact resistance ≥2000Ω, you must disconnect the E-lines from the MTU/MTU-A. Measure from the ground terminal to each E-line end, and between the two E-line ends of each dipole. The instrument should be powered off when no E-lines are connected.

Setting the power line filter

Be sure to set the **Power Line Filter** according to the local power line frequency: 50Hz or 60Hz. This filter setting not only reduces noise from the power grid, but also determines the sampling rate, as explained under "Setting gain parameters" on page 88. Data collected without power line filtering can not be processed by standard software.

To set the Power Line Filter:

- Select either **50Hz** or **60Hz**, to match the local line frequency:

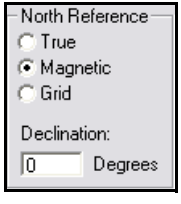


Note It is possible to turn off the comb filter entirely by selecting **None** as the **Power Line Filter** setting. This setting is provided for custom applications and custom processing software.

SSMT2000 does not accept data collected without power line filtering.

Setting the North Reference

It is critical that survey sites are oriented carefully and that the orientation is recorded correctly in the Site Parameter file. The **North Reference** parameter allows the data processing software to correctly compensate for magnetic declination and site rotation:



To set the North Reference:

- If you will orient your site to true north (adjusting for magnetic declination in the field), select **True**.
- If you will orient your site to magnetic north (making no adjustment in the field) select **Magnetic**.
- If you will orient your site to an arbitrary azimuth on a grid plan, select **Grid**.

Setting magnetic declination

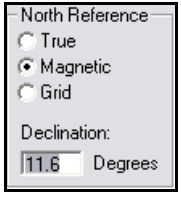
If you plan to orient your sites to true north or to an arbitrary azimuth on a grid plan, you should set magnetic declination to zero.

If you plan to orient your sites to magnetic north, you should set the magnetic declination of the survey area so that the processing software can compensate for it.

(If you do not set the correct value for magnetic declination before acquiring data, you can make the correction when editing the Site Parameter file in SSMT2000.)

To set the magnetic declination:

- In the **North Reference** area, type the declination in degrees:



Setting coupling parameters

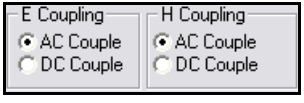
The coupling setting governs the high pass filter.

When the MTU is set to AC coupling, it uses a high pass filter with a corner frequency of 0.005Hz that removes self-potential from the dipole. Because signal strength increases with wavelength, this design allows acquisition of lower frequencies without saturating the input channels. For most MT soundings, use AC coupling for both E and H channels.

In the case where the DC potential measured on the electrodes is very low (less than about 20 mV) and the target wavelengths are >1000s, you may find that DC coupling (no filter) improves results.

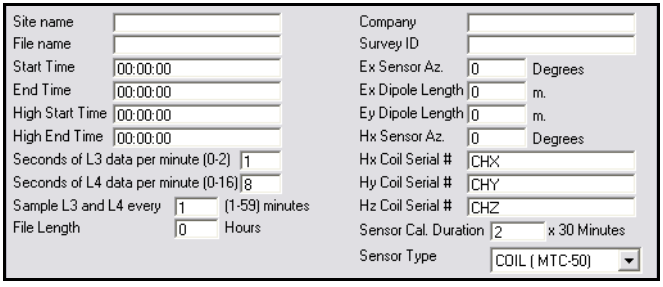
To set E and H Coupling:

- Except as noted above, select **AC Couple** for both E and H:



Setting site parameters

The lower half of the main window contains a series of parameters related to the site and the sounding itself:



All the parameters except the times can be edited in post-processing and are therefore non-essential when setting up an instrument. However, entering the information before acquiring data saves time during the survey, especially if you are creating a STARTUP.TBL file that will be used at multiple sites.

Completing the text fields

Site name. Maximum 8 characters. In WinHost, type the complete site name. In WinTabEd (creating a STARTUP.TBL file for multiple sites) type any characters that will be common to all sites, or leave the field blank.

File name. Maximum 8 characters. In WinHost, type the complete file name. In WinTabEd (creating a STARTUP.TBL file for multiple sites) leave the field blank. The software will create a file name based on the serial number of the instrument and the date of the sounding. The format of the file name is `ssssHDhh`, where:

- `ssss` represents the serial number of the instrument.
- `H` represents the month in hexadecimal.
- `D` represents the day of the month using the characters 1–9, A–U.
- `hh` is the order of repeated soundings at a single site, in hexadecimal.

Company. Maximum 12 characters. Type your company or institution name.

Survey ID. Maximum 12 characters. Type an identifying code for this survey.

Azimuths and Dipole Lengths. In WinHost, type the measured orientations of the E_x dipole and the H_x sensor (if used). Type the measured lengths of the E_x and E_y dipoles.

In WinTabEd (creating a STARTUP.TBL file for multiple sites) type the planned orientations of the E_x dipole and the H_x sensor (if used). Type the planned lengths of the E_x and E_y dipoles.

Sensor identification. In WinHost, type the name of the calibration file for each of the sensors in use. (The calibration file is named `COILssss.CLC` or `LOOPssss.CLC`, where `ssss` is the sensor serial number.)

In WinTabEd, type either `COIL` or `LOOP`; you will fill in the serial number during data processing.

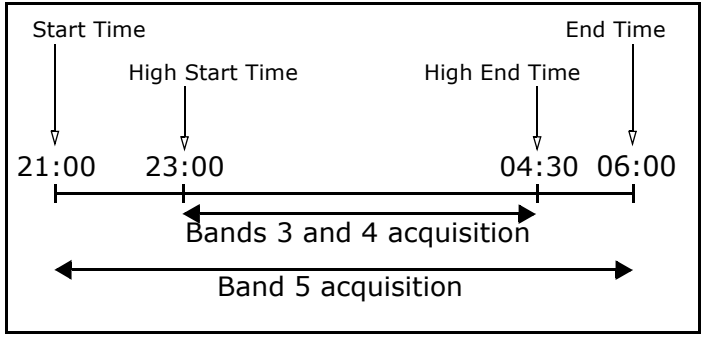
Setting acquisition times

Note All times are UTC, in the format HH:MM:SS (hours:minutes:seconds). To specify a date, use the format YYYY/MM/DD (year/month/day) followed by a space, then the time (YYYY/MM/DD HH:MM:SS).

For MT surveys, the instruments are usually installed during the day and left unattended overnight to acquire data. WinTabEd allows you to set up an appropriate schedule to start and stop acquisition automatically. To save space on the CompactFlash card, you can also program the instrument to acquire high frequency data for a shorter period of time—a subset of the overall duration. Beginning with firmware version 3112F, this shorter period can be repeated on each day of a multi-day sounding.

Four parameters control acquisition times: **Start Time**, **End Time**, **High Start Time**, and **High End Time**.

If you want to reduce file size by recording Bands 3 and 4 data for a subset of the total duration, specify a time for **High Start Time** that is after **Start Time** and before **End Time**; specify a time for **High End Time** that is after **High Start Time** and before **End Time**. For example, you might want to record 9 hours of low frequency data but only 5.5 hours of high frequency data:



In this example, you would set **High Start Time** to 23:00 and **High End Time** to 04:30.

When to include dates. Typical MT surveys are carried out over a period of days or weeks, using the same set of acquisition parameters at each site. If this is your method, then do not include dates when setting up acquisition times. A time without a date will cause the instrument to respond at that time on any day that it is powered. The instrument will save in the Site

Parameter file the actual start and stop dates and times of each sounding.

If your method involves soundings spanning several days, or continuous soundings in a monitoring application, then you must include dates as well as times in **Start Time** and **End Time**.

- If you want high frequencies recorded only once, then include dates as well as times in **High Start Time** and **High End Time**.
- If you want high frequency recording to be repeated daily during the sounding, then specify times but not dates in **High Start Time** and **High End Time**.
- If you want high frequency recording to be continuous throughout the sounding, leave **High Start Time** and **High End Time** set to 00:00:00. (File sizes may become very large.)
- For a monitoring application, set **Start Time** to the present date and time; set the **End Time** to some date and time in the distant future.

To set acquisition times:

1. Type the **Start Time** in the format described above.

   If the **Start Time** has already passed when the MTU is powered but the current time is less than 12 hours after that time, acquisition will start immediately. Otherwise, the MTU will idle in Standby Mode until the **Start Time**.

2. Type the **End Time** in the same format.
3. To record Bands 3 and 4 data throughout the entire sounding, leave **High Start Time** and **High End Time** set to 00:00:00.
4. To reduce file size by recording Bands 3 and 4 data for a subset of the total duration, type a time for **High Start Time** that is after **Start Time** and before **End Time**; type a time for **High End Time** that is after **High Start Time** and before **End Time**.

Automatic clearing of dates in Start Time and End Time (WinHost). When you save the settings of an MTU using WinHost, dates associated with **Start Time** and **End Time** may be cleared (that is, not saved). If **Start Time** is more than 12 hours prior to the current time, only the time is saved; the date is not saved. If **End Time** is

less than 12 hours after the current time, only the time is saved; the date is not saved.

High Start Time and **High End Time** are always saved unchanged.

Setting sampling parameters

This section explains sampling rates and frequency bands, sample interval ("time slot"), and the sampling schedule.

Frequency bands, sampling rates, and sample interval.

A Phoenix MTU acquires data in three frequency bands (numbered 3 through 5), each with different characteristics. (Frequency bands were formerly called Levels, and are abbreviated as "L".)

Figure 3-3 illustrates the way the bands are sampled.

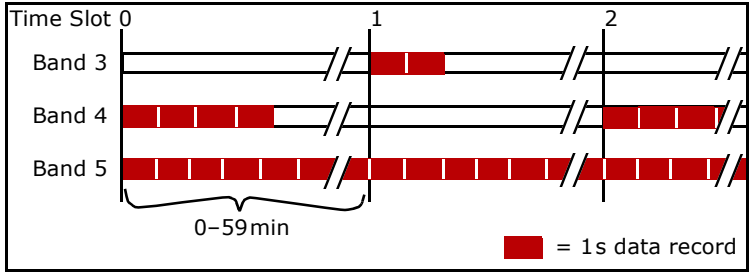


Fig. 3-3: MTU sampling scheme.

The lowest frequencies are sampled continuously. To keep files to reasonable sizes, the two higher frequency bands are sampled only periodically.

The user defines a time slot of duration from 1 to 59 min for periodic sampling. The MTU samples the two higher frequency bands alternately at the beginning of each time slot in a pattern that repeats each hour. (Regardless of the defined duration, a new time slot pattern begins at the start of each UTC hour.) The shorter the time slot, the more often records will be captured, and the larger the data files will become. The time slot can be as long as 59 min. For most MT soundings, a value from 1 to 5 min is typical; an integer

factor of 60 is preferable. For lengthy soundings, a higher value may be necessary depending on the capacity of the Compact Flash card.

The number of samples in each one-second data record depends on the settings of both **Line Frequency** and **Sampling Schedule**. Table 3-3 on page 99 shows the sampling rate for each frequency band at each of the settings. If you choose the V5 compatible sampling schedule, your data will be compatible with data acquired by the previous generation of MT equipment, the V5. If you choose the V5-2000 sampling schedule, your data will be compatible with data acquired by an MTU-A, shown by the shading in Table 3-3.

Band 3 (the highest frequencies) is sampled at one of the rates shown in Table 3-3, with each record starting on the UTC minute for a duration of 1s. Up to two such records can be captured at the beginning of each odd-numbered time slot. A higher number improves data quality, but also increases file size.

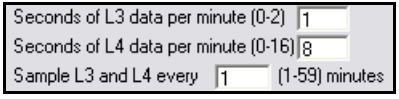
Table 3-3: MTU/MTU-A sampling rates (number of samples per one-second record).

Band	MTU			MTU-A	
	V5 Compatible		V5-2000	Data Type	
	50Hz	60Hz		MT	AMT
2	—	—	—	—	24 000
3	2560	3072	2400	2400	2400
4	320	384	150	150	150
5	24	24	15	15	—

Band 4 (intermediate frequencies) is sampled at one of the rates shown in Table 3-3, with each record starting on the UTC minute for a duration of 1s. Up to 16 such records can be captured at the beginning of each even-numbered time slot. A higher number improves data quality, but also increases file size.

Band 5 (the lowest frequencies) is sampled continuously at 24Hz or 15Hz, regardless of the length of the timeslot or the filter used.

Three fields in the main window control the length of the time slot and the number of records for each frequency band:



To set the number of samples per record:

1. Set **Seconds of L3 data per minute (0-2)** to a value from 1 to 2.
2. Set **Seconds of L4 data per minute (0-16)** to a value from 4 (preferably 8) to 16.

To set the time slot length:

- After **Sample L3 and L4 every**, type a value from 1 to 59.

Note When setting parameters for a reference site and survey sites, make sure that the time slot length and sampling parameters are identical in all instruments. Data from a reference site cannot be used if its parameters differ from those of the survey sites.

If you are combining MTU and MTU-A instruments in a survey, be aware that the time slot units are different: an MTU time slot is defined in minutes, whereas an MTU-A time slot is defined in seconds.

Sampling schedule. The sampling schedule can be set for backward compatibility with the V5 (a previous generation of MT equipment) or for compatibility with V5-2000 instruments. The difference lies in the number of samples in each one-second data record. (See Table 3-3 on page 99.)

