LMX100

User's Guide

Ground Penetrating Radar (GPR) Technology

Sensors & Software

subsurface imaging solutions

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Table of Contents

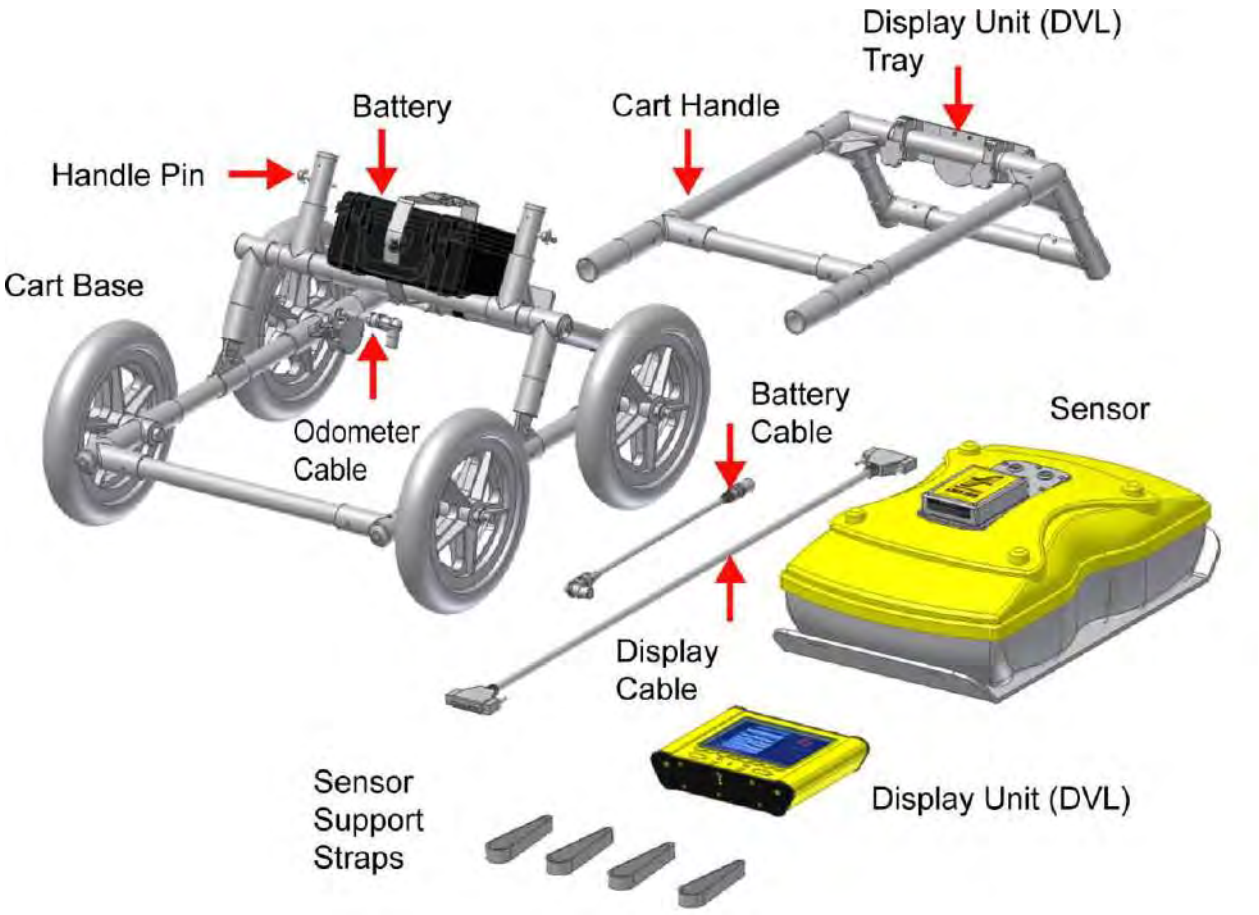
1. Overview

Congratulations on purchasing the LMX100, the Locate & Mark™, cart-based ground penetrating radar (GPR) system optimized for utility locating. The system is so simple and user-friendly that you will be finding targets in minutes.

This manual describes everything you need to assemble the system, change the settings and start scanning. There is also a section describing the proper technique for locating utilities for maximum productivity.

2. System Assembly

1) Open the main box; remove the accessory box, cart base, cart handle and GPR sensor box. Open each box and lay out all the components.



2) Attach the Cart Handle to Cart Base using the Handle Pins. Ensure the Display Unit (DVL) Mount is facing upwards.

3) Attach the Sensor to the Cart using the Sensor Support Straps. Ensure the Sensor is oriented the correct way with the connections toward the back of the Cart. Using the Sensor Support Straps, adjust the height of the Sensor so it is 1-2 cm (½ – ¾ inch) above the ground. The best way to get a uniform Sensor height is to place a couple of sheets of thick cardboard, particle board or Styrofoam under the sensor before securing the Sensor Support Straps.

4) Attach the Display Unit to the Display Unit Mount on the Cart. Depress the flexible clip and slide the Display Unit back far enough so the clip catches and secures it firmly in place. Adjust the angle of the Display Unit by loosening the hand-screws underneath the Display Unit Mount, rotating the Display Unit to the desired angle and tightening the hand-screws. This ensures the Display Unit does not rotate and damage the Display Cable.

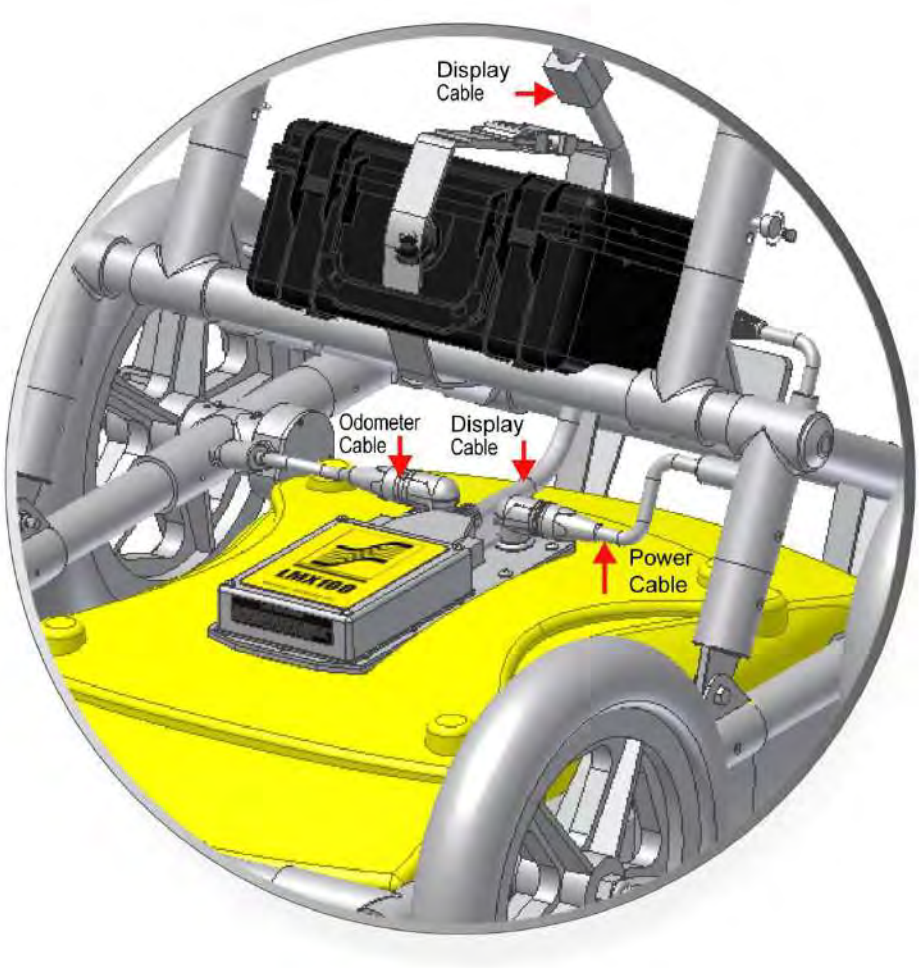
5) Attach the Display Cable to the back of the Display Unit with the jackscrews. Connect the other end of the cable to the Sensor. Ensure the cable is routed correctly; above the lower cross arm on the Cart Handle and under the Battery tray.

6) If the optional LMX ImageView Software Kit was purchased with the LMX100, with the system powered down, the Compact Flash (CF) memory card should be carefully inserted into the top compartment of the Display Unit. Loosen both thumbscrews on the door and open it by rotating it.

7) Attach the Odometer and Battery Cables:

The Odometer Cable connects to the closest receptacle on the Sensor.

Attach the Battery Cable to the Sensor and the Battery.



The upper red light on the Display Unit will illuminate indicating that there is power available for the system. The system is now ready to use.

3. Getting Started

3.1. Using the Display Unit

The Display Unit has eight buttons numbered 1 to 8, larger Pause and Camera buttons as well as buttons to increase and decrease the screen Contrast and Brightness.

Turn on the system by pressing any button on front of the Display Unit. Both red lights will illuminate and after few seconds, the splash screen and menu appears.

The menu option on the screen above the button indicates its function.

To operate the system:

a) The first screen displayed when the system is powered on is the **System Settings Screen.** It has options to start scanning or change settings such as language, measurement units, date, time, and odometer calibration (refer to Section 3.2).

b) To start scanning, press **Scan** to display the **Scanning Screen**. When the scale appears on the right side of the screen, push the cart. The data image scrolls across the screen from the right (refer to Section 3.3).

c) Stop and back up to see the **Locating Screen** (refer to Section 3.4) to mark the exact position of a target on the ground and to access the menu to estimate its depth.

d) When you push the cart forward again and reach the point where you originally stopped and backed up, the system will automatically start scanning again. Or press **Clear Screen** to start fresh.

e) At any time press the **Pause** button to change Depth, Color, Gain etc. using the **Image Settings Screen** (refer to Section 3.5) then press **Scan** (or **Pause** again) to continue.

f) If the optional LMX ImageView Software Kit was purchased and a Compact Flash (CF) card is present in the top compartment of the Display Unit, pressing the **Camera** button saves the current screen image to the CF card. Later, images are transferred to a PC for plotting and printing using the LMX ImageView software (refer to Section 7).

3.2. System Settings Screen

3.2.1. Scan

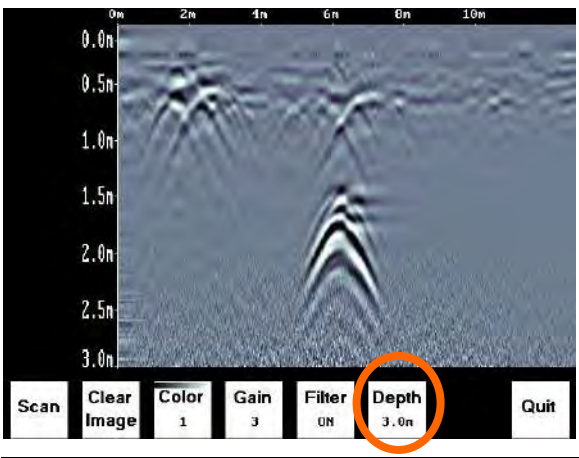
Press the **Scan** button to start scanning (refer to Section 3.3).

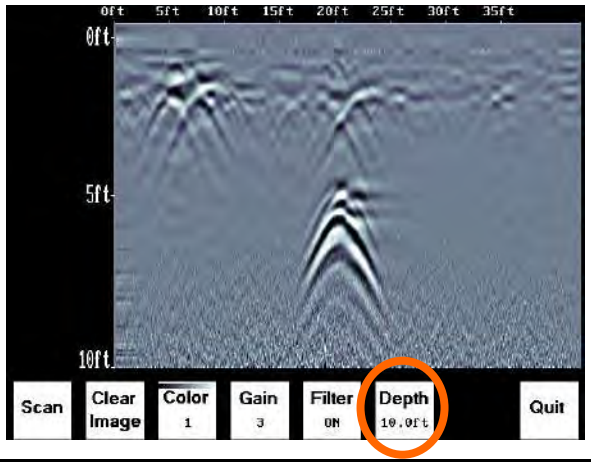
3.2.2. Language

Press the Language button to select the language for the menus. The system defaults to English on start-up. This manual generally uses the English menus. Refer to Section 3.7 for a chart showing all the equivalent icons.

3.2.3. Units

Units for the Position Axis, Depth Axis and Depth Indicator can be set to either **Meters** or **Feet**.

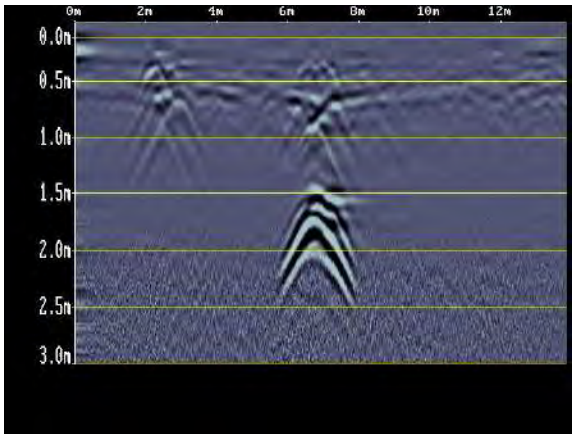




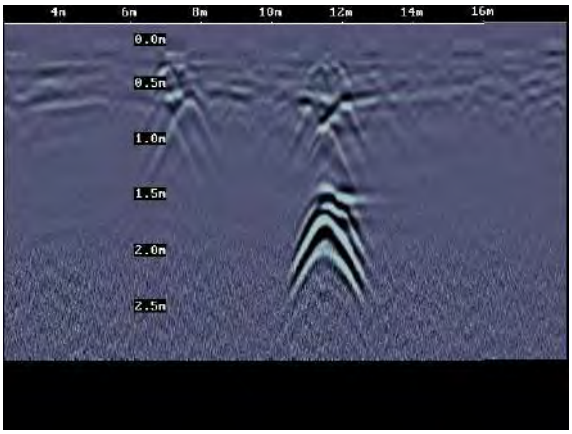
3.2.4. Scale

The Scale button toggles to four different Scale options:

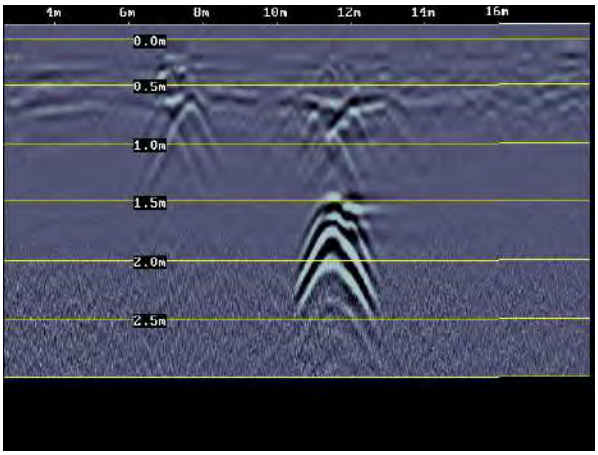
1) **Lines** means Depth Lines are plotted on the data image to assist with determining the depth of targets (also refer to Section 3.3).



2) **Text** means Depth Values are plotted in the center of the data image every 8 meters or 26 feet:



3) **Both** means both Depth Lines and Values are plotted on the data image:



4) **Off** means no Depth Lines and Values are plotted on the data image.

3.2.5. Date

Opens the **Date Screen** to change the current date (refer to Section 3.5). Images are saved with this date.

3.2.6. Time

Opens the **Time Screen** to change the current date (refer to Section 3.5). Images are saved with this time.

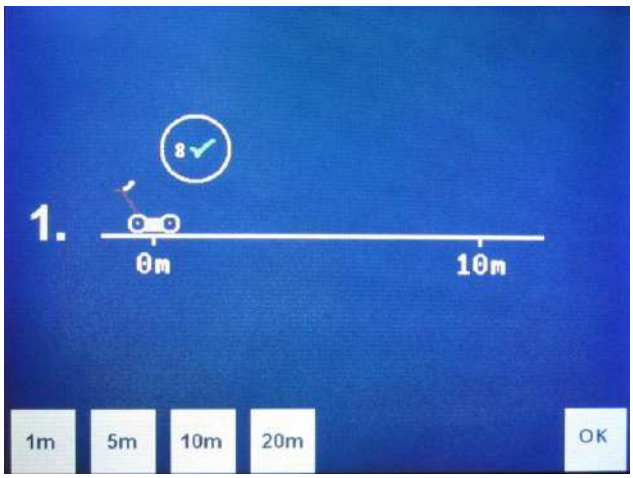
3.2.7. Odometer Calibration

Opens a sub-menu to calibrate the odometer.

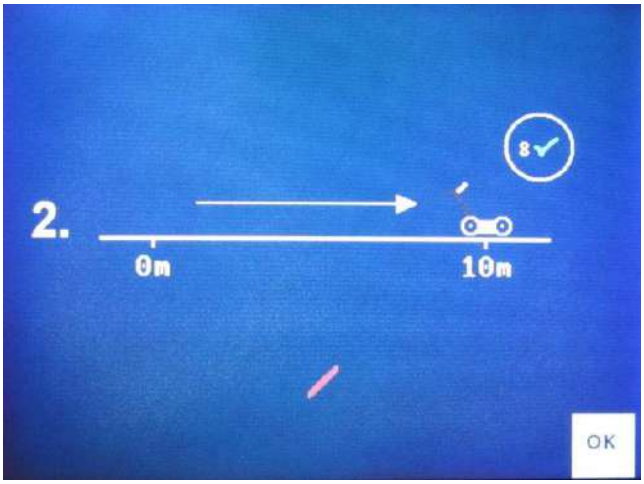
The odometer is factory calibrated but should be periodically calibrated for positional accuracy.

To calibrate the odometer, follow the steps as they appear on the screen:

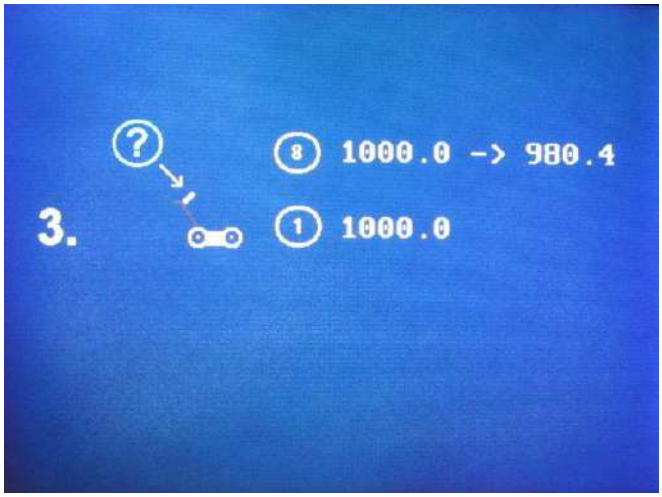
1) Select the length of your odometer calibration distance: 1, 5, 10 or 20 meters or 3, 10, 30 or 60 feet (depending on the units (refer to Section 3.2.3). The default length is 10 meters or 30 feet. Set the GPR system at the starting position and press '8'.



2) Move the system the calibration distance; a red line rotates as you move to indicate that the odometer is turning. Then press '8'.



3) This screen displays the new and old calibration values. Press '8' to accept the new calibration value or press '1' to cancel out of the calibration and use the old value.



3.2.8. Power Off

Opens a sub-menu to confirm powering off the system. There is also an option to restore the system to factory default settings.

3.2.9. System Information

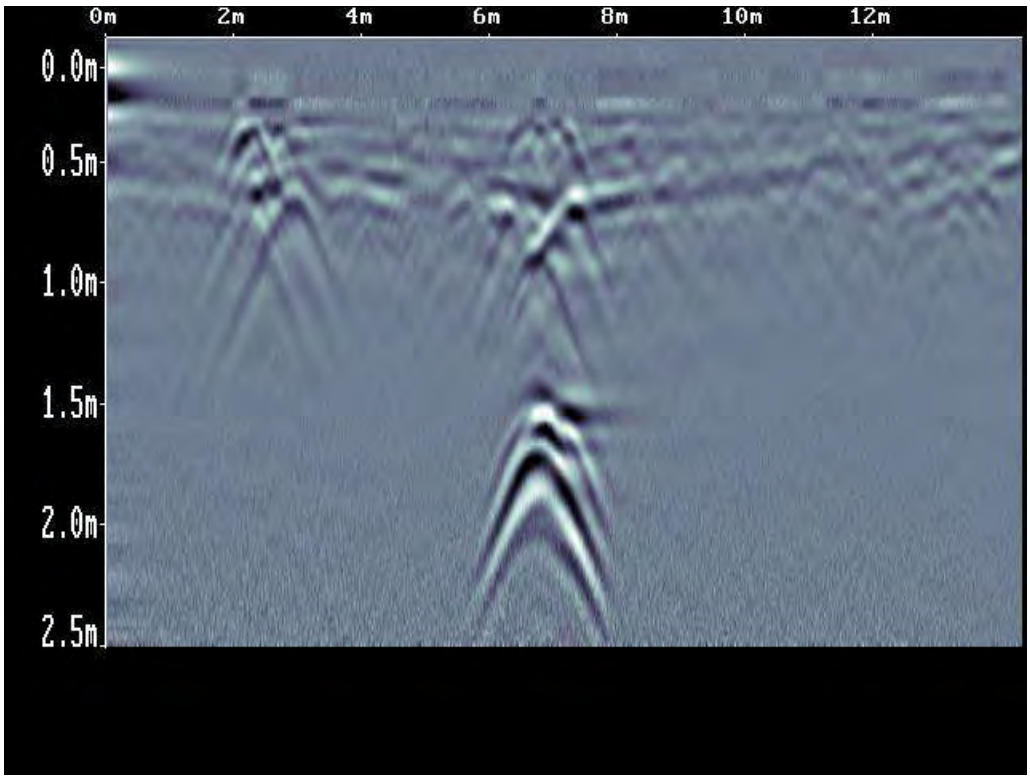
The top of the **Systems Setting Screen** displays the serial number of the GPR sensor, the software version number, the GPR Sensor frequency (in MHz) and the current battery voltage.