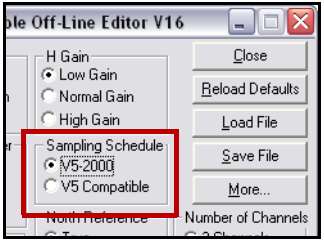
If the V5 Compatible sampling schedule is chosen, a survey can use a mix of V5 and V5-2000 MTU instruments. Either instrument type can serve as a reference.

If the V5-2000 sampling schedule is chosen, a survey can use a combination of MTU and MTU-A equipment. Either instrument type can serve as a reference, and

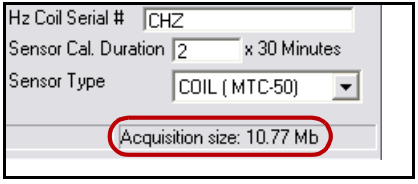
data from the entire MT and AMT frequency spectrum can be merged.

To set the sampling schedule:

- Select the desired compatibility from the **Sampling Schedule** area of the main window:



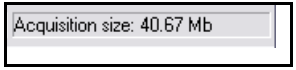
Storage space required. As you change the values to set up the sampling parameters, the software displays at the right end of the status bar the amount of storage space required for the amount of data you have specified:



Note Phoenix MTUs are shipped with Compact Flash cards large enough to acquire about 36 hours of continuous data at settings of 2 records of Band 3 and 16 records of Band 4 per 5min time slot. These settings will generally assure high-quality data.

To check the storage space required:

1. After setting your sampling parameters, update the storage calculation by pressing the Tab key, and examine the status bar at the bottom right corner of the main window:



2. Verify that your CompactFlash card has enough storage space for the **Acquisition size** reported.

Setting power status after acquisition

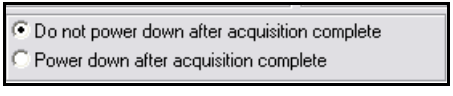
After acquisition is complete, the MTU can either continue operating in Standby mode, or automatically power down.

If the instrument continues operating, you will be able to quickly check its status using either the LED signals or a PC and WinHost.

If the instrument powers down, you will preserve battery life and save a little time when retrieving the equipment.

To set the power status:

- Select either **Do not power down after acquisition complete** or **Power down after acquisition complete**, as required:



Saving the parameters

Once you have completed your setup, you need to save the parameters in a file, either on the PC for transfer to the MTU (WinTabEd) or on the instrument itself (WinHost).

To save a parameter file (WinTabEd):

1. From the command buttons on the right of the main window, click

.

   A standard Windows **Save As** dialog box appears.

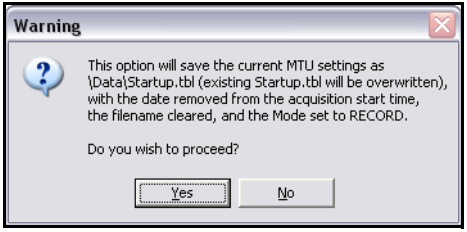
2. Navigate to the folder where you want to save the file. (This might be anywhere on the PC, or the `\DATA` folder on a CompactFlash card that will be installed in an MTU.)
3. Name the file STARTUP and press Enter. (The software will add the extension `TBL`.)

Note If you are preparing multiple files, you can give them any names at this point and save them on the PC or on a CompactFlash card. However, one file only must be named STARTUP.TBL in the CompactFlash card `\DATA` folder for the file to be recognized and used by the MTU.

To save a parameter file (WinHost):

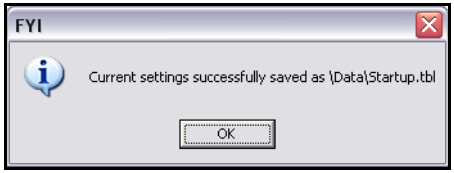
1. From the command buttons on the right of the main window, click Save Settings.

   A **Warning** dialog box appears:



2. To save the settings, click **Yes**. To cancel, click **No**.

   A confirmation dialog box appears:



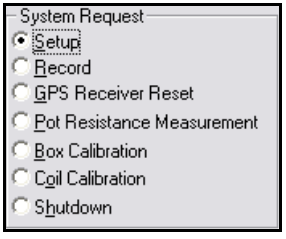
3. Click **OK**.

Changing operational mode (WinHost)

Once you've set up the parameters for your data acquisition (or calibration of instrument or sensors), you can control the operation of the instrument using WinHost.

To change operational mode:

- In the **System Request** area at the top left of the main window, select the mode you want and answer **Yes** in the confirmation dialog box.



The MTU changes mode immediately.

If you selected **Record** mode and the current time is within 12h after the **Start Time**, recording will begin immediately.

Measuring electrode resistance

Beginning with firmware version 3112F, the MTU is capable of measuring the contact resistance of the porous pot electrodes. The measurement is performed automatically at the beginning of each acquisition. You can also perform a measurement manually.

The resistance measurement takes approximately one minute in the default configuration, but you can lengthen the duration of measurement by changing the timing multiplier parameter, PZLT. Each integral increment of PZLT adds approximately 30 seconds to the duration of the measurement.

You can also specify a maximum acceptable resistance in the parameter MAXR. If the measurement on any electrode exceeds the value of MAXR (in ohms), the LED on the MTU will warn you with six flashes after the alert flicker. (For more information on LED indications, see "Instrument status" on page 41.)

To set the duration of resistance measurement:

1. In WinHost or WinTabEd, click More....
2. From the **Parameter** list, select **PZLT**.
3. For minimum duration, set the **Value** to 1; for a longer duration, increase the **Value** to a higher number.
4. Click Apply.

To specify a maximum acceptable electrode resistance:

1. In WinHost or WinTabEd, click More....

2. From the **Parameter** list, select **MAXR**.
3. Change the **Value** to the maximum resistance you deem acceptable, in ohms, or to accept any resistance, change the **Value** to zero.
4. Click Apply.

To measure electrode resistance manually:

1. If the instrument is not in Setup mode, then in the **System Request** area select **Setup**.
2. In the **System Request** area, select **Pot Resistance Measurement**.

Monitoring the MTU during acquisition (WinHost)

The WinHost program provides an **Information Parameters** dialog box to allow you to monitor various aspects of the instrument's operation while it is acquiring data or performing a calibration:

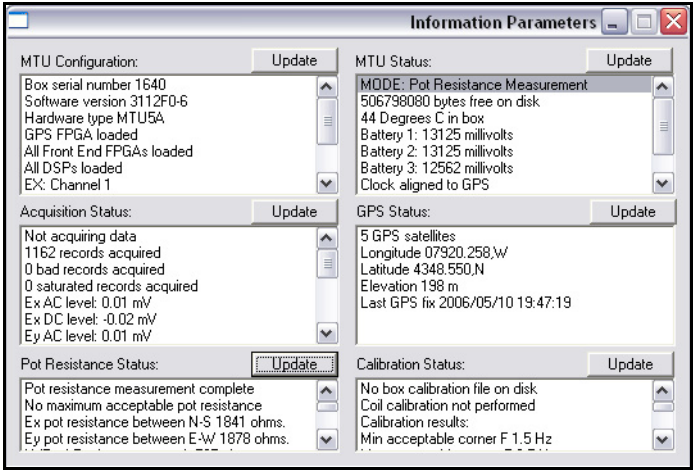


Fig. 3-4: The **Information Parameters** dialog box.

Each of the six panes in the dialog box provides information on various aspects of the instrument status. Some of the information is intended only to help Phoenix support staff troubleshoot problems. However, the remaining parameters are valuable indicators of how your equipment is performing.

To monitor an MTU:

1. From the command buttons on the right of the main window, click MTU Status.

   The **Information Parameters** dialog box appears.

2. Scroll up and down in each pane as necessary to see all of the information. Parameters of particular interest include:
   - Number of GPS satellites acquired (a minimum of 4 must be acquired at least briefly before site or calibration data can be recorded).
   - Current Mode of the instrument—Standby or Record.
   - Remaining free space on the CompactFlash card.
   - Instrument's internal temperature (do not allow the temperature to reach 60°C).
   - Battery voltages.
   - Acquisition Status, especially the number of saturated records as a percentage of acquired records. (More than 1–2% indicates a problem—probably gain settings that are too high.)
   - Pot Resistance Status, which can help identify faulty electrodes or connections.

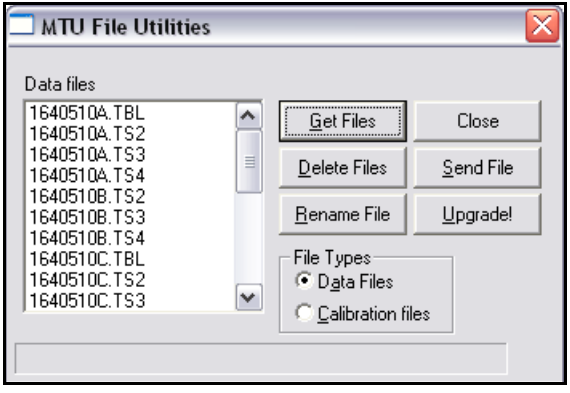
Working with files (WinHost)

WinHost includes a facility for transferring files to and from the instrument. This feature allows you to transfer startup files, data and calibration files, and if necessary, firmware files between the instrument and the PC.

To transfer files to the instrument:

1. From the command buttons on the right side of the main window, click MTU Files.

The **MTU File Utilities** dialog box appears:



2. Click Send File.

   A standard Windows file selection dialog box appears.

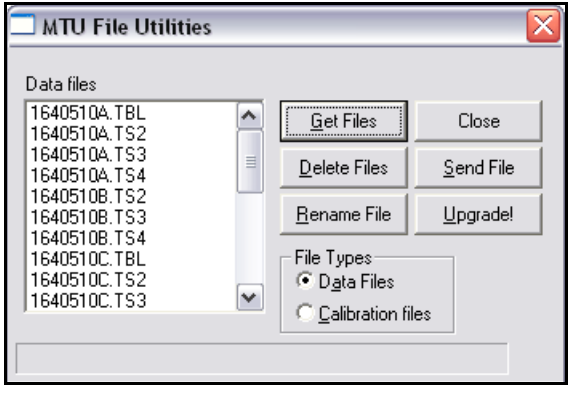
3. Navigate to the folder containing the file you want to transfer.

4. Select the file and click Open.

To transfer files to the PC:

1. From the command buttons on the right side of the main window, click MTU Files.

   The MTU File Utilities dialog box appears:



2. In the **File Types** area, select the type of file (data or calibration) that you want to transfer.
3. From the list of files on the left, select the file(s) you want to transfer.
4. Click Get Files.

A confirmation dialog box appears.

5. Click **Yes**.

   A standard Windows **Save As** dialog box appears.

6. Navigate to the folder where you want to save the file and click Save.

To delete files from the instrument:

- Follow the procedure just given for transferring files, but click Delete Files in step 4.

Managing files on the internal CF card

Each instrument operates with two CompactFlash cards. One is removable and is used for storing your data and calibration files. The other is internal, non-removable, and is intended for instrument firmware and temporary files.

"Phantom" calibration files. The internal card contains a `\CAL` directory, which is where calibration files are created; they are copied to the external CF card after a calibration ends successfully. Calibration files on the internal card are also copied to the external card each time the instrument is powered on. An existing calibration file on the internal card is erased only when you begin another calibration of the same sensor.

This arrangement can sometimes lead to the appearance of "phantom" files—calibration files for sensors other than those you have just calibrated. These files are left over from some previous sensor calibration, perhaps from an earlier survey with different sensors, or possibly from testing after repair by Phoenix. You can ignore these files or delete them using the procedure described on page 109.

Internal data files. If an instrument acquires data when the external CF card is missing, it will create a `\DATA` directory on the internal card and store the time series files there. However, storage space on that card is very limited. The card will quickly fill to capacity, aborting the acquisition and possibly preventing further calibrations. You should delete these files (copying

them to your PC first if you want to keep the data), using the procedure described next.

To transfer or delete files from the internal CF card:

1. With the instrument powered off, remove the external CF card.
2. Ground all the E-line terminals to the GND terminal.
3. Connect a PC to the instrument.
4. Power the instrument on.
5. Start WinHost.
6. Follow the instructions for "Working with files (WinHost)" on page 106 to transfer or delete the files. (The files listed in the **MTU File Utilities** dialog box will be the ones on the internal CF card.)

Upgrading instrument firmware (WinHost)

From time to time, Phoenix releases new versions of operating firmware for the MTU/MTU-A. You can use WinHost to perform the upgrade, in a four-step process:

1. Prepare for the upgrade, including preserving your data.
2. Transfer the new firmware to the instrument.
3. Verify the upgrade.
4. Test the instrument.

Warning! An upgrade of instrument firmware will erase any data and calibration files on the instrument. Transfer your data to a PC before performing an upgrade.

Preparing to upgrade

Before transferring the new firmware to the instrument, you should determine the current

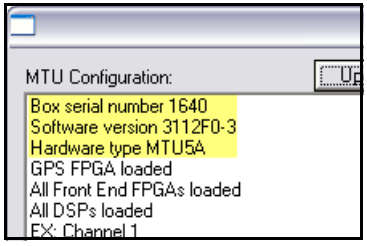
instrument status, and preserve any data files that are on the CompactFlash card.

To prepare for the upgrade:

1. With the instrument connected to the PC and powered on, launch WinHost and ensure that the instrument is in Setup mode.
2. Follow the instructions on page 107 to transfer any data files from the instrument to the PC.
3. From the command buttons on the right of the main window, click MTU Status.