3.3. Scanning Screen

After pressing the **Scan** button, wait a few seconds for the vertical depth scale to appear on the right side of the screen, and then push the Cart forward.

A cross-sectional image of the ground scrolls onto the screen from the right to left. The position is displayed on the horizontal axis at the top while the depth is displayed on the vertical axis. The position and depth axes units are meters or feet depending on the units set in the **Systems Setting Screen** (Section 3.2).

If the **Scale** or **Both** option is selected (refer to Section 3.2), horizontal depth lines appear on the image to assist with determining the depth of targets.



Approximately 16 meters or 50 feet of data is displayed on one screen. If the survey line exceeds this distance the image will scroll off the left side of the screen.

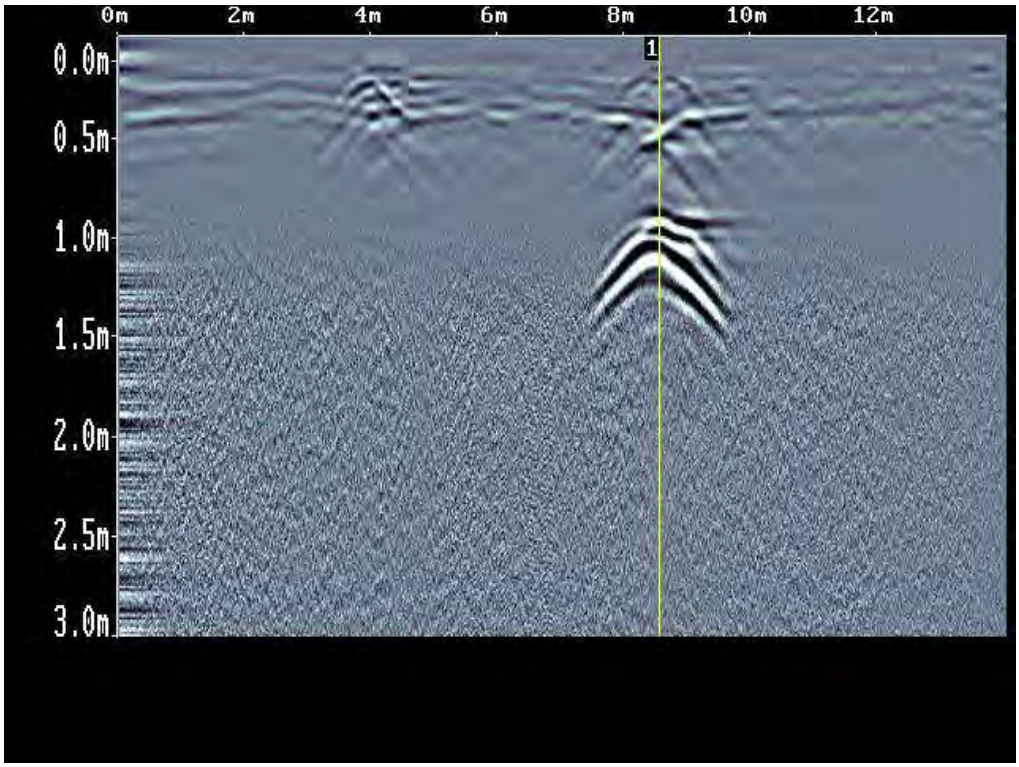
3.3.1. Saving Screen Images

To save the current screen image to file, press the **Camera** button on the Display Unit (refer to Section 3.1). The image number appears on the bottom of the screen with a message to press any button to continue.

A message will appear on the screen if there is no Compact Flash card in the Display Unit. Images are only saved when a card is present.

3.3.2. Adding Markers to Images

Pressing any of the number buttons on the Display Unit marked 1 to 8 while scanning adds a numbered marker at the current sensor position.



3.3.3. Backing Up to Locate Targets

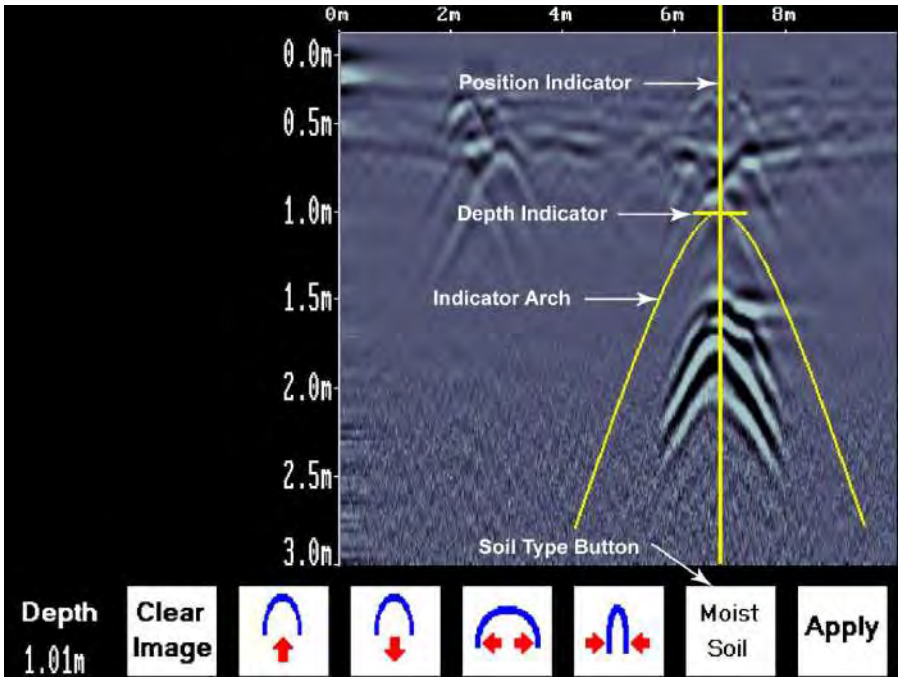
Stopping and pulling the cart backwards along the same path automatically opens the **Locating Screen** (refer to Section 3.4) used to pinpoint the position and depth of a target.

3.3.4. Pausing Data Collection

Pressing the **Pause** button opens the **Image Settings Screen** to change the current Color Palette, Depth, Filter and Gain (refer to Section 3.5).

3.4. Locating Screen

The **Locating Screen** is accessed by stopping and pulling the cart backwards while scanning. The cursor moves over the image and menu options appear at the bottom of the screen.



3.4.1. Locating Cursor

The **Cursor** consists of 3 parts:

Position Indicator Vertical cross-hair is tied to the odometer and corresponds to the location at the center of the GPR sensor. As the cart is pulled backwards, the Position Indicator moves to indicate the current location of the center of the GPR sensor.

Depth Indicator Horizontal cross-hair found at the peak of the soil type indicator arch indicating the depth. The Depth Indicator moves up or down using the Arch Up and Down buttons.

Indicator Arch Idealized representation of a typical pipe-like target response observed on the GPR image. The width of the arch is controlled by soil type setting. The soil type setting is changed using the Arch buttons. Increasing the soil type makes the indicator arch wider while decreasing the soil type makes it narrower.

3.4.2. Soil Type

To obtain an accurate depth axis and depth estimations of targets in the GPR image, a Soil Type Calibration must be performed. Soil Type Calibration can be done 3 ways:

1) Matching the shape of a target arch,

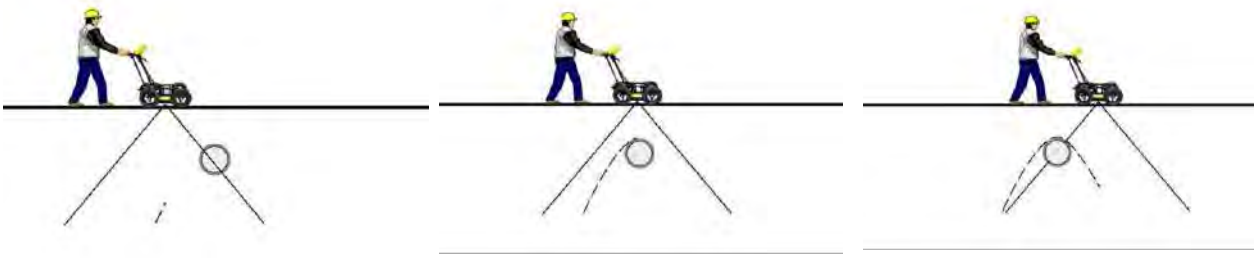
2) Using a target at a known depth, or

3) Using the moisture level of the soil.

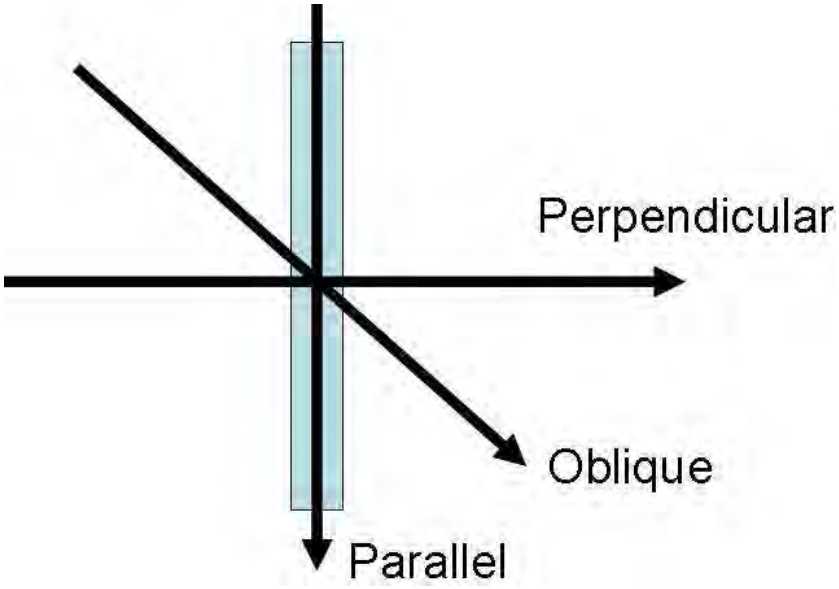
Matching a Target Arch

Targets like pipes, cables, buried artifacts, tree roots and rocks generate arch-shaped responses on the GPR image.

Arches occur because GPR energy does not travel into the ground as a pencil-thin beam but more like a 3D cone. Reflections can appear on the record even though the object is not directly below the GPR sensor. Thus, the GPR sensor "sees" the pipe before and after going over top of it and forms an arch-shaped response on the image.

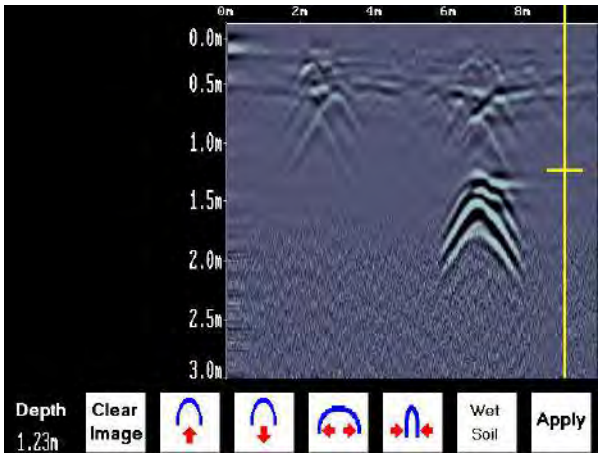


Cross long, linear targets like pipes or cables at a 90 degree angle to produce a target arch suitable for the soil type calibration. The depth estimation of a target will be incorrect if the soil type calibration is done on a target arch produced at an oblique angle (smaller than 90 degrees).