   The **Information Parameters** dialog box appears.

4. From the list under **MTU Configuration**, make a written record of:
   - Box serial number
   - Software version
   - Hardware type



5. Close the **Information Parameters** dialog box.

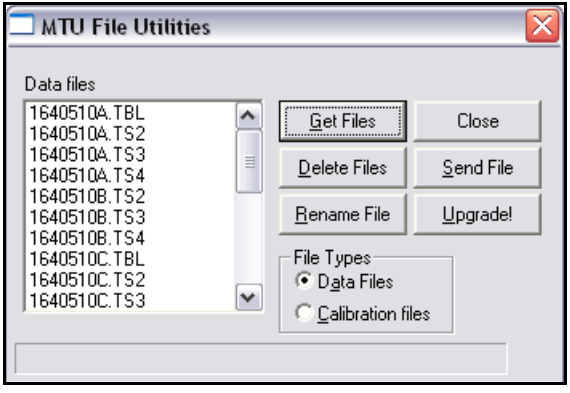
Performing the upgrade

The upgrade process is similar to that for transferring files from the PC to the instrument.

To upgrade the instrument:

1. From the command buttons on the right of the main window, click MTU Files.

The **MTU File Utilities** dialog box appears:



2. Click Upgrade!.

A Warning dialog box appears.

3. Click **Yes** to continue (or **No** to cancel).

A standard Windows file selection dialog box appears.

4. Navigate to the folder containing the upgrade file you want to transfer. The file name must correspond to the Hardware type that you wrote down when preparing to upgrade. For example, if your Hardware type is MTU52, find the `MTU52.upg` file.

5. Select the file and click Open.

The **MTU Software Upgrade** dialog box appears.

6. Click **OK**, and watch the LED on the MTU, which will perform two reboots. Wait for the steadily lit LED, indicating that the upgrade is complete.
7. Close the **MTU File Utilities** dialog box.

Verifying the upgrade

To be sure that the upgrade was successful, you should check the instrument status again.

To verify the upgrade:

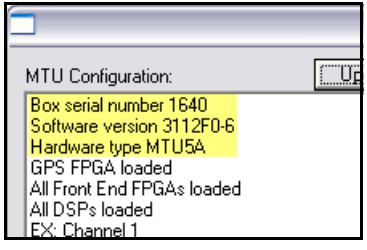
1. From the command buttons on the right of the main window, click Get All Settings.

   A message box appears:

2. Click **OK**.
3. From the command buttons on the right of the main window, click MTU Status.

   The **Information Parameters** dialog box appears.

4. From the list under **MTU Configuration**, ensure that the Box serial number and Hardware type are the same as what you noted when preparing to upgrade.



5. Verify that the Software version has changed to the new version number.
6. Close the **Information Parameters** dialog box.

Testing the instrument

Now that the software is current, recalibrate the instrument and test it for normal operation.

Chapter 4

Programming an MTU-A using WinHost and WinTabEd

Phoenix Audio Magnetotellurics Units (designated with an "A" in the product name) can acquire data in both the MT and AMT frequency ranges, depending on the type of sensor used (MTC-30 for AMT, MTC-50 for MT). This chapter explains how to set up an MTU-A for MT and AMT data acquisition using WinHost or WinTabEd.

The content in this chapter assumes that you have read Chapter 3 to learn how to launch the programs and to become familiar with the parameters and procedures that are common to MT and AMT.

Differences between MT and AMT

A number of key differences between AMT and MT must be taken into account when setting up parameters for data acquisition. This section explains these differences.

WinTabEd and WinHost

Different versions of WinTabEd and WinHost exist for use with MTU versus MTU-A instruments. The versions are identified on the Programs menu as Phoenix Geophysics MTU Host Software or Phoenix Geophysics MTU-AMT Host Software. Each program is compatible with only one instrument type. **Be sure that you use the correct program for your equipment.**

Frequency ranges

Phoenix MTU-A instruments can acquire data in four frequency bands (numbered 2 through 5), each with different characteristics. For AMT data, the instruments acquire Bands 2, 3, and 4. For MT data, the instruments acquire Bands 3, 4, and 5.

The lowest frequencies are sampled continuously. To keep files to reasonable sizes, the two higher frequency bands are sampled only periodically. Beginning with firmware version 3112F, two new sampling schemes are available: "Dense AMT", which samples only Band 2 (periodically) and Band 3 (continuously), and "AMT-Compatible MT" in which **High Start Time** and **High End Time** affect only the highest band, not the usual *two* highest bands.

The user defines a time slot of duration between 0 and 3600s for periodic sampling. (This corresponds to the time slot duration of 0 to 59 *minutes* in an MTU.) The MTU-A samples the two higher frequency bands alternately at the beginning of each time slot in a pattern that repeats each hour. (Regardless of the defined duration, a new time slot pattern begins at the start of each UTC hour.)

Figures 4-1 to 4-3 illustrate the way the bands are sampled:

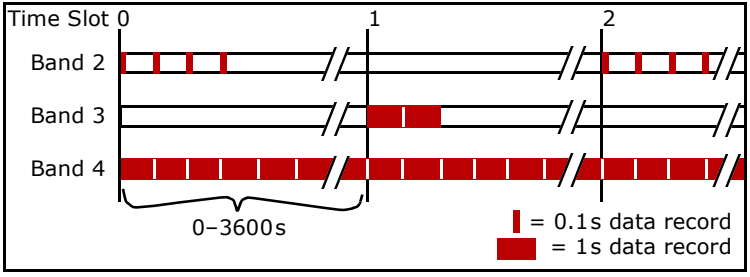


Fig. 4-1: MTU-A sampling scheme (AMT data and AMT-compatible MT data).

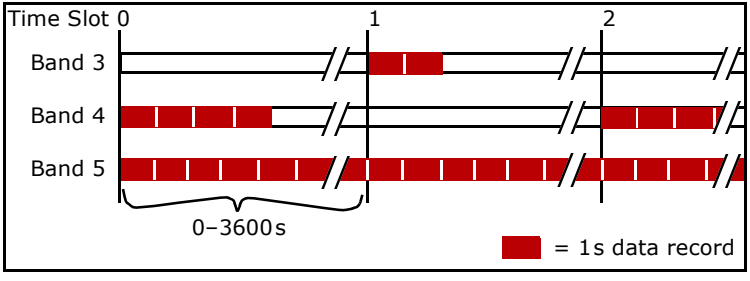


Fig. 4-2: MTU-A sampling scheme (MT data).

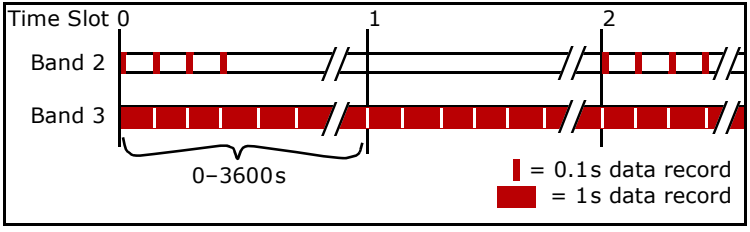


Fig. 4-3: MTU-A sampling scheme ("Dense" AMT data).

Band 2 refers to frequencies up to about 10 800 Hz. This band is sampled at 24 kHz, with each record starting on the UTC second for a duration of 0.1 s (2400 scans). Up to four such records can be captured at the beginning of each even-numbered time slot. A higher number improves data quality in the frequency range 1–3 kHz where signal strength is very low, but also increases file size. Band 2 is not used when the MTU-A acquires MT data because only the AMTC-30 sensor is designed to acquire this range.

Band 3 refers to frequencies up to about 1000 Hz. This band is the intermediate range in AMT soundings and the high range in MT soundings. Band 3 is sampled at 2.4 kHz, with each record starting on the UTC second

for a duration of 1s (2400 scans). With MT and AMT data types, up to two such records can be captured at the beginning of each odd-numbered time slot. With the Dense AMT data type, Band 3 is recorded continuously.

Band 4 refers to frequencies up to about 60Hz. This band is the low range in AMT soundings and the intermediate range in MT soundings. In AMT soundings, Band 4 is sampled continuously at 150Hz. In MT soundings, Band 4 is sampled at 150Hz, with each record starting on the UTC second for a duration of 1s (150 scans). Up to 16 such records can be captured at the beginning of each even-numbered time slot.

Band 5 refers to frequencies up to about 6Hz. This band is the low range in MT soundings and is not used in AMT soundings. Band 5 is sampled continuously at 15Hz.

Note A Phoenix MTU-A is shipped with either a 192MB or 512MB Compact Flash card.

The 192MB card is large enough to acquire about 12 hours of continuous data at settings of four records of Band 2 and two records of Band 3 per 60s time slot.

The 512MB card is large enough to acquire about 6 hours of continuous data at settings of four records of Band 2 and two records of Band 3 per 5s time slot.

Combining instrument types. When an MTU sampling schedule is set to V5-2000, its sampling rate is compatible with that of the MTU-A. The shaded areas in Table 4-1 show this compatibility. If you intend to combine MTU and MTU-A instruments in a survey, be sure to use the V5-2000 setting in the MTU instruments. (See “Sampling schedule” on page 100.)

Table 4-1: MTU/MTU-A sampling rates (number of samples per one-second record).

Band	MTU			MTU-A	
	V5 Compatible		V5-2000	Data Type	
	50Hz	60Hz		MT	AMT DAMT[1] ACMT
2	—	—	—	—	24 000
3	2560	3072	2400	2400	2400
4	320	384	150	150	150[1]
5	24	24	15	15	—

[1] In Dense AMT mode, Band 4 is not sampled.

Gain

Three gain settings are available on both the MTU and the MTU-A: Low, Normal, and High. Table 4-2 on page 119 shows the gain factor that is applied at each setting.

Table 4-2: Gain Factors

Setting	MTU		MTU-A
	E Gain	H Gain	E and H Gain
Low	10	3	1
Normal	40	12	4
High	160	48	16

On an MTU, the gain settings apply much larger factors than on an MTU-A. This means that whereas an MTU gain is almost never set to High, an MTU-A gain is almost always set to High, unless saturations or other problems occur.

Filters

The input low pass filter can be optimized for MT, AMT, or broadband acquisition, over a wide range of electrode resistances. For AMT, an optional VLF (Very Low Frequency radio signals) trap can be added.

Coupling

When set to AC Coupling, the MTU-A uses a high pass filter with a corner frequency of 2Hz. This means that for AMT soundings, either AC or DC coupling may be appropriate depending on the depth of investigation. However, for MT soundings, the MTU-A should be set to DC coupling for both E and H channels—AC Coupling would attenuate the frequencies of interest in MT.

Setting frequency parameters

This section explains the settings for data type (AMT or MT), frequency bands, and sample interval ("time slot").

Setting the Data Type

An MTU-A can acquire AMT data (frequency Bands 2, 3, and 4) using AMTC-30 sensors, or MT data (Bands 3, 4, and 5) using MTC-50 sensors.

Two new data types were introduced with instrument firmware 3112F: Dense AMT (DAMT) and AMT-compatible MT (ACMT). Dense AMT is useful when...

AMT-compatible MT is useful when...

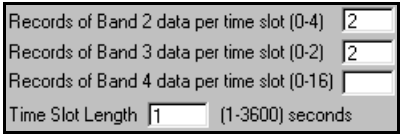
You must set the data type parameter in order to optimize the instrument circuitry for your purpose.

To set the Data Type:

- In the **Data Type** area of the main window, select either **AMT** or **MT**.

Setting sampling parameters

The four fields in the lower left corner of the WinHost main window control the number of records per time slot and the duration of the time slot.



Setting sampling parameters for AMT. If the Data Type is AMT, the third field will be unavailable (it will appear dimmed), since it is not used in AMT soundings.

To set the number of samples per record (AMT):

1. Set **Records of Band 2 data per time slot (0-4)** to a value between 1 and 4.
2. Set **Records of Band 3 data per time slot (0-2)** to a value of 1 or 2.

Setting sampling parameters for MT. If the Data Type is MT, the first field will be unavailable (it will appear dimmed), since it is not used in MT soundings.

To set the number of samples per record (MT):

1. Set **Records of Band 3 data per time slot (0-2)** to a value of 2.
2. Set **Records of Band 4 data per time slot (0-16)** to a value of 4 (preferably 8) to 16.

Setting the time slot length. The time slot is the duration between periodic sampling of intermediate and high frequencies. The shorter the time slot, the more often records will be captured, and the larger the data files will become. The time slot can be as long as 3600s. For lengthy AMT soundings, a higher value is necessary depending on the capacity of the Compact Flash card; for MT soundings, a value from 60 to 300s (1 to 5min) is typical.

To set the time slot length for AMT:

- For short soundings (less than an hour) enter a value of 1 or 2.
- For longer soundings, enter a value from 60 to 3600.

To set the time slot length for MT:

- Enter a value from 60 to 300s.

Note When setting parameters for a reference site and survey sites, make sure that the time slot length and sampling parameters are identical in all instruments. Data from a reference site cannot be used if its parameters differ from those of the survey sites.

If you are combining MTU and MTU-A instruments in a survey, be aware that the time slot units are different: an MTU time slot is defined in minutes, whereas an MTU-A time slot is defined in seconds.