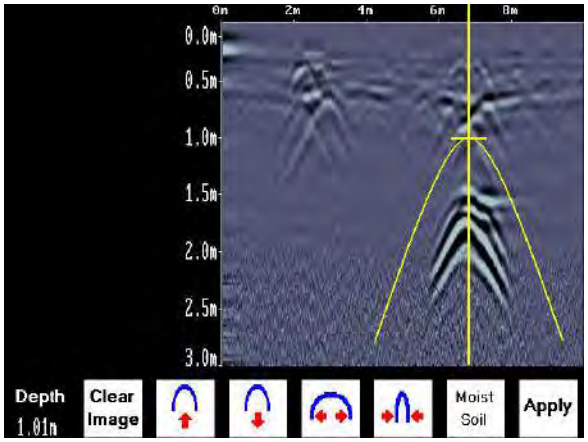


To determine the Soil Type using a Target Arch:

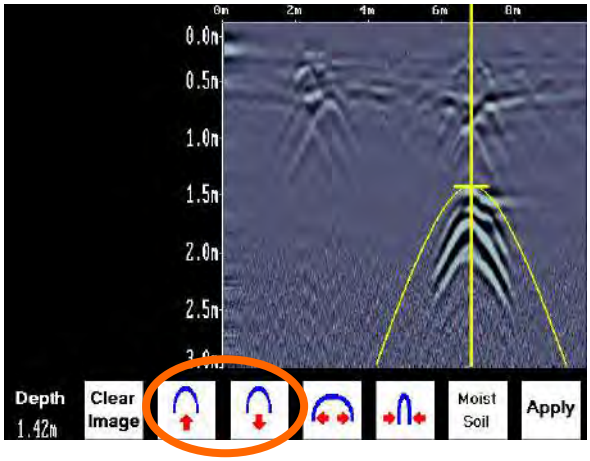
1) With a target arch visible on the image, back the cart up until the **Position Indicator** is centered on the target arch in the GPR image; preferably one with long tails because this provides the most accurate soil type calibration.



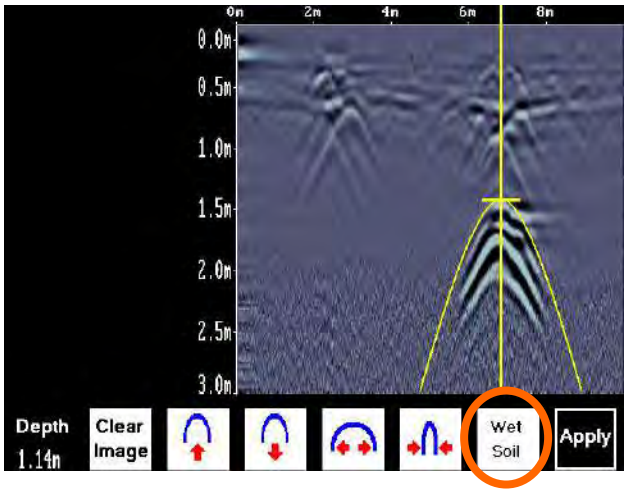
2) As you slow down and stop, the **Indicator Arch** will appear on the data image.



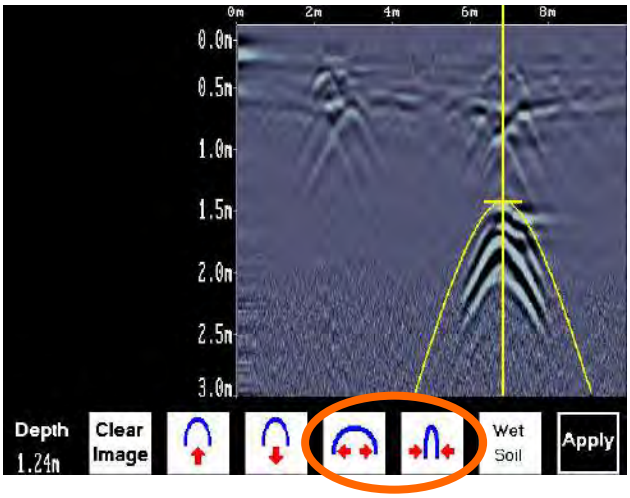
3) Use the **Up** and **Down Arrows** to move the **Indicator Arch** shallower or deeper in the GPR image respectively, until it lies overtop of the target arch.



4) Press the Soil Type button and toggle through the five different soil types to find the one that roughly fits the shape of the Indicator Arch to the shape of the Target Arch.



5) Use the **Wide** and **Narrow Arch** buttons to change the shape of the Indicator Arch to match the shape of the Target Arch on the GPR image. The depth of the target is indicated on the bottom left.



6) Press the **Apply** button to save the Soil Type and update the Depth Axis on the Scanning Screen. The Depth Axis can now be used to estimate the depth of targets while scanning in the area.

3.4.2.1. Target at Known Depth

If there are no suitable arches visible in the image to perform the Target Arch Matching described above, there may be a target of known depth in the area being scanned.

To determine the Soil Type using a target at known depth:

1) With the target response visible on the image, use the **Up** and **Down** Arrows to move the Depth Indicator (and Indicator Arch) until it lies on top of the GPR response of the known target.
2) Use the Wide and Narrow Arch buttons to change the shape of the Indicator Arch until the depth of the target, displayed in red above the menu, is correct.
3) Once the depth is matched, save the Soil Type value by pressing the **Apply** button.

3.4.2.2. Soil Moisture

If a good target arch or a target of known depth is not available, the user will have to estimate the Soil Type. The soil type is most strongly affected by water so the soil type options relate to the amount of water in the soil.

Change the soil type by pressing the Soil Moisture button until the option that best describes the soil in the area is displayed. The options are Very Dry, Dry, Moist, Wet and Very Wet Soil.

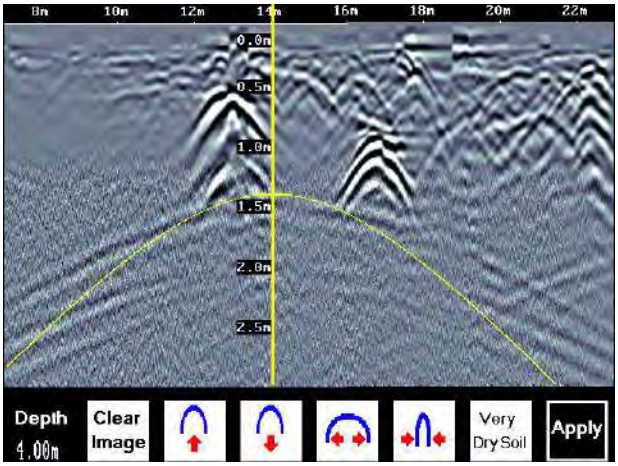
3.4.3. Identifying Air Wave Reflections

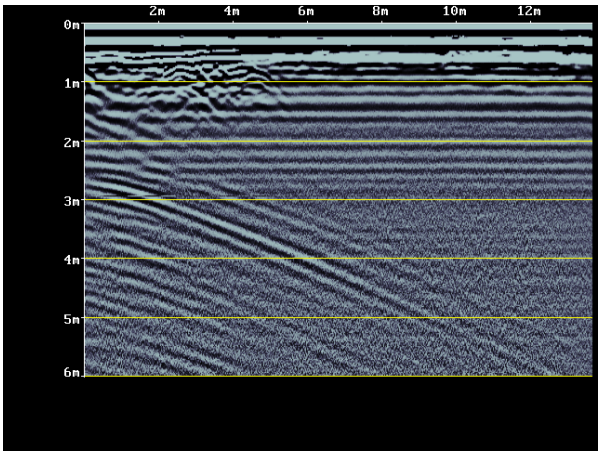
Some arches in the image can be caused by objects that are not in the subsurface, such as posts, fences, overhead wires and even trees.

An important part of understanding the data image is learning to recognize these unwanted "air" targets and differentiate them from the targets in the ground.

One way of identifying air reflections is to use the target arch method described above. However, arches from above-ground objects are wider than objects in the ground and out of the range of the maximum Soil Type.

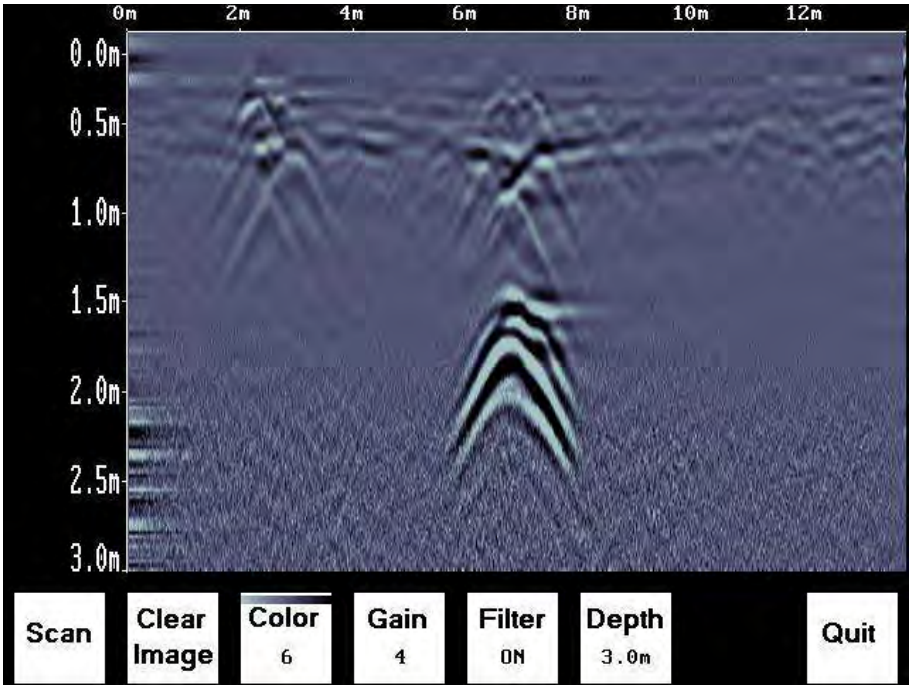
Therefore, if the widest Indicator Arch is still not wide enough to match the target arch, the target arch is from on object in the air, not the ground.





3.5. Image Settings Screen

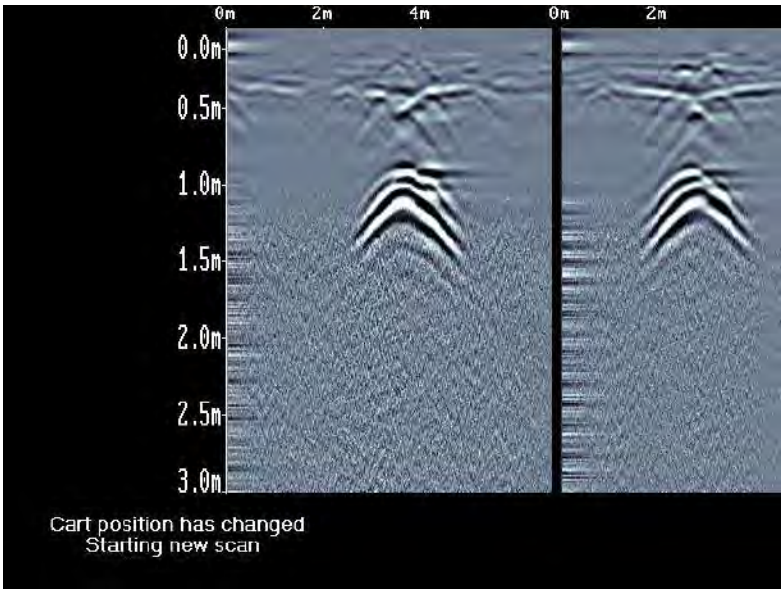
The **Image Settings Screen** is accessed by pressing the **Pause** (**||**) button while in the **Scanning Screen** or the **Locating Screen**. Menu options appear along the bottom of the screen:



3.5.1. Scan

To exit from the Image Settings Screen and resume Scanning, press the **Scan** button or the **Pause** (||) button again (to *un*Pause). The Scanning Screen returns at the current location with the position information preserved.

If, while paused in the **Image Settings Screen**, the cart has moved more than a few centimeters, when scanning is restarted, a gap called a **Position Break** will appear in the image. The position break is also indicated by a message on the bottom of the screen and the **Position Axis** along the top of the data image resetting to zero.

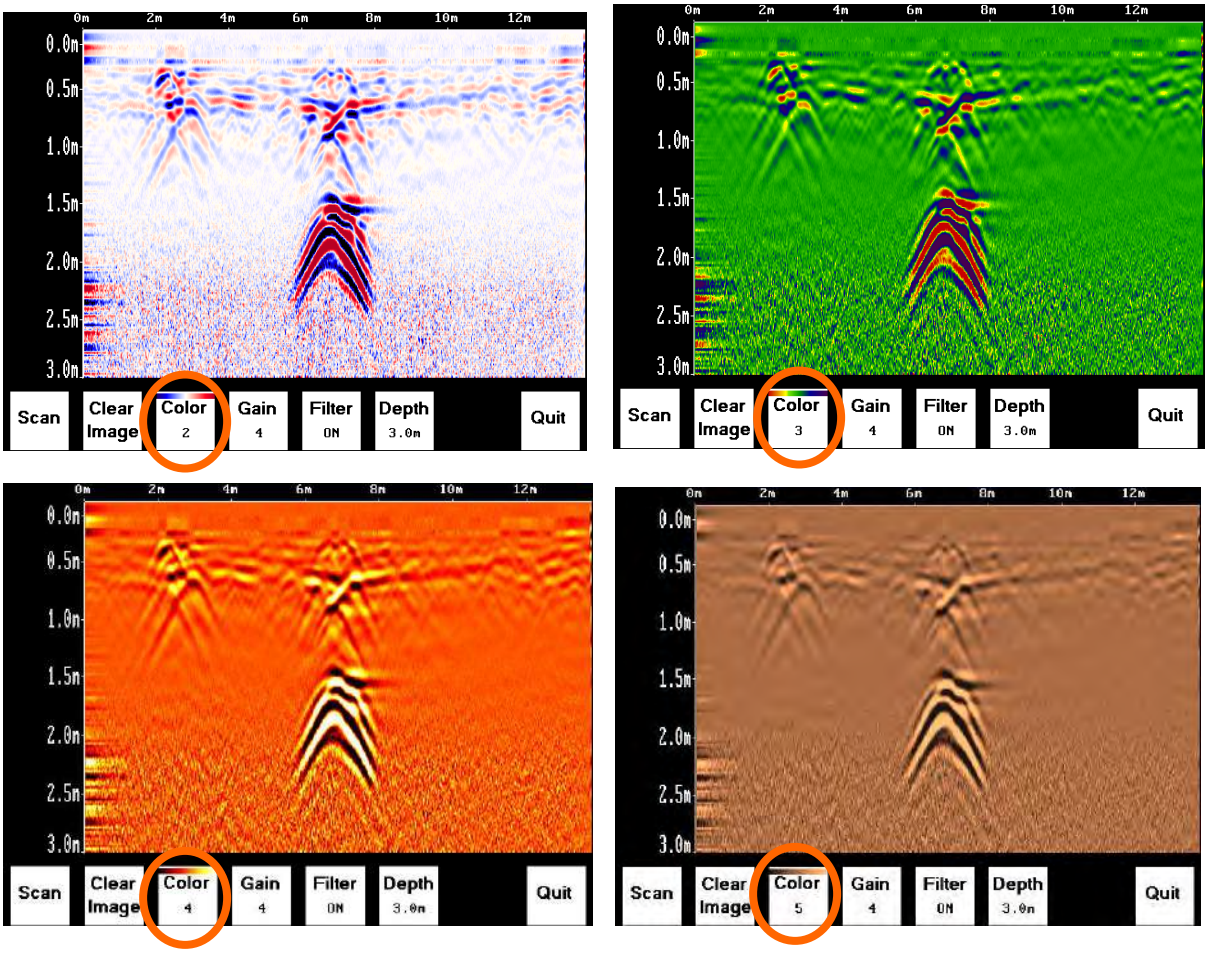


3.5.2. Clear Image

Deletes the current data image on the display.

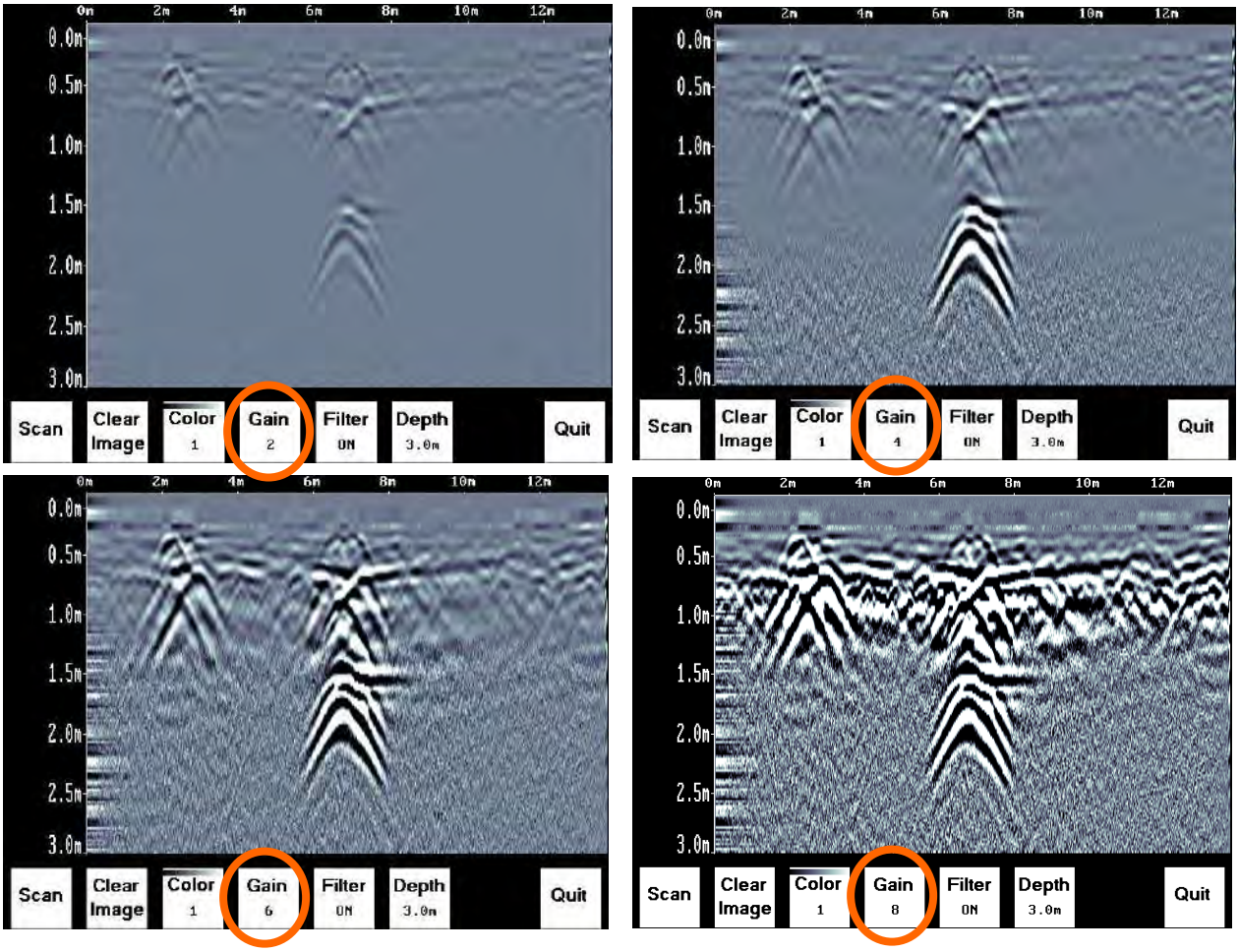
3.5.3. Color

GPR images are displayed in colors corresponding to a color palette. In general, stronger GPR signals appear in stronger colors. A number of different color palettes are available to display the image. Some color palettes may show the target better than others.



3.5.4. Gain

Since GPR signals are absorbed by the material being scanned, deeper targets have weaker signals. Gain acts like an audio volume control, amplifying the signals and making deeper targets appear stronger in the image. The Gain varies from 1 to 9 with 1 being no gain and 9 being the maximum gain.



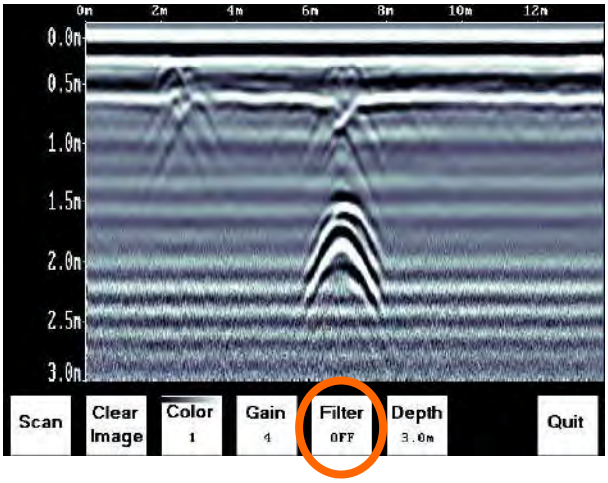
As the Gain changes, the current image on the display updates so it is not necessary to re-collect an image with a different gain setting. Use the lowest gain setting that shows the targets. Try to avoid over-gaining as understanding the image may become more difficult.