Setting acquisition times

Note All times are UTC, in the format HH:MM:SS (hours:minutes:seconds). To specify a date, use the format YYYY/MM/DD (year/month/day) followed by a space, then the time (YYYY/MM/DD HH:MM:SS).

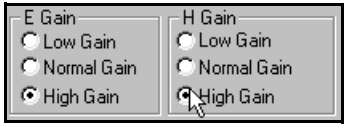
Set acquisition times on the MTU-A exactly as for an MTU, but for AMT data, bear in mind that the signal strength in that frequency range is about 10 times greater at night than during the day. You may want to acquire Band 2 data for a subset of the total duration by specifying a **High Start Time** and **High End Time** so that this Band is acquired after sunset. (See "Setting acquisition times" on page 96.)

Setting gain parameters

As explained under the heading "Gain" on page 119, the gain factors in the MTU-A differ from those in the MTU. High and Normal settings are used more often than Low.

To set E and H Gain for AMT or MT:

- Select **High Gain** for both E and H. If initial soundings contain many saturated records (>2%), reduce the settings to **Normal Gain**. In extreme conditions, it may be necessary to select **Low Gain**.



Setting coupling parameters

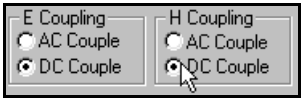
The coupling setting governs the high pass filter, corresponding to DC coupling (no filter) or AC coupling with a 2 Hz corner frequency.

To set E and H Coupling for AMT:

- If the frequency range you are investigating is entirely above 1 Hz, select **AC Couple**.
- If the frequency range you are investigating extends below 1 Hz, select **DC Couple**.

To set E and H Coupling for MT:

- Select **DC Couple**:



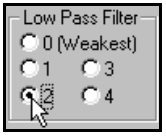
Setting low pass filter parameters

The low pass filter (LPFR parameter) allows optimization for MT, AMT, or broadband, in the presence or absence of VLF noise and over a wide range of electrode resistance. The filter should be set to the lowest value that effectively reduces noise, because phase shift error in the higher frequencies increases with the strength of the filter.

See "Low pass filter graphs" on page 126 for the effects of various filter settings.

Setting the low pass filter for AMT or MT

For data acquisition without VLF trapping, use the main window **Low Pass Filter** settings.



The choices from 0 (weakest) to 4 (strongest) optimize the MTU-A for data acquisition at successively lower cutoff frequencies.

When strong VLF radio signals are present (within approximately 150km of a transmitter), a special VLF filter that provides a sharper cutoff between 10kHz and 20kHz may improve AMT data quality. (VLF filtering is not appropriate for MT data.)

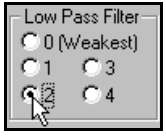
To determine the best value for a given electrode resistance, see "Low pass filter graphs" on page 126.

To set the low pass filter:

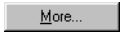
1. Determine the best filter value for the expected or measured electrode resistance.

Tip For AMT acquisition up to 10kHz with electrode resistance of a few hundred ohms, a filter value of 2 is a good first choice.

2. Select the appropriate **Low Pass Filter** value:



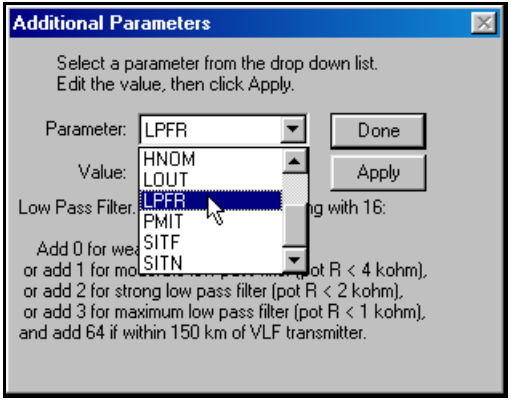
To turn on the VLF filter:

1. Set the low pass filter as just described.
2. In the WinHost or WinTabEd main window, click 

.

   The **Additional Parameters** dialog box appears.

3. In the **Parameter** list, select **LPFR**:



4. Add 64 to the **Value** and click Apply.
5. Click Done to return to the main window.

To turn off the VLF filter:

1. In the WinHost or WinTabEd main window, click More....

   The **Additional Parameters** dialog box appears.

2. In the **Parameter** list, select **LPFR**.
3. Change the **Value** to 0 and click Apply.
4. Click Done to return to the main window.
5. Click again on the Data Type and Low Pass Filter that you want to use. (You must click on at least one of these choices, even if they already reflect your intention—otherwise the LPFR parameter will remain set to 0.)

Setting the low pass filter for broadband

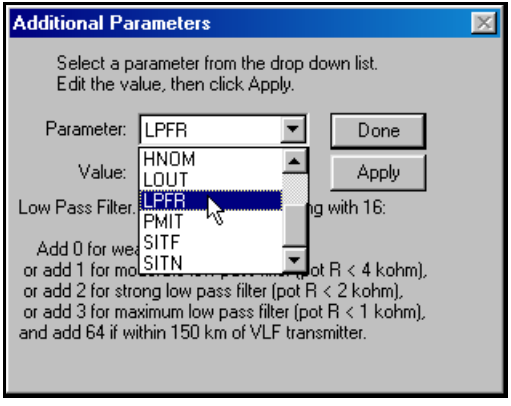
The MTU-A can be configured to acquire data in the range above 10kHz ("broadband") by disabling the feedback function. This is done by manually setting a value for the LPFR byte.

To set the low pass filter for broadband:

1. In the WinHost or WinTabEd main window, click More....

The **Additional Parameters** dialog box appears.

2. In the **Parameter** list, select **LPFR**:



3. Change the **Value** to 0 (VLF filter off) or to 64 (VLF filter on) and click Apply. (For best results with broadband, do not use any filtering: set LPFR to 0.)

4. Click Done to return to the main window.

Note After you set the low pass filter for broadband, **do not click on either the Data Type or Low Pass Filter options on the main window**. Doing so will set the low pass filter to the default values for the chosen data type, and the instrument will not be optimized for broadband.

Low pass filter graphs

Figures 4-5, 4-6, and 4-7 show frequency response versus electrode resistance with various Low Pass Filter settings. The numbers beside the data point symbols in the legends correspond to the the cutoff frequency selected in the **Low Pass Filter** area of the main window.

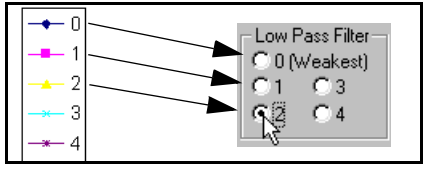


Fig. 4-4: Correspondence between graph legend and Low Pass Filter setting.

The filter should be set to the lowest value that effectively reduces noise, because phase shift error in the higher frequencies increases with the strength of the filter.

Values greater than 4 are shown on the graphs for completeness, although data acquired with such settings are generally not useable.

Note Because the calibration function of the data processing software attempts to correct for the filter effects, it is still possible to acquire useable data at frequencies above the curves on the graphs.

Figures 4-5 and 4-6 contrast the effect of no feedback versus a feedback corner frequency of 10 kHz. Feedback provides a means to optimize the MTU-A for AMT or MT soundings, and is enabled when the instructions for setting low pass filter parameters are followed.

Figure 4-7 shows the effect of turning off the VLF trap; this is the default setting of the MTU-A.

Figures 4-5 and 4-6 also demonstrate that for electrode resistance in the range of 1–4 kΩ, only values of 0 or 1 for the low pass filter will yield satisfactory phase shift and/or amplitude attenuation at AMT frequencies. With lower electrode resistance (<1 kΩ), a stronger filter setting of 2 or 3 may be practical, but stronger filter settings cap the practical frequency range at about 1 kHz.

Figure 4-8 shows the effect of the filter settings when the data type is MT.

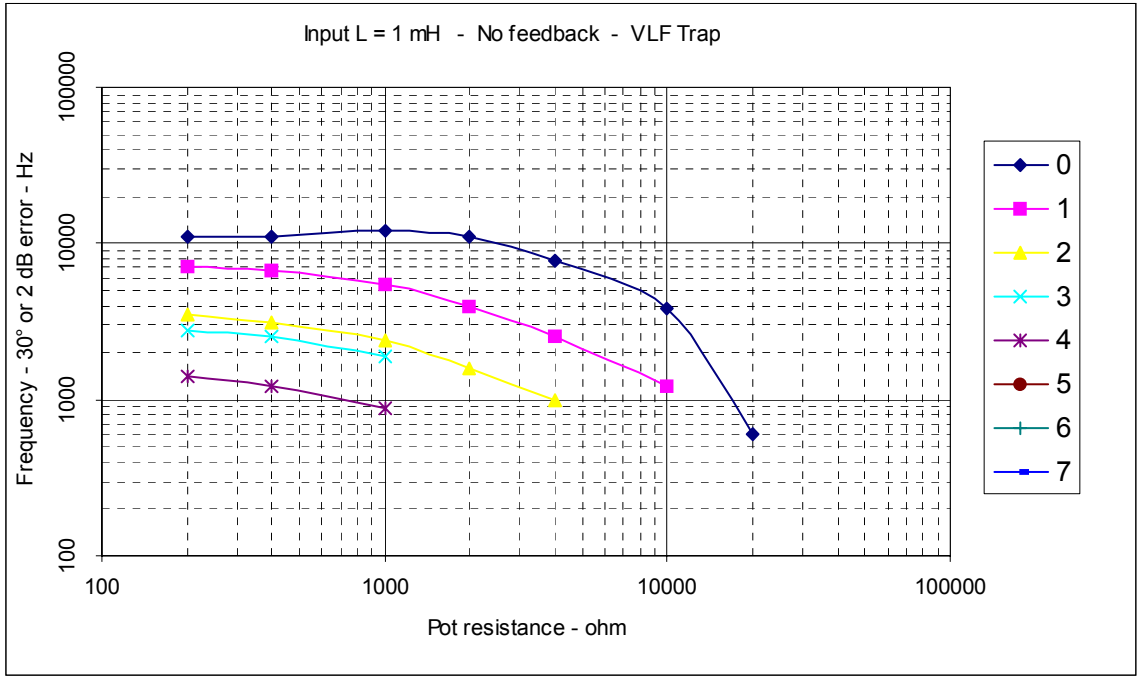


Fig. 4-5: Response curves for broadband (no feedback corner frequency) with VLF trapping On.

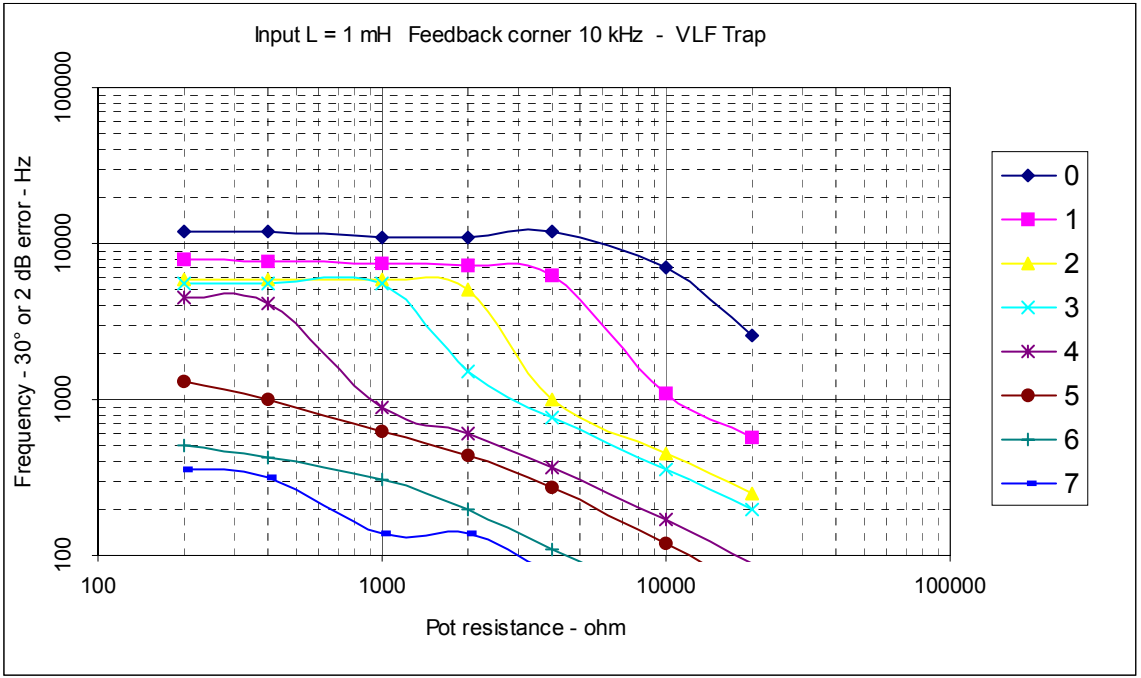


Fig. 4-6: Response curves for AMT (10kHz feedback corner frequency) with VLF trapping On.