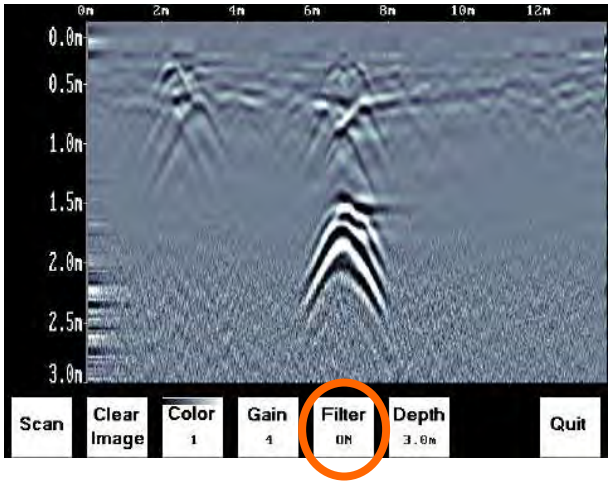
3.5.5. Filter

The filter has the effect of removing flat-lying reflections in the image and enhancing the dipping reflections and arches usually caused by targets. It can also assist in identifying very shallow targets that might be masked by the strong signals at the top of the image.

The Filter defaults to ON, so if you are looking for a layer or other flat-lying target, turn the Filter OFF.

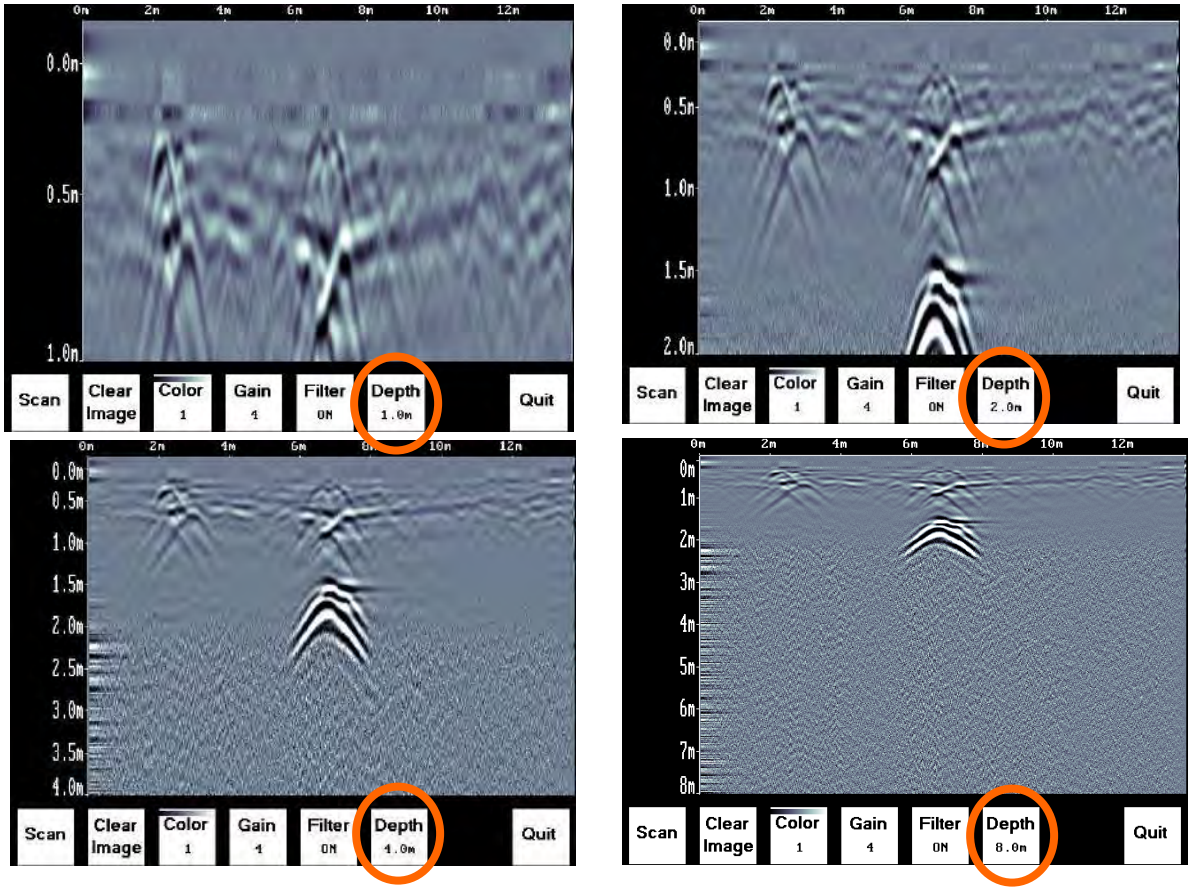
The image below shows the same scan with the Filter OFF and ON.





3.5.6. Depth

The depth setting is an estimate of the total depth displayed on the Scanning Screen based on the current Soil Type setting. The depth setting ranges from 1 to 8 meters (3 to 30 feet).



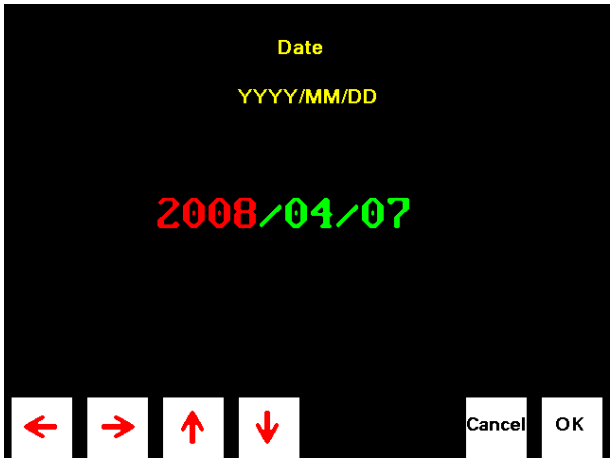
The system always collects data to a depth of approximately 8 meters (30 feet) but the **Depth** setting on this menu determines how much of the data is displayed on the screen. It is possible to scan with a Depth setting of, say 2 meters (6 feet), pause scanning and then increase the depth setting to re-display the image to look for deeper targets.

3.5.7. Quit

Exits the **Scanning** and **Image Settings Screens** and returns to the **Systems Settings Screen**.

3.6. Changing the Date and Time

From the **System Settings Screen**, select the **Date** option. The **Time** option is similar.



Use the **Left** and **Right Arrow** buttons to highlight the number to change in red.

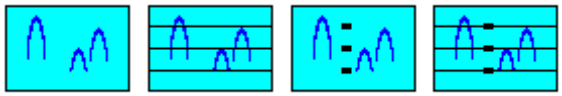
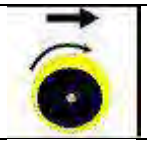
Increase the number using the **Up Arrow** and decrease the number using the **Down Arrow**.

Pressing **OK** saves the new date or time and exits the screen.

Pressing **Cancel** exits the screen without saving the date or time.

3.7. English and Equivalent Icons

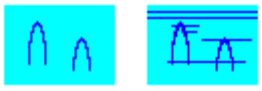
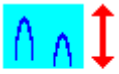
3.7.1. System Settings Screen Menu

Scan	
 English	
Units	**m** **ft** 
Scale	
Date	
Time	
Odom cal.	
Power Off	
Def.	

3.7.2. Locating Screen Menu

Clear Image	
	
Very Dry Soil / Dry Soil / Moist Soil / Wet Soil / Very Wet Soil	
Apply	

3.7.3. Image Settings Screen Menu

Scan	
Clear Image	
Gain	
Filter	
Depth	
Quit	

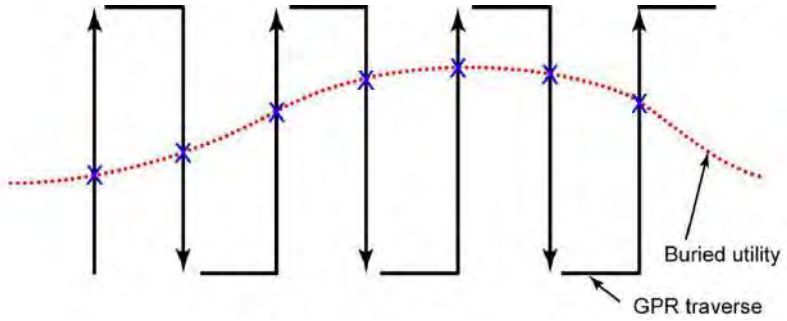
3.7.4. Date and Time Menus

	
	
Cancel	
OK	

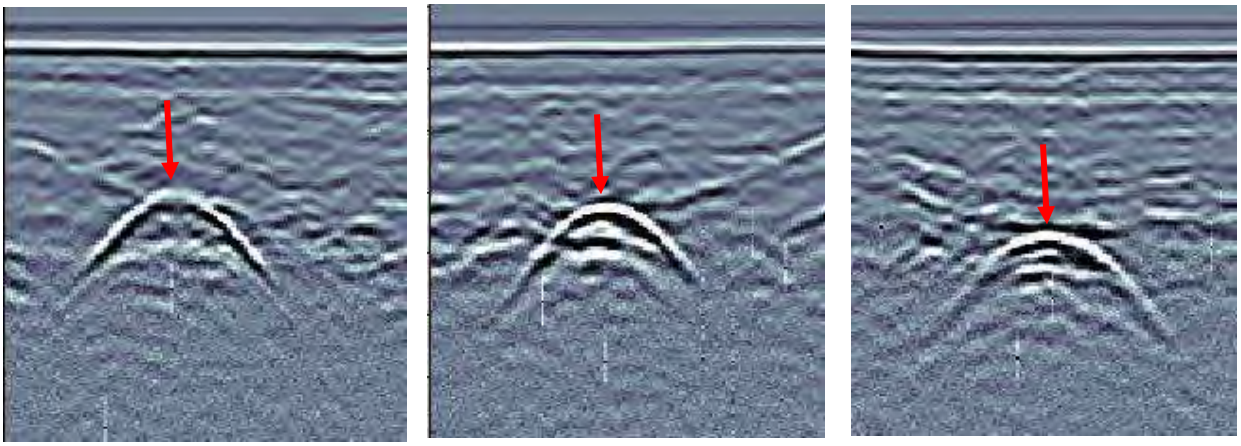
4. Surveying Technique

The most common method of locating is cross and mark as you go. This method works well in favourable soils and uncluttered settings. Cross and mark is very similar to the use of traditional current tracking utility detectors. The Cart is moved along sweeps perpendicular to the anticipated utility axis (refer to figure below). When the GPR sensor crosses the utility, the image shows an arch. The top of the arch is the position of the utility. The depth to the top of the arch is an estimated depth.

By moving the GPR back and forth and marking the ground where the top of the arch is observed, the alignment of the subsurface utility can be traced out (refer to the series of X's in the figure below).



For example, a concrete storm sewer alignment was located under the road in the figure and data images of lines 1, 2 and 3 below. The target arch visible on each scan clearly identifies the pipe alignment.



Notice that as the pipe gets deeper, the strength of the target arch gets weaker. This is a result of the GPR signal being absorbed as it travels deeper into the subsurface. In all soil types eventually the GPR signal will be completely absorbed and only the background radio noise in the area will be detected by the GPR sensor. The noise is seen in the image a fuzzy signal like a TV station not properly received. To see the deepest possible targets with a GPR, it is important to have a quiet, highly sensitive system.

4.1. Limitations

GPR is not without its limitations. GPR radio wave signals are absorbed by the ground with some soils (clays, saline) greatly limiting exploration depth. GPR effectiveness is thus site specific and varies greatly from place-to-place. GPR also responds to changes in soil type, density, water content, as well as many other buried objects; making unique identification of the desired target difficult. (i.e. you cannot see the individual tree in the middle of the forest).

5. Troubleshooting

The LMX100 system is designed to minimize user problems; however, all electronic devices are subject to possible failure. The following are troubleshooting hints in the likelihood of occurrence if your system fails to operate.

5.1. Power

The most common problem that can occur while trying to run the system is insufficient power. The battery may be dead, have a low voltage or the fuse may be blown.

If there is enough power to run the Display Unit, the upper red light on the front of the Display Unit will illuminate when the battery is plugged in.

If the battery voltage is less than about 10.2 volts, the Display Unit may not turn on and the upper red light will flash or not illuminate at all.

Check that battery voltage with a voltmeter. Try to do this while the system is still attached to the Cart to get a true measure of the voltage while under load (it will be necessary to open the Cart battery case and connect the voltmeter to the positive and negative battery terminals). If the battery has a low voltage or seems dead, try the system with another battery (if available), or give the battery a good 12-14 hour charge and try running the system again.

If the battery does not charge up to 12 Volts or more, it should be replaced.

Batteries are fused to protect the system. Open the battery case and check that the 10 Amp fuse is OK. If necessary, replace it with one of the spare fuses available inside the battery case.

If the battery seems OK but the system still does not power up, check the battery cable connections and inspect the battery cable for damage.

5.2. System Communications

If the battery is OK and the Display Unit turns on but the GPR sensor does not scan, there may be a communication failure between the Display Unit and the GPR sensor. If an error occurs, an error message will appear. Power Off the system and disconnect the battery.

Make sure the display cable is not damaged; all pins are straight and blow out the connector sockets as small debris may block individual pin connections and disrupt communications. Ensure that the cable connections are tightly secured. Sometimes vibrations cause the cable connections to loosen just a bit and break contact and this can cause errors. Disconnecting the cable and reconnecting it may provide a better contact and solve the problem. Plug in the battery, turn on the system and try scanning again.

If the battery, Battery Cable and Display Cable are OK, the problem is either a failure of the Display Unit or the GPR sensor. These units have no user-serviceable parts so they will have to be returned to the vendor for inspection and possible repair.

5.3. System Overheating

The GPR system is designed to operate to a maximum *internal* temperature of 70 C or 158 F. In situations of high ambient temperatures or long exposure to direct sun, this maximum internal temperature may be exceeded and cause the system to fail.

If you suspect that the GPR sensor is overheating, shut it off and give it a chance to cool down in a shady location before trying to run it again. Placing a wet cloth on top of the GPR may help in cooling it down.

If the situation is such that the high temperatures or direct sun cannot be avoided, it may be a good idea to put some sort of shade over the GPR sensor.

5.4. Display Unit Problem

While the Display Unit is weatherproof and fairly rugged, it should be handled in much the same way a notebook computer is. If the Display Unit does not power up, there may be a problem with the CPU or the storage media.

5.5. Wobbly Wheels

If, over time a wheel becomes wobbly, the wheel nut will need to be manually tightened.

Insert a large slotted screwdriver into the end of the axle (there's already a slot there for it) and use a large wrench to slightly tighten the wheel nut. The nut only has to be turned slightly, 1/8th -1/16th of a turn is usually enough. Spin the wheel to make sure it's still free and not too tight.

5.6. Test Line

One of the best ways of detecting problems with the system is, shortly after receiving the system and getting comfortable with its operation, collect a line of data at a convenient, easily accessible location. The line does not have to be too long but one screen (16 meters or 50 feet) is a good guide. This data line should be saved electronically and perhaps plotted out on paper and dated. The test line could be collected say, every 6 months and, by reviewing the previous data, system problems can be detected early. As well, if there is a suspected problem with the system, this test line could be collected and compared with earlier tests.

5.7. Contacting the Vendor for Service

When returning the system to the Vendor, have the following information available:

1) GPR sensor Serial Number displayed at the top of the **System Settings Screen**.
2) A brief description of when the error is happening and the operating conditions (temperature, humidity, sunshine, system settings, etc.).

6. Care and Maintenance

6.1. Battery Care

The LMX100 uses a 9-Amp-hour, 12-Volt sealed lead acid battery. It is fused with a 10 Amp fuse to protect it from short circuit damage.

The battery unit should run the LMX100 continuously for 6 hours before recharging is necessary. If long days of data surveying are typical, a second battery unit may be a useful item.

The battery is strapped onto the cart base and is normally recharged without removing it from the cart. However, the battery can be easily removed for maintenance or for recharging, if required.

If batteries are maintained in a charged condition they will give long life and reliable service. Improper use and lack of maintenance will greatly reduce their life.

Sealed lead acid batteries should **NEVER** be left in a discharged condition for any period of time. Charge the batteries as soon as possible after use.

Charge the battery at room temperature whenever possible.

The LMX100 has a voltage monitoring circuit that will turn off the unit when the input voltage drops below 10.2 volts.

If a battery has been deeply discharged or left in a discharged condition for some period of time it may not accept charge immediately when it is connected to the charger (the fast charge light will not illuminate). If the fast charge light does not come on within 6 hours the battery should be considered damaged and should be discarded.

Do not assume that a battery that is still charging after 8 hours is nearing the end of its charge cycle. Typical charging time for an empty battery is 12-14 hours from start of fast charge.

Ensure that the batteries are fully charged before storing. If practical, store the batteries in a cool place, 10^{o}c (a refrigerator is ideal), but make sure the temperature is not likely to drop below -30^{o}C or the electrolyte may freeze and possibly split the case.

6.2. Cable Care

1) The cable connectors as well as the connectors on the GPR Sensor and Display Unit need to stay clean and free of dust and moisture. Use a brush or air spray to clean dust, lint and other foreign particles from these connectors.
2) When the system is not being used, make sure the connections are protected to prevent dust and moisture from collecting inside. If the connectors are exposed, cover them with some sort of dust cap.
3) Cables are designed to be as tough as practical.
4) Careless use of cables making them carry loads that they are not designed for can cause internal damage.
5) Connectors are weak points in any system. With the use of this product in rough, dusty and outdoor environments, users can minimize potential down time if they care for cables and treat connectors with respect.
6) Cables and connectors are not designed to suspend or tow or otherwise carry the weight of systems. They are part of the electronic circuit and should be treated accordingly. When not in use they should be placed in their storage box.

6.3. Skid Pad

The bottom of the GPR Sensor is covered with one large wear-resistant skid pad. The skid pad is designed to take the majority of the abrasive wear. If the pad wears down enough, the less-resistant plastic housing may start to wear. If this occurs, it is best to replace the skid pad. It is easily removed with a screwdriver and a new one can be purchased from the vendor.

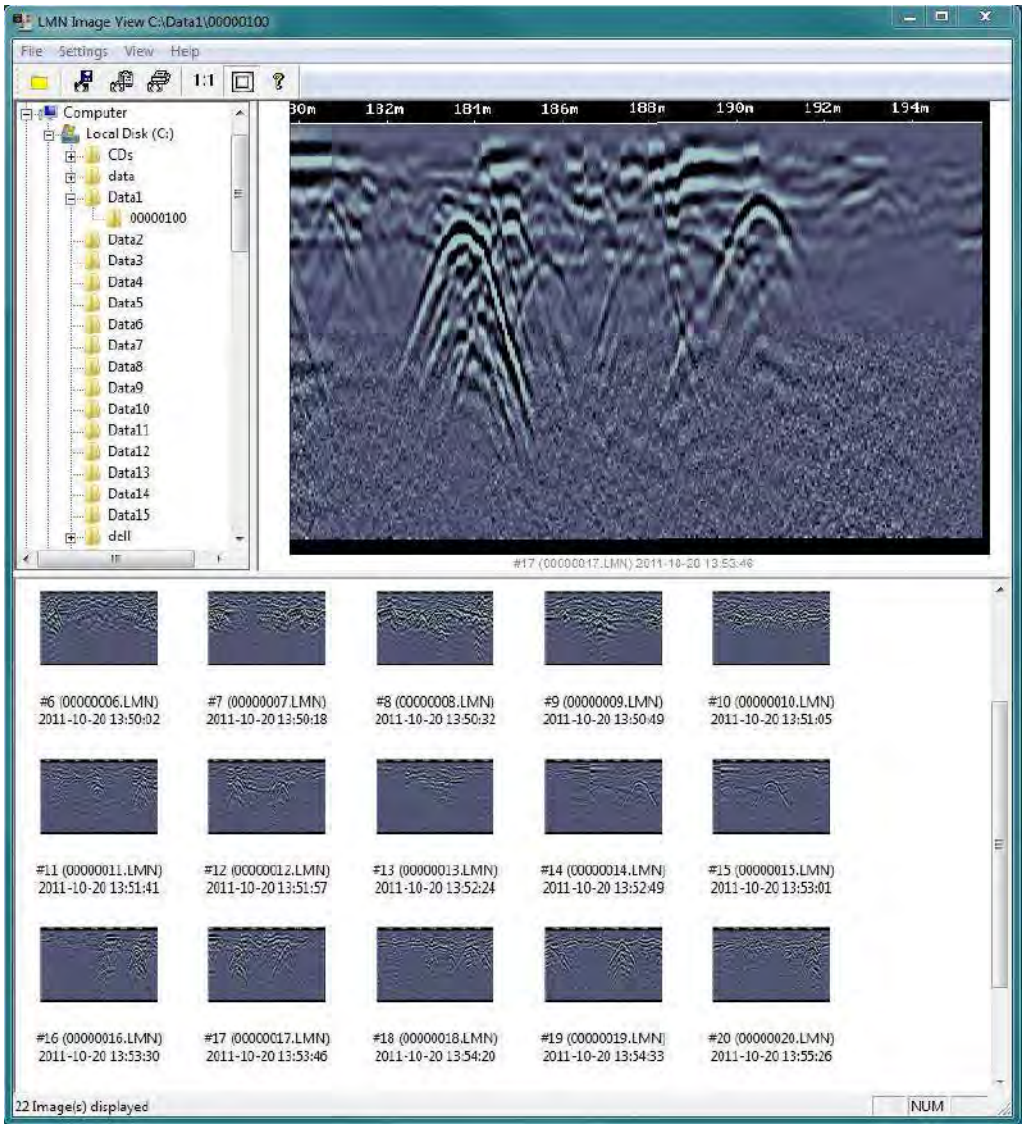
6.4. Odometer

The odometer should be periodically calibrated (refer to Section 3.2.7) to ensure accuracy.

7. Using LMX ImageView Software

If the optional LMX ImageView Software Kit was purchased with the LMX100, the LMX ImageView software can be used to display, on a PC, the GPR data images captured and saved to a Compact Flash (CF) card during data collection (refer to Section 3.1).