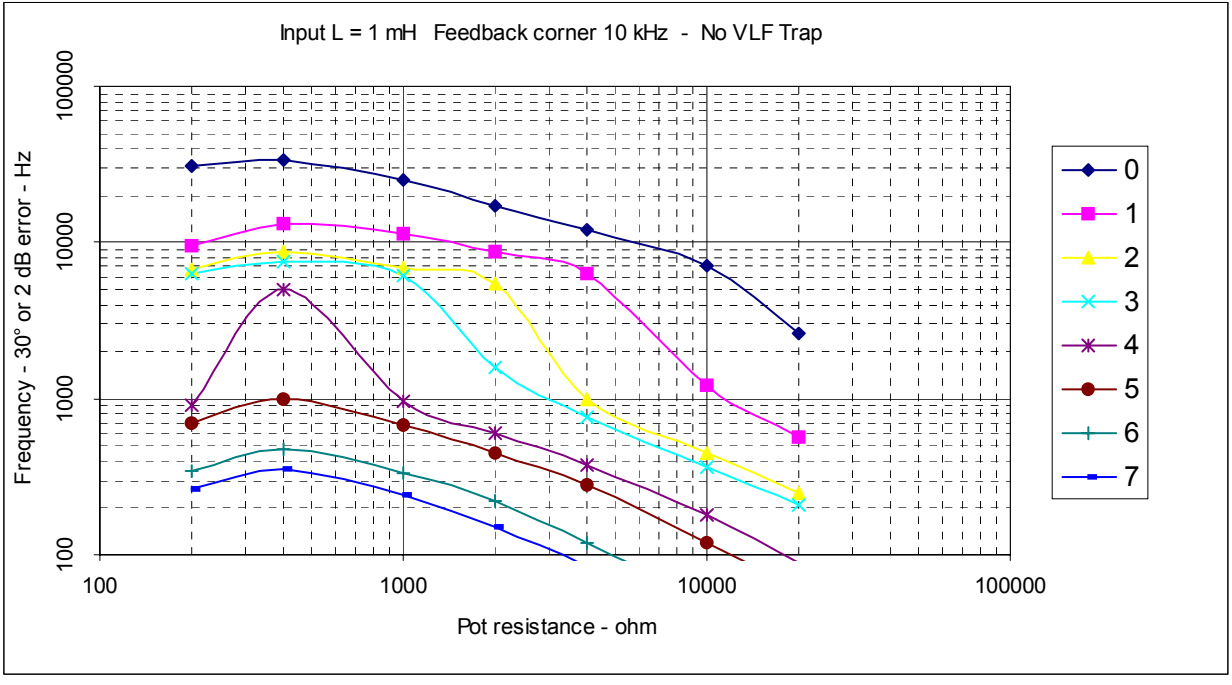


Fig. 4-7: Response curves for AMT (10kHz feedback corner frequency) with VLF trapping Off.

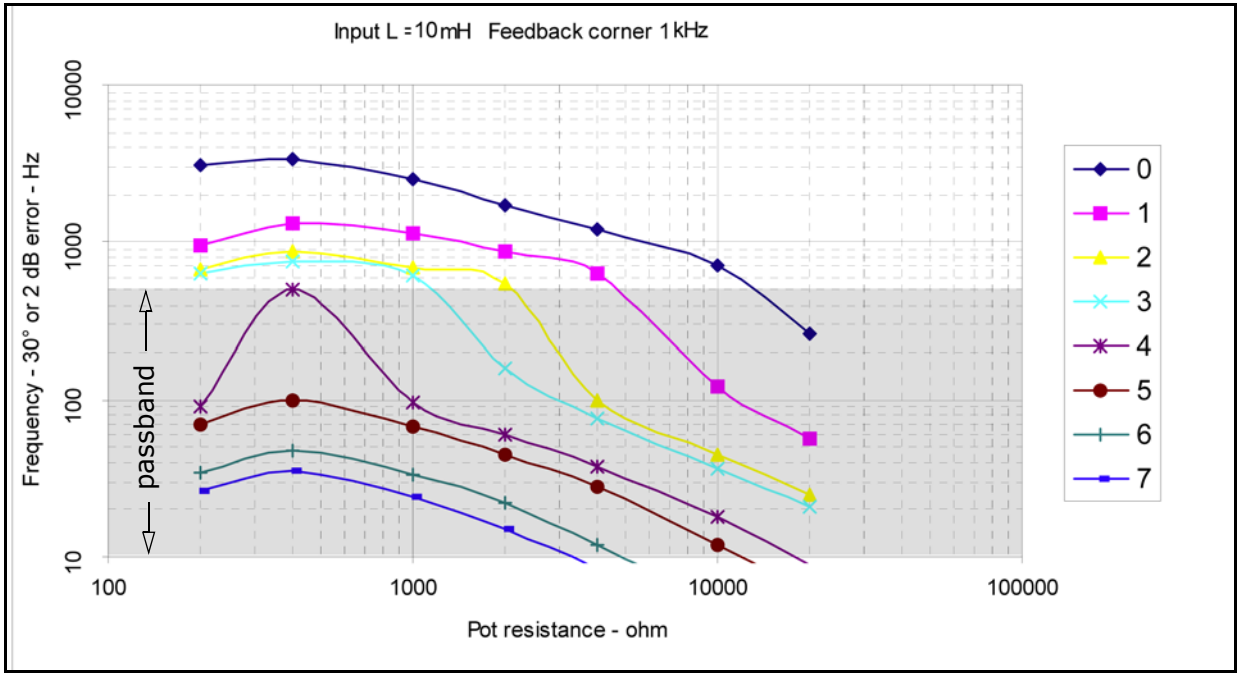


Fig. 4-8: Response curves for MT (1kHz feedback corner frequency) with VLF trapping Off.

Setting sensor calibration parameters

Calibration of Phoenix sensors is explained in Chapter 2, page 54. If you are using sensors from another manufacturer, contact Phoenix for instructions on setting the calibration parameters.

Setting additional parameters

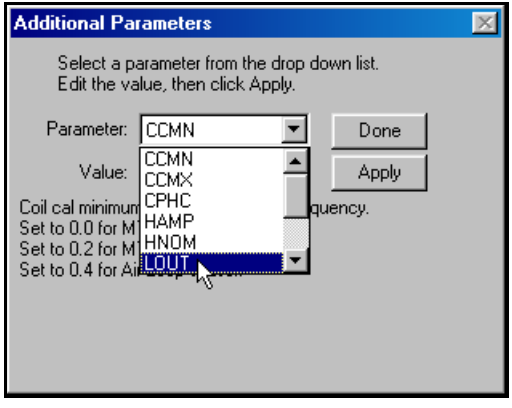
Several additional parameters can be set using WinHost v.6 and WinTabEd v.5. These parameters allow you to record the Permitter and Layout Chief names and to reset the GPS receiver (WinHost).

Layout Chief and Permitter

Layout Chief and Permitter are text fields only and do not affect data acquisition or processing. They are included for ease of record-keeping, and if entered in the STARTUP.TBL, do not have to be added repeatedly later during data processing.

To set Layout Chief and Permitter names:

1. In the WinHost or WinTabEd main window, click More....
2. In the **Parameter** list, select **LOUT**:



3. Type up to 12 characters of the Layout Chief's name and click Apply.

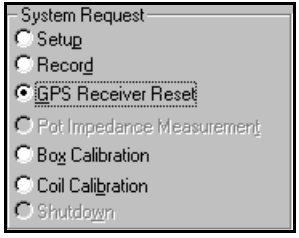
4. In the **Parameter** list, select **PMIT**.
5. Type up to 12 characters of the Permitter's name and click Apply.
6. Click Done to return to the main window.

Resetting the GPS receiver

If an instrument has been moved a great distance since it last achieved satellite lock, it can take up to 30 min to acquire satellite signals. Resetting the GPS receiver can significantly reduce this delay.

To reset the GPS receiver:

1. In the **System Request** area, select **GPS Receiver Reset**:



The instrument immediately resets the GPS receiver.

2. Select **Setup** to continue.

Appendix A

This appendix contains a sample Layout Sheet as used by Phoenix survey personnel. You can design and print your own Layout Sheets, or order a supply from Phoenix, printed on the same waterproof, tear-proof paper as this User Guide.

Sample layout sheet

Obtaining a supply of Layout Sheets

To purchase Layout Sheets from Phoenix, send us your order using these part numbers:

Table A-1: Layout Sheet part numbers

Content	Part Number
Binder only	7355
30 Layout Sheets for left-handed writers	7356
30 Layout Sheets for right-handed writers	7357
Binder plus 30 left-handed sheets	8081
Binder plus 30 right-handed sheets	8082

Phoenix Geophysics Limited MT Survey Layout Sheet © 2003

Project: THREE RIVERS **Site #:** TRV-043a **Date:** 2003/MAR/18

MTU- 5A **SN:** 1413

North Ref.: Magnetic ☑ True ☐

Declination: −10 °

Latitude: 54:53.785 N

Longitude: 35:00.409 E

Flash Memory #: 4

GPS Antenna #: 2

GPS Cable #: 2

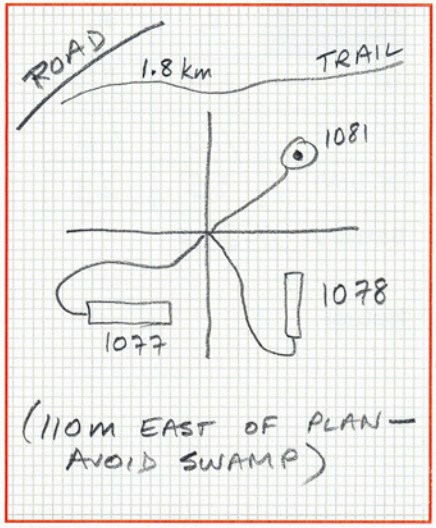
Battery #: 8 **V:** 12.9

Battery Cable #: 8

Compass SN:

E Gain: NORM **H Gain:** HIGH

Low Pass Filter: 2



Dipoles	E_x	E_y
Length (m)	100	99
kΩ	1.8	2.2
AC (mV)	1.0	1.0
DC (mV)	57	22
Azimuth	0°	

Sensors	H_x	H_y	H_z
MTC-50			
AMTC-30	1078	1077	1081
Azimuth	0°		
Cable #	6	11	7

Electrodes	kΩ to Gnd	Distance to MTU (m)	Incline θ	Pot #	Cable #
Gnd	—		—		
N	2.5	50			
S	2.0	50			
E	2.0	50			
W	2.3	49			

GPS lock achieved: ☑

Technician: _____ **Assistant:** _____

Status on equipment retrieval:

Dipoles	E_x	E_y
kΩ	1.9	2.3
AC (mV)	1.0	1.0
DC (mV)	55	23

Battery: 11.3 **V**

Notes:

Appendix B

Sample equipment checklist

Phoenix Geophysics Limited
MT 5-Component Survey Equipment Checklist

	Use one column for each scheduled site			
Instrument & Components	**ID Number**	**ID Number**	**ID Number**	**ID Number**
MTU Box				
Flash Memory				
Battery				
Battery Cable				
GPS Antenna				
GPS cable				
Pot 1				
Pot 2				
Pot 3				
Pot 4				
Pot 5				
Sensor 1				
Sensor 2				
Sensor 3				
Airloop				
Sensor cable 1				
Sensor cable 2				
Sensor cable 3				
3-way Sensor connector				
E-line cable 1				
E-line cable 2				
E-line cable 3				
E-line cable 4				
Ground pot cable				
Parallel cable, PC				
PC				

Tools	**Qty Req'd**	**Qty Loaded**
Shovel		
Level		
Electrician's Tape		
Coloured Tape		
Ranger Compass		
Brunton Compass		
Brunton Mount		
Brunton Tripod		
Cable Reel & Cable		
Measuring Tape		
Wire stripper/cutter		
Water		
Salt		
Bentonite or granular clay		
Layout Binder & Sheets		
Pencils		
Map		
Analog Ohmmeter		
Digital Voltmeter		
GPS Receiver		

Appendix C

Parallel and White Noise Testing

This appendix explains how to set up the folowing tests in the field or labratory:

- parallel noise test
- white noise test
- parallel white noise test

About noise tests

Three types of tests can be performed, using either natural or artificial signals. Artificial signals are provided by the Phoenix Dual Random Noise Generator.

About the Phoenix Dual Random Noise Generator

Phoenix manufactures a Dual Random Noise Generator (WN-2) specifically for testing System 2000 and System 2000.*net* receivers. Two separate noise generators are contained within the case, with outputs marked as E_x and H_y for one generator and as E_y and H_x for the other generator.

Specially configured cables are provided to connect the WN-2 to the receiver and to connect input terminals in parallel. The cable that connects the H_y terminal on the WN-2 to the MAG INPUT or AUXILIARY terminal of the receiver is wired to provide the same signal to both the H_y and H_z channels.

Controls. A rotary control on the WN-2 selects high frequency output (10kHz–1Hz), low frequency output (500Hz–0.002Hz or 500s), or turns the unit off. Use the HI setting for testing the AMT data type. Use the LO setting for testing the MT data type. Turn the unit OFF when not in use.

Fig. C-1: WN-2 Dual Random Noise Generator.

Power. The generator is powered by a 9V battery. A fresh battery will last for about 24h of use.

Check the battery voltage before each noise test. Turn the output to either HI or LO and probe the built-in battery test terminals with a voltmeter. If the voltage is not at least 7V, replace the battery before continuing.

To replace the battery:

1. Remove the four screws from the top of the WN-2 enclosure and remove the cover.
2. Replace the spent battery with a fresh 9V battery.
3. Replace the cover and the four screws.

Cables. Three cables are supplied with the WN-2. The two-way mag input cable is internally wired so that the H_y signal is duplicated on the H_z input. The E_x and E_y cables have red and black wires ending with two and three lugs, respectively. This configuration allows flexibility in setting up the different tests.

Note
The instructions for setting up the tests sometimes specify that more than one lug be connected to a terminal. The purpose is to prevent dangling wires from touching and causing short circuits.

Purposes of noise tests

Sensor noise floor. To test the noise floor of sensors (telluric or magnetic), conduct a parallel noise test in the field using the natural MT signal.

Transfer function of receiver. To test the transfer function of an instrument, conduct a white noise test in the laboratory or field, using a Phoenix WN-2 Dual Random Noise Generator.

Input amplifiers. To test the noise floor of the instrument's front-end board amplifiers, conduct a parallel white noise test in the laboratory or field, using a Phoenix WN-2 Dual Random Noise Generator.

Duration of tests

All tests should acquire data for at least two hours. The longer the test, the lower the frequency for which results are valid. A two hour test is long enough to give results down to 0.002Hz (500s).

Calibration

Calibrate the instrument before conducting any noise tests. Before conducting a parallel noise test, also calibrate the sensors. The calibration files are essential for data processing.

Setting up a parallel noise test

Parallel noise tests to check the noise floor of sensors should be conducted in the field, under normal survey conditions.

The physical setup is similar to a normal site setup except for the placement of electrodes and/or sensors. You can test just the E-channels, just the H-channels, or both.

Warning

If you test only the H-channels, connect all of the E-line terminals to the instrument ground. The terminals are connected directly to amplifier inputs, and open circuits produce steady-state saturation.
Failure to ground the E-line terminals may damage the receiver and void your warranty.

Preparing a Startup.Tbl file

Before you begin the test, prepare a Startup.Tbl file on the CompactFlash card that will be used. For a parallel noise test, the settings for filters, gains, etc. should be the same as for data acquisition at the same site.

To set up a parallel noise test:

1. Set up the calibrated receiver and sensors as for a regular data acquisition, but place the electrodes on two parallel lines about 10cm apart, and place the coil sensors about 1.5m apart, at right angles to

the E-lines. (See Fig. C-2.) The electrodes can be buried in two large holes or in four separate holes.

2. Make sure the instrument is properly grounded, and if you are testing only magnetic sensors, ground all the E-line terminals.
3. Acquire data for at least two hours.
4. Process the data as instructed in the *Data Processing User Guide*.

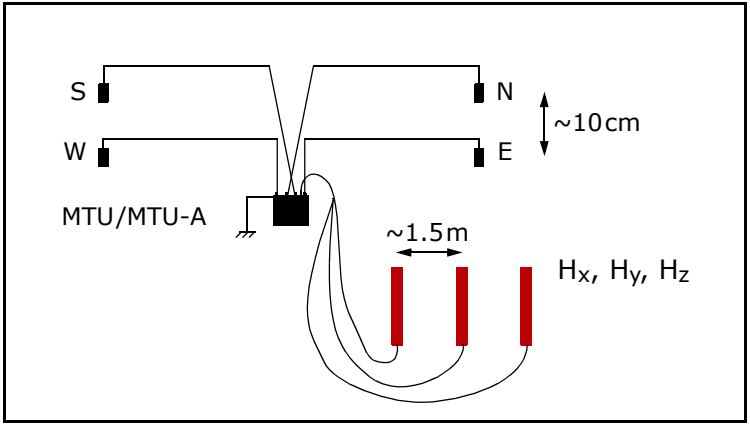


Fig. C-2: Setup for parallel noise test. (Battery and GPS antenna omitted for clarity.)

Setting up a white noise test

White noise tests to check the transfer function of an instrument can be set up in the field or indoors in a laboratory, as long as GPS signals can be aquired.

Preparing a Startup.Tbl file

Before you begin the test, prepare a Startup.Tbl file on the CompactFlash card that will be used.

To prepare a Startup.Tbl file:

1. Start WinHost.
2. Set the E_x and E_y dipole lengths to 1m.
3. Set the Low Pass Filter to 0 (Weak or Weakest).
4. For MT data, set all of the H sensor serial numbers to COIL0000.
5. For AMT data, set all of the H sensor serial numbers to AMTC0000.
6. Set appropriate acquisition times.
7. Save the file and load the card in the receiver.

To set up a white noise test:

1. Connect the calibrated receiver to a GPS antenna and a 12V power supply, but do not turn it on yet.
2. Using the special cable supplied with the WN-2, connect the E_X terminal of the WN-2 to the N and S terminals of the receiver: Connect all three lugs on the black wire to the S terminal and both lugs on the red wire to the N terminal. (See Fig. C-3.)

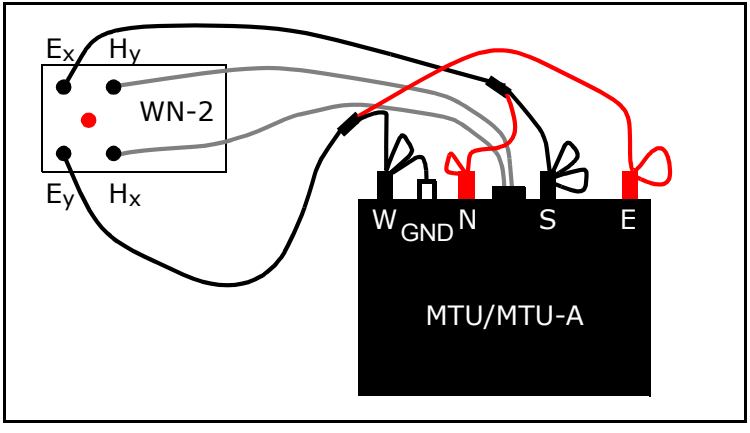


Fig. C-3: Setup for white noise test. (Battery and GPS antenna omitted for clarity.)

3. Connect the E_Y terminal of the WN-2 to the GND, E and W terminals of the receiver: Connect the lug at the end of the black wire to the GND terminal and the other two lugs to the W terminal. Connect both lugs on the red wire to the E terminal. (See Fig. C-3.)
4. Connect the H_X and H_Y terminals of the WN-2 to the MAG INPUT terminal of the receiver. (The cable wiring supplies the H_Y signal to the H_Z input as well.)
5. Turn on the receiver and set the WN-2 to LO for MT data or to HI for AMT data.
6. Acquire data for at least two hours.
7. Process the data as instructed in the *Data Processing User Guide*.

Setting up a parallel white noise test

Parallel white noise tests to check the noise floor of an instrument's input amplifiers can be set up in the field or indoors in a laboratory, as long as GPS signals can be aquired.

The instructions that follow ensure that both E channels receive an identical signal and that all three H channels receive an identical signal. (The H_z channel is connected in parallel with the H_y channel by the internal wiring of the MAG INPUT cable.)

Preparing a Startup.Tbl file

Before you begin the test, prepare a Startup.Tbl file on the CompactFlash card that will be used.

To prepare a Startup.Tbl file:

1. Start WinHost.
2. Set the E_x and E_y dipole lengths to 1m.
3. Set the Low Pass Filter to 0 (Weak or Weakest).
4. For MT data, set all of the H sensor serial numbers to COIL0000.
5. For AMT data, set all of the H sensor serial numbers to AMTC0000.
6. Set appropriate acquisition times.
7. Save the file and load the card in the receiver.

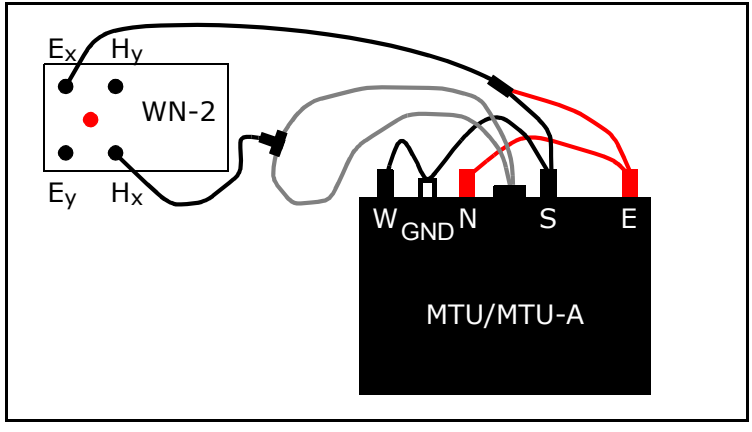


Fig. C-4: Setup for parallel white noise test. (Battery and GPS antenna omitted for clarity.)

To set up a parallel white noise test:

1. Connect the calibrated receiver to a GPS antenna and a 12V power supply, but do not turn it on yet.
2. Connect a cable to the E_X terminal of the WN-2.
3. Connect the lugs on the red wire of the cable to the red terminals of the receiver. (See Fig. C-4.)
4. Connect the lugs on the black wire of the cable to the GND and black terminals of the receiver.
5. Connect the two-way cable to the MAG INPUT terminal of the receiver and join the free ends of the cable with a T-connector.
6. Connect the H_X terminal of the WN-2 to the T-connector. (The cable wiring supplies the H_Y signal to the H_Z input as well, so all H channels receive the same signal.)
7. Turn on the receiver and set the WN-2 to LO for MT data or to HI for AMT data.
8. Acquire data for at least two hours.
9. Process the data as instructed in the *Data Processing User Guide*.

Appendix D

Magnetic declination resources

The following Internet sites (valid July, 2003) provide background information on magnetic declination. These sites also include on-line or downloadable calculators that provide an approximate magnetic declination, given a latitude, longitude, and date.

http://www.geolab.nrcan.gc.ca/geomag/mirp_e.shtml

http://www.thecompassstore.com/decvar.html#

http://geomag.usgs.gov/Freeware/geomagix.htm

For further resources, type the terms "magnetic declination", with or without "chart map" or other relevant terms into an Internet search engine such as:

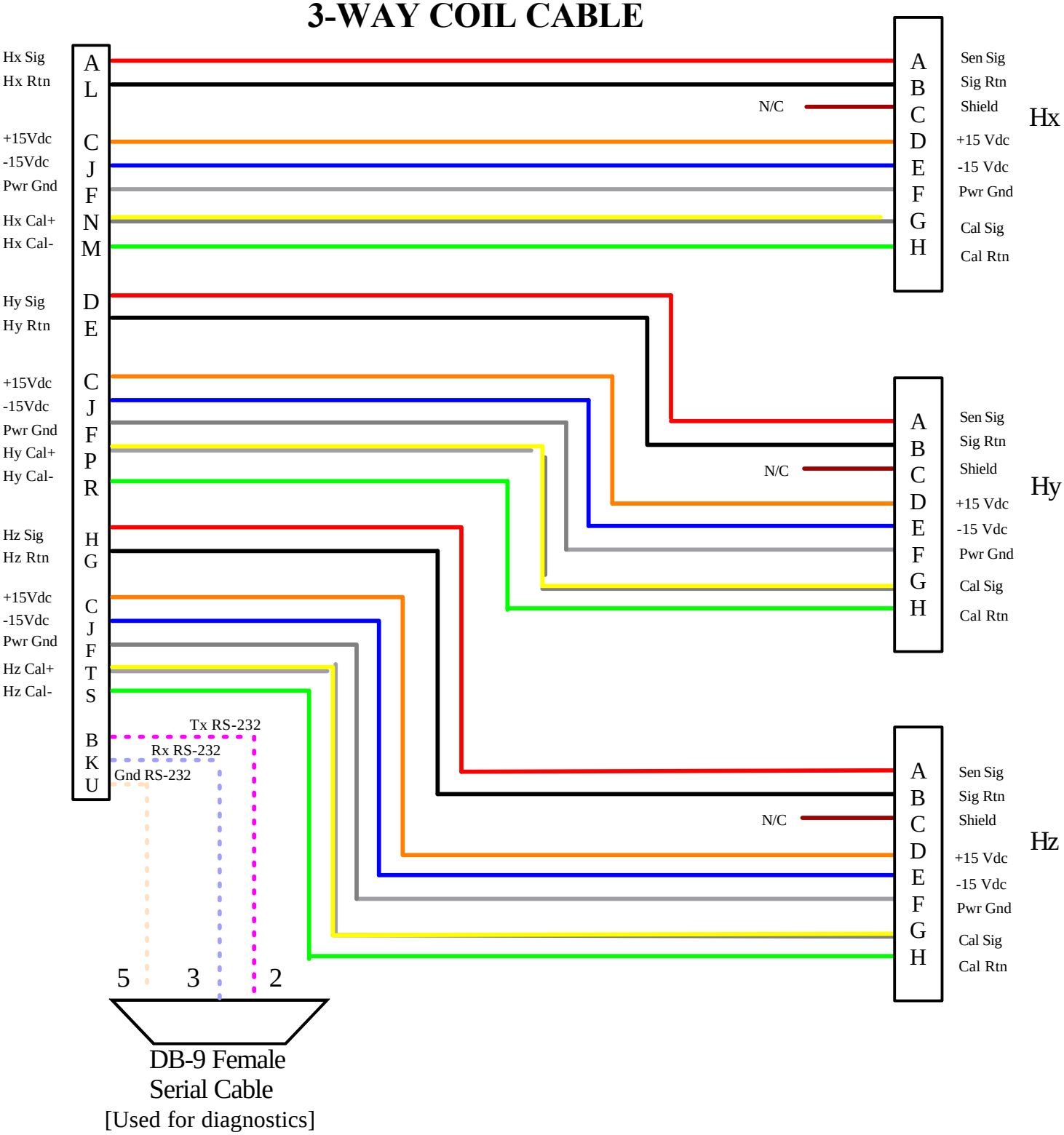
http://www.google.com

Appendix E

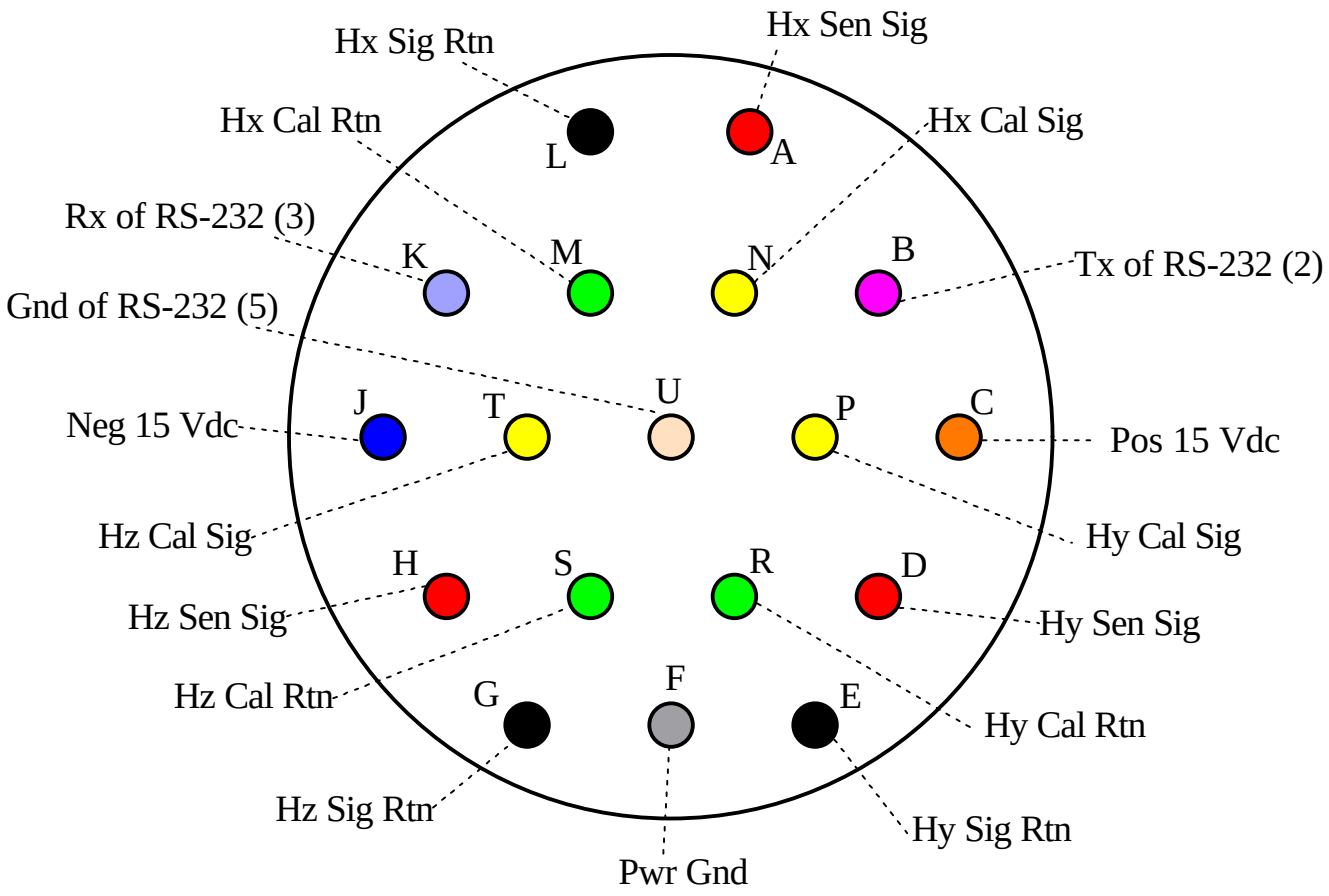
Sensor cable pin-out diagram

This appendix provides a diagram showing the wiring of all the pins on the connectors of the instrument MAG INPUT terminal, 3-way cable, and MTC-50 and AMTC-30 coil sensors and cables. To test for cable breaks, use a continuity tester or ohmmeter at matching pins on each end of the cables.

3-WAY COIL CABLE

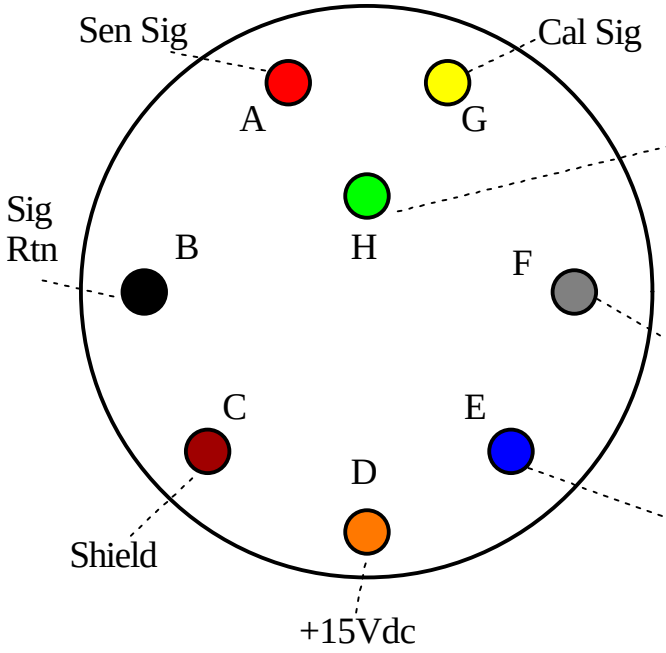


Mag Input Connector



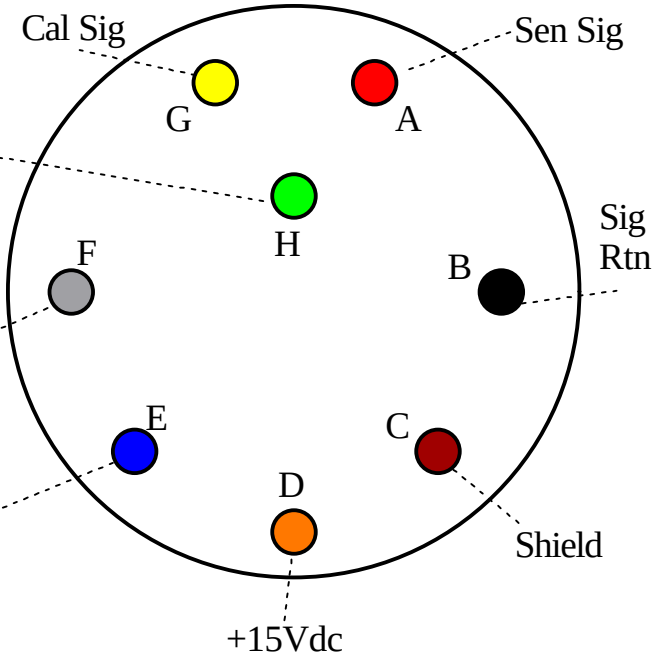
18-Pin Male

3-Way Pig-Tail Connector



8-Pin Female

Coil Cable Connector



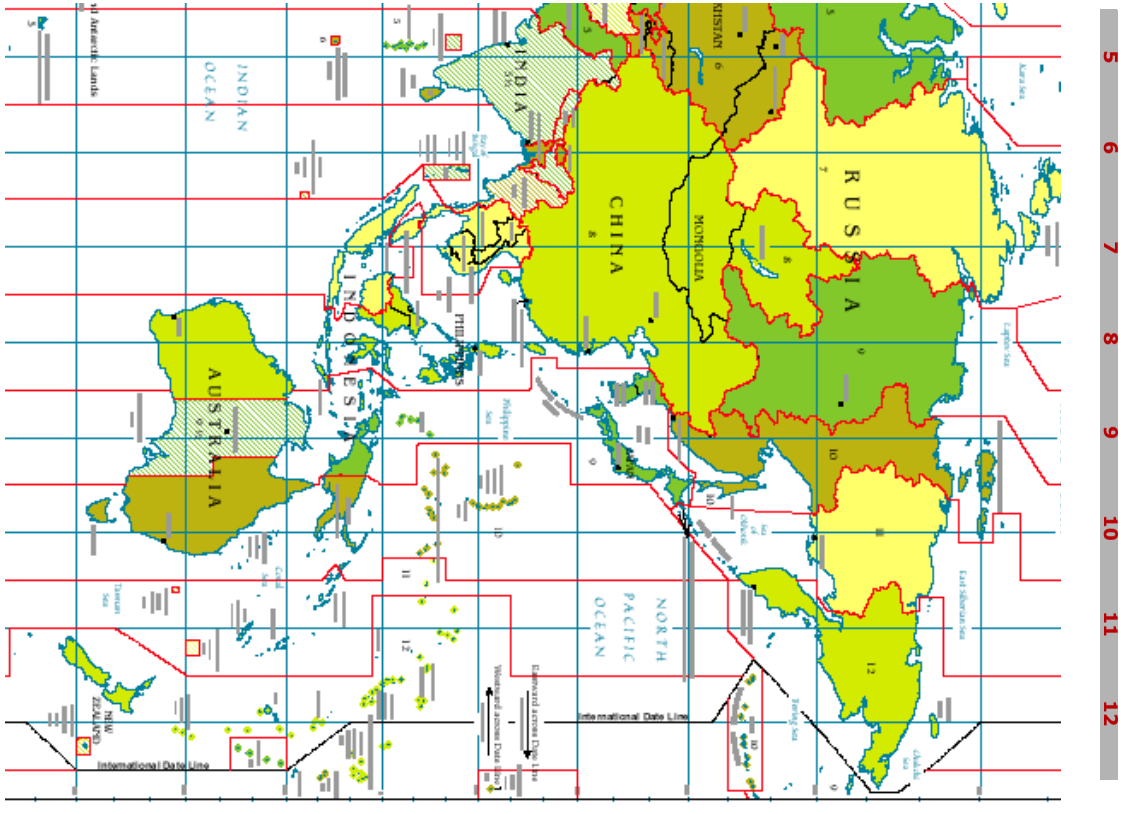
8-Pin Male

Appendix F

Time Zone Map

11
10
9
8
7
6
5
4
3
ARCTIC OCEAN
Greenla
(DENMARK)
U.S.
CANADA
UNITED STATES
MEXICO
NORTH
PACIFIC
OCEAN
NORTH
ATLANTIC
OCEAN
SOUTH PACIFIC
OCEAN
COLOMBIA
PERU
BRAZIL
BOLIVIA
ARGENTINA
CHILE
French Polynesia
Scale 1:85,000,000 at 0°
Miller Cylindrical Projection

2
1
0
1
2
3
4
5
Greenland Sea
Barents Sea
Kara Sea
Norwegian Sea
Denmark Strait
NORWAY
SWEDEN
FINLAND
North Sea
KAZAKHSTAN
Black Sea
TURKEY
Mediterranean Sea
IRAN
2%
ALGERIA
LIBYA
EGYPT
SAUDI ARABIA
INDIA
5%
Arabian Sea
MALI
NIGER
CHAD
SUDAN
DEM. REP. OF THE CONGO
ANGOLA
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
SOUTH AFRICA
French Southern and Antarctic Lands
Coordinated Universal Time (UTC)
formerly


INDIA
CHINA
RUSSIA
MONGOLIA
AUSTRALIA
INDONESIA
PHILIPPINES
INDIAN OCEAN
NORTH PACIFIC OCEAN
International Date Line
5
6
7
8
9
10
11
12

Appendix G

System 2000 MTU family specifications

This Appendix provides specifications for the System 2000 family of MTU instruments:

- MTU-P (2E, 2H, 3H, 5)
- MTU-A (2EA, 2HA, 3HA, 5A)

MTU-P indicates an instrument capable of acquiring MT data, equipped with a pluggable CompactFlash storage card. (Earlier instruments had non-removable storage.)

MTU-A indicates an instrument capable of acquiring MT and AMT data. All versions have removable storage.

The values and specifications given here are typical, and are subject to change. They are not claimed to be worst-case specifications.

General

Channels

Instruments acquire and store two electric field channels (E) and/or two or three magnetic field channels (H).

Sampling

Frequency ranges. MT signals are defined as the frequency range up to approximately 400 Hz. AMT signals are defined as the frequency range up to 10 000 Hz.

The MTU-A family acquires MT or AMT signals using V5-2000 (S2000) sample rates.

The MTU-P family acquires MT signals using either V5-2000 or V5-compatible sample rates.

Sampling rates. Time series of signals are stored at three different sample rates. The signals sampled at the lowest rate are acquired continuously. Signals sampled at the two higher rates are sampled intermittently in a pattern programmed by the user. For more information, refer to "Programming an MTU using WinHost and WinTabEd" on page 83 and "Programming an MTU-A using WinHost and WinTabEd" on page 115.

Table G-1 illustrates the sampling rates for frequency bands 2 (highest) to 5 (lowest).

Table G-1: A/MTU sampling rates.

Band	MTU			MTU-A	
	V5-Compatible		V5-2000	Data Type	
	50 Hz	60 Hz		MT	AMT
future	—	—	—	—	96 000
future	—	—	—	—	48 000
2	—	—	—	—	24 000
3	2560	3072	2400	2400	2400
4	320	384	150	150	150
5	24	24	15	15	—

Bandwidth. Signal bandwidth is typically 42% of the sample rate in V5-2000 modes and 25% of the sample rate in V5-compatible modes.

Resolution. Samples are 24-bit resolution.

Filtering and noise

Noise floor. Typical noise floor (MTU-2EA, high gain, DC coupling) is $10 nV/\sqrt{Hz}$ above 30 Hz.

Line frequency digital comb filter. At the lowest sample rate, a comb filter attenuates odd harmonics of the line frequency.

Except at the 24 000 Hz sample rate, the higher sample rates use a comb filter to attenuate all harmonics of the line frequency. At the 24 000 Hz sample rate, a digital high-pass filter (nominal 600 Hz corner frequency) is used.

Clocking and synchronization

Sample times are synchronized with UTC using a combination of global positioning system (GPS) signals and stable oven-controlled crystal oscillator (OCXO) clock.

Long-term absolute accuracy when locked to GPS is 1 µs or better.

Typical short-term stability governed by OCXO during GPS dropouts is $\pm 5 \times 10^{-9}$.

Any Phoenix GPS-equipped devices (MTUs, current sources, related controllers, etc.) can be synchronized at any location worldwide without communication among the units.

Calibration

Units perform multi-frequency self-calibration and magnetic sensor calibration on command. The resulting files contain a complete calibration of the instrument or sensor over its useful frequency range, independent of

the mode of operation (e.g., line frequency, AC/DC coupling). For more information on file format and content, see “Calibration file naming and content” on page 162.

Power

Power consumption varies from 14W (MTU-5 with three magnetic sensors) to as low as 8W (MTU-2E). With appropriate external battery(ies), units will operate for 24h or more.

Units shut down automatically when battery voltage is low.

All inputs are protected against power surges.

Scheduling

Acquisition start and stop dates and times are user-programmable. Within the overall duration, acquisition of the two higher frequency bands can start and stop together independently of the lowest band.

The schedule (and other parameters) can be established on-line with a PC connected to the instrument or off-line by saving a startup file on the CompactFlash card to be used in the acquisition.

Data storage and transfer

Calibration and acquisition data are stored on a removable CompactFlash card of up to 512MB capacity.

Data can be transferred to a PC either by connecting to the instrument with a parallel cable or by physically transferring the CompactFlash card.

External connections

Multi-pin connectors are military grade, environmentally sealed.

Ground

An external binding post provides the case ground, which should be connected to a porous pot electrode.

Telluric inputs

Units are equipped with four binding posts, marked WNSE for ease of cable connection.

Parallel port

A multi-pin connector is used for control and data transfer via an external adapter.

- Circular, 26-pin, shell size 16.
- Pinouts compatible with IEEE 1284 ECP bidirectional PC parallel port (pin A = PC pin 1, pin B = PC pin 2, etc.).
- Electrostatic discharge protection on all pins.
- 5V logic levels.

Auxiliary connector

- Circular, 18-pin, shell size 14.
- Provides signal input, power output, and calibration signals to three magnetic sensors.

Battery connector

- Circular, 4-pin, shell size 8.
- Surge protection and overload protection on all pins.
- Pin A: Battery 1, +12VDC.
- Pin B: Battery 2, +12VDC.
- Pin C: Battery common.
- Pin D: Battery common.

GPS antenna connector

- Circular, BNC-type.

Mechanical and environmental

Case. Environmentally sealed diecast aluminum.

Weight. 4.4kg.

Dimensions. 230mm x 225mm x 110mm.

Operating temperature. –20°C to +50°C.

WEEE Disposal. With respect to the Waste Electrical and Electronic Equipment directive of the European Commission, return equipment to Phoenix for proper disposal at product end-of-life.

File types and logical record formats

Results are stored in the files described in the following paragraphs. To allow future changes in file formats to be made transparent, Phoenix software uses a library of C-language functions to access the files. Anyone writing software to access files generated by the MTU family is strongly advised to used the Phoenix C library.

Calibration file naming and content

Calibration files are in a proprietary binary format. Human-readable calibration information can be extracted from calibration files by supplying the SYSCAL program with a text file of frequencies. SYSCAL then computes and displays the response of the instrument or sensor at those frequencies.

Instrument. Instrument calibration files are named automatically in the format `ssss.CLB`, where `ssss` is the instrument serial number.

Sensors. Sensor calibration files are named by the user, and should be in the format `COILssss.CLC` (for MTC-50 sensors), `AMTCssss.CLC` (for MTC-30 sensors), or `LOOPssss.CLC` (for AL-100 airloop sensors), where `ssss` is the coil or loop serial number.

Time series file naming and content

Time series files can be named by the user. If the user does not supply a name, files are named automatically. In firmware versions prior to 3112F, the format is `ssssHdda`, where:

- `ssss` is the instrument serial number
- `H` is the month in hexadecimal
- `dd` is the day in decimal
- `a` is an alpha character denoting the order of repeated soundings on the same day.

Beginning with firmware version 3112F, the format is `ssssHDhh`, where:

- `ssss` is the serial number of the instrument.
- `H` is the month in hexadecimal.
- `D` is the day of the month using the characters 1–9, A–U.
- `hh` is the order of repeated soundings on the same day at a single site, in hexadecimal.

The file extension is in the format `TSH`, `TSL`, or `TSn` and denotes the sample rate:

`.TSH` = V5-compatible Bands 3 and 4 sample rates.

`.TSL` = V5-compatible Band 5 sample rates.

`.TS2` = 24 000Hz sample rate.

`.TS3` = 2400Hz sample rate.

`.TS4` = 150Hz sample rate.

`.TS5` = 15Hz sample rate.

Note `TS2` to `TS5` may use other sample rates in the future. `TSH` and `TSL` apply only to MTU instruments in V5-compatible modes.

Time series file format

Time series files consist of *records* containing time series data, written chronologically from the time of the first sample in the record.

Record lengths within a single file may vary.

Each record consists of a *tag* followed by time series data. Figure G-1 on page 164 illustrates the file format graphically.

The time series data is stored in 24-bit two's complement format, three bytes per sample, least significant byte first. A *scan* is a set of samples, one from each channel, taken simultaneously. A complete scan from one sample time is stored consecutively in order of channel number. (Channels are numbered starting at 1, not 0.) Scans are stored in order of sample time.

The first scan in a record always starts exactly on a UTC second, and the scan rate is always an exact integer multiple of 1 Hz.

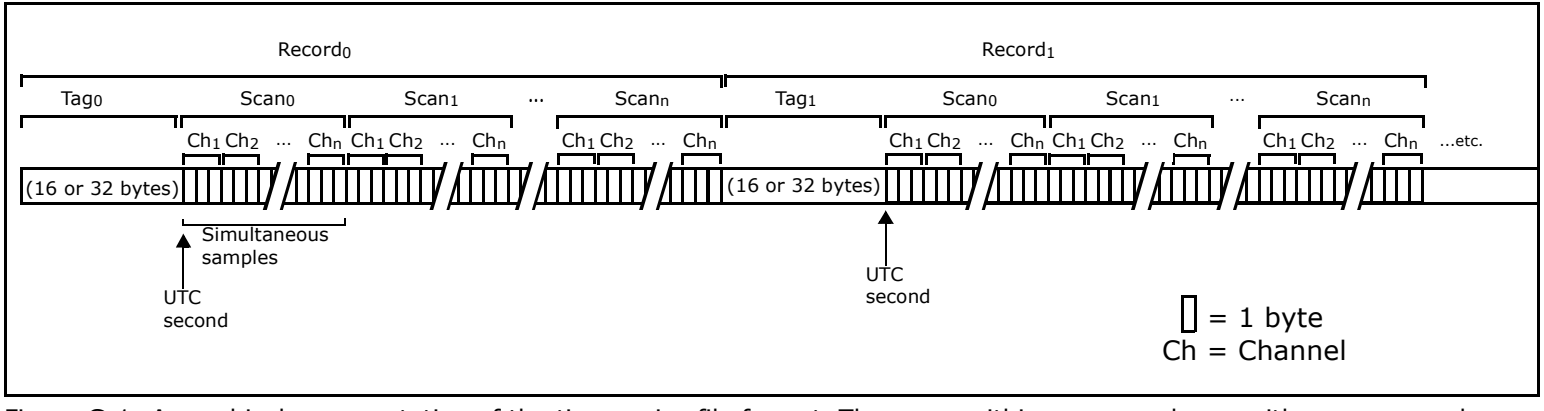


Figure G-1: A graphical representation of the time series file format. The scans within one record span either one second (Bands 3, 4, and 5) or 0.1 second (Band 2). Records always begin on a UTC second, but not necessarily on consecutive UTC seconds.

Time series tag format

The tag format may vary depending on instrument firmware, but only one tag format is used in any one file.

Table G-2: Summary of tag byte assignments

Byte	Meaning
0–7	UTC time of first scan in the record.
0	second
1	minute
2	hour
3	day
4	month
5	year (last 2 digits)
6	day of week
7	century
8–9	instrument serial number (16-bit integer)
10–11	number of scans in the record (16-bit integer)
12	number of channels per scan
13	tag length (TSn) or tag length code (TSH, TSL)
14	status code

Currently, tags are 16 bytes long in TSH and TSL files and 32 bytes long in TSn files. Table G-1 summarizes the byte assignments within the tags, and the paragraphs that follow provide additional detail.

Table G-2: Summary of tag byte assignments (cont'd)

Byte	Meaning
15	bit-wise saturation flags
Tags in TSH or TSL files end with byte 15	
16	reserved for future indication of different tag and/or sample formats
17	sample length in bytes
18–19	sample rate (in units defined by byte 20)
20	units of sample rate
21	clock status
22–25	clock error in µs
26–31	reserved; must be 0

Bytes 10–11. The number of scans in the record. Except in TS2 files, every record contains 1s of data, so this 16-bit integer is also the sample rate in Hz. (TS2 records contain 0.1s of data.)

Byte 13. In TSn files, this byte contains the tag length in bytes (currently 32). In TSL and TSH files, this byte contains the code 0, indicating a 16-byte tag length.

Byte 14. The instrument status code values are explained in Table G-3.

Table G-3: Status codes (Tag Byte 14)

Value	Meaning
0	normal completion
1	internal error
2	reserved
3	saturation of front-end board analog circuits
4	internal error in front-end board digital signal processor (DSP)
5	internal error
6	processor timed out without receiving data from front-end board DSP
7	internal error
8	internal error

Byte 15. Saturation flags. Each bit corresponds to a different channel (bit 0 for channel 1, bit 1 for channel 2, etc.). A bit's value will be 1 if either the common mode or differential mode input voltage limit is exceeded in any sample.

Byte 16. This byte is reserved for future use to identify different tag formats or different sample formats, such as floating point or compressed format. The value is currently 0.

Byte 17. The sample length in bytes, currently 3. Future changes in sample formats (32-bit integer or floating point, for example) may cause this value to change.

Bytes 18–19. The sample rate (per unit time as specified by Byte 20). For the range of possible values, see Table G-1 on page 158.

Byte 20. Time unit of the sample rate. The current range of values is shown in Table G-4. Other values may be defined in the future.

Table G-4: Sample rate units (Tag Byte 20)

Value	Unit
0	second (Hz)
1	minute
2	hour
3	day

Byte 21. Clock status. This byte reflects the status of the clock at the time the record is taken. A value of 4 indicates that the clock was locked to GPS. A value of 3 indicates that the time is based on the crystal oscillator initialized by GPS.

Bytes 22–25. Clock error in μs. The value will be 0 unless GPS lock has been lost and reacquired. Recovery from GPS dropout (re-synchronization of the crystal oscillator) can take up to 20 min. During this time, the difference between the recorded sample time (bytes 0–7) and the actual sample time is recorded as clock error. This value is a 32-bit two's complement integer, positive if the sample is late, negative if it is early.

Related products

Several other products for similar or specialized applications are available or under development.

MTU-TXC

Used to synchronize other equipment, such as current sources, to System 2000 equipment.

UTC signal output:

- 921 600 Hz
- 1 Hz
- 1/60 Hz

Geophysical current source control output:

- 0.001 Hz to 10 kHz

Control waveforms are referenced to zero phase at UTC 2000 Jan 01 00:00:00.

MTU-2ESD, MTU-5ESD

Used in remote reference and monitoring applications, these instruments use a 33.6kb/s dialup telephone connection for control and data transfer.

MTU-2ES, MTU-5S

Also used in monitoring applications, these instruments use a serial interface for control and data transfer, typically connecting to a fibre optic or copper wire modem.

MTU-5LR

Used in surveys with extended depths of investigation, these instruments employ a ring-core fluxgate magnetic sensor and low sample rates.

MTU-AI family

These instruments, under development in 2003, provide an infrared interface to allow setup and monitoring from Palm OS® handheld devices.

System2000.*net* family

These instruments, introduced in 2004, are multichannel, multifunction receivers. The family includes the V8 and RXU receivers and the RXU-TM transmitter controller. The V8 has a full-colour, sunlight-readable display and keyboard, while the RXUs are equipped with an infrared interface and are sold with Palm OS® handheld terminals. All the instruments can optionally be equipped with wireless network capability, so controlled-source techniques no longer require kilometres of cable between instruments.

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