After transferring the images from the CF card to a PC, the LMX ImageView software makes it easy to scroll through the GPR images to view ones of interest, print them, save them as graphic images files or copy them to the clipboard for insertion into documents.



See the LMX ImageView software manual for details.

Appendix A

Health & Safety Certification

Radio frequency electromagnetic fields may pose a health hazard when the fields are intense. Normal fields have been studied extensively over the past 30 years with no conclusive epidemiology relating electromagnetic fields to health problems. Detailed discussions on the subject are contained in the references and the web sites listed below.

The USA Federal Communication Commission (FCC) and Occupational Safety and Health Administration (OSHA) both specify acceptable levels for electromagnetic fields. Similar power levels are mandated by corresponding agencies in other countries. Maximum permissible exposures and time duration specified by the FCC and OSHA vary with excitation frequency. The lowest threshold plane wave equivalent power cited is 0.2 mW/cm^2 for general population over the 30 to 300 MHz frequency band. All other applications and frequencies have higher tolerances as shown in graphically in Figure B-1.

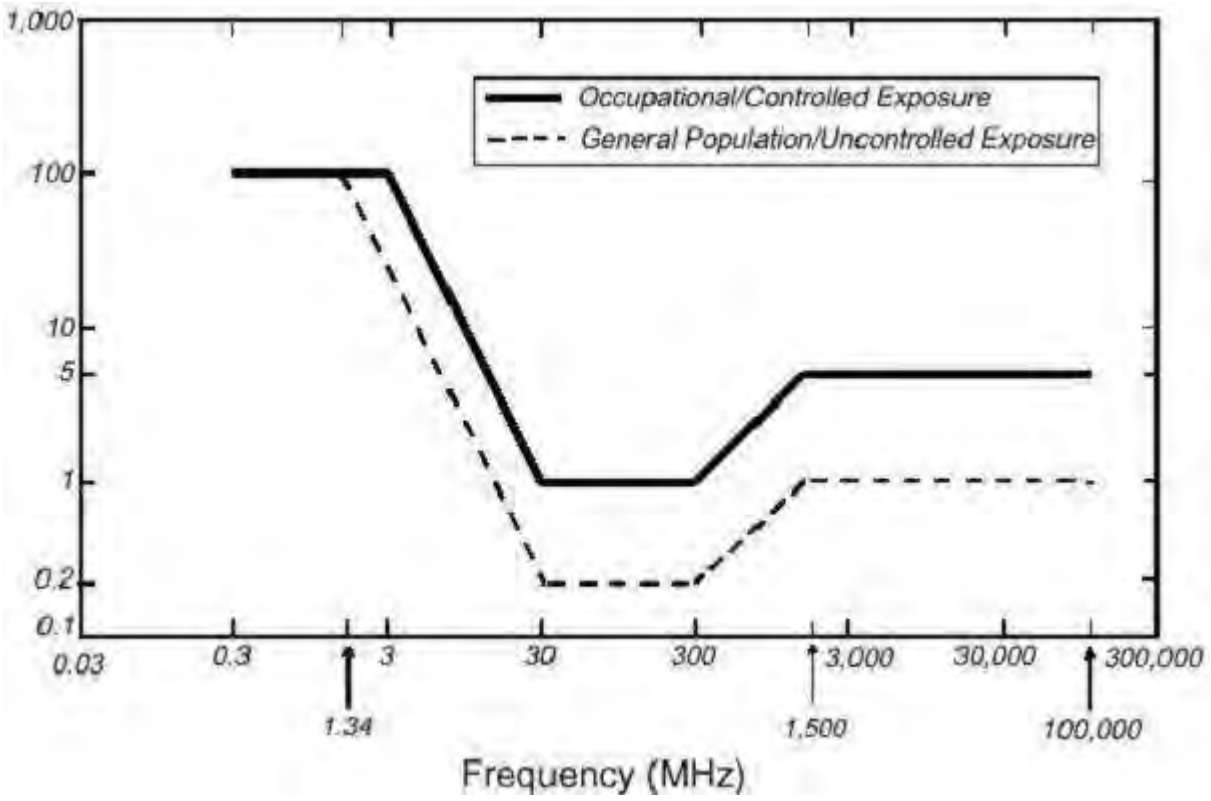


Figure B-1: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2.

All Sensors & Software Inc. GPR products are normally operated at least 1 m from the user and as such are classified as "mobile" devices according to the FCC. Typical power density levels at a distance of 1 m or greater from any Sensors & Software Inc. product are less than 10^{-3} mW/cm^2 which are 200 to 10,000 times lower than mandated limits. As such, Sensors & Software Inc. products pose no health and safety risk when operated in the normal manner of intended use.

References

Questions and answers about biological effects and potential hazards of radio-frequency electromagnetic field.

USA Federal Communications Commission, Office of Engineering & Technology

OET Bulletin 56

(Contains many references and web sites)

Evaluation Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields.

USA Federal Communications Commission, Office of Engineering & Technology

OET Bulletin 56

(Contains many references and web sites)

USA Occupational Safety and Health Administration regulations paragraph 1910.67 and 1910.263.

Web Sites

www.fcc.gov

www.osha-slc.gov (refer to radio frequency)

Appendix B

GPR Emissions, Interference and Regulations

All governments have regulations on the level of electromagnetic emissions that an electronic apparatus can emit. The objective is to assure that one apparatus or device does not interfere with any other apparatus or device in such a way as to make the other apparatus non-functional.

The manufacturer test their GPR products using independent professional testing houses and comply with latest regulations of the USA, Canada, European Community, and other major jurisdictions on the matter of emissions.

Electronic devices have not always been designed for proper immunity. If a GPR instrument is placed in close proximity to an electronic device, interference may occur. While there have been no substantiated reports of interference to date, if any unusual behavior is observed on nearby devices, test if the disturbance starts and stops when the GPR instrument is turned on and off. If interference is confirmed, stop using the GPR.

Where specific jurisdictions have specific GPR guidelines, these are described below.

FCC Regulations

This device complies with Part 15 of the USA Federal Communications Commission (FCC) Rules. Operation in the USA is subject to the following two conditions:

1. this device may not cause harmful interference and
2. this device must accept any interference received, including interference that may cause undesired operation.

Part 15 – User Information

This equipment has been tested and found to comply with the limits for a Class A digital device, where applicable, and for an ultrawide bandwidth (UWB) device where applicable, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

WARNING

Changes or Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

Certification of this equipment has been carried out using approved cables and peripheral devices. The use of non-approved or modified cables and peripheral devices constitutes a Change or Modification outlined in the warning above.

Operating Restrictions

Operation of this device is limited to purposes associated with law enforcement, firefighting, emergency rescue, scientific research, commercial mining, or construction. Parties operating this equipment must be eligible for licensing under the provisions of Part 90 of this chapter.

FCC Interpretation of Operation Restrictions issued July 12, 2002

(FCC Order DA02-1658, paragraph 9)

The regulations contain restrictions on the parties that are eligible to operate imaging systems (Refer to 47 C.F.R. 5.509(b), 15.511(b), and 15.513(b)). Under the new regulations, GPRs and wall imaging systems may be used only by law enforcement, fire and emergency rescue organizations, by scientific research institutes, by commercial mining companies, and by construction companies. Since the adoption of the *Order*, we have received several inquiries from the operators of GPRs and wall imaging systems noting that these devices often are not operated by the users listed in the regulations but are operated under contract by personnel specifically trained in the operation of these devices. We do not believe that the recent adoption of the UWB rules should disrupt the critical safety services that can be performed effectively only through the use of GPRs and wall imaging systems. We viewed these operating restrictions in the broadest of terms. For example, we believe that the limitation on the use of GPRs and wall imaging systems by construction companies encompasses the inspection of buildings, roadways, bridges and runways even if the inspection finds no damage to the structure and construction does not actually result from the inspection; the intended purpose of the operation of the UWB device is to determine if construction is required. We also believe that the GPRs and wall imaging systems may be operated for one of the purposes described in the regulations but need not be operated directly by one of the described parties. For example, a GPR may be operated by a private company investigating forensic evidence for a local police department.

FCC Permitted Mode of Usage

The GPR antenna must be kept on the surface to be in compliance with FCC regulations. Use of the antenna is not permitted if it is lifted off the surface. Use as a through-the-wall imaging device is prohibited.

GPR Use Coordination

FCC regulation 15.525(c) (updated in February 2007) requires users of GPR equipment to coordinate the use of their GPR equipment as described below:

TITLE 47--TELECOMMUNICATION

CHAPTER I--FEDERAL COMMUNICATIONS COMMISSION

PART 15_RADIO FREQUENCY DEVICES

Subpart F_Ultra-Wideband Operation Sec.

15.525 Coordination requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply operational areas to the FCC Office of Engineering and Technology, which shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired

geographical area(s) of operation, and the FCC ID number and other nomenclature of the UWB device. If the imaging device is intended to be used for mobile applications, the geographical area(s) of operation may be the state(s) or county(ies) in which the equipment will be operated. The operator of an imaging system used for fixed operation shall supply a specific geographical location or the address at which the equipment will be operated. This material shall be submitted to:

Frequency Coordination Branch, OET
Federal Communications Commission
445 12th Street, SW, Washington, D.C.
20554
Attn: UWB Coordination

(**Sensors & Software Inc. Note**: The form given on the following page is a suggested format for performing the coordination.)

(c) The manufacturers, or their authorized sales agents, must inform purchasers and users of their systems of the requirement to undertake detailed coordination of operational areas with the FCC prior to the equipment being operated.

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The FCC/NTIA coordination report shall identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited. If additional coordination is required for operation within specific geographical areas, a local coordination contact will be provided. Except for operation within these designated areas, once the information requested on the UWB imaging system is submitted to the FCC no additional coordination with the FCC is required provided the reported areas of operation do not change. If the area of operation changes, updated information shall be submitted to the FCC following the procedure in paragraph (b) of this section.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in Sec. 2.405(a) through (e) of this chapter, is followed by the UWB equipment user.[67 FR 34856, May 16, 2002, as amended at 68 FR 19751, Apr. 22, 2003]

Effective Date Note: At 68 FR 19751, Apr. 22, 2003, Sec. 15.525 was amended by revising [[Page 925]] paragraphs (b) and (e). This amendment contains information collection and recordkeeping requirements and will not become effective until approval has been given by the Office of Management and Budget.

FCC GROUND PENETRATING RADAR COORDINATION NOTICE

NAME:

ADDRESS:

CONTACT INFORMATION [CONTACT NAME AND PHONE NUMBER]:

AREA OF OPERATION [COUNTIES, STATES OR LARGER AREAS]:

FCC ID: QJQ-NG250

EQUIPMENT NOMENCLATURE: NG250

Send the information to:

Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination
Fax: 202-418-1944

INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

ETSI Regulations for the EC (European Community)

In the European Community (EC), GPR instruments must conform to ETSI (European Technical Standards Institute) standard EN 302 066-1 v1.2.1. Details on individual country requirements for licensing are coordinated with this standard. For more information, contact Sensors & Software's technical staff.

All Sensors & Software ground penetrating radar (GPR) products offered for sale in European Community countries or countries adhering to ETSI standards are tested to comply with EN 302 066 v1.2.1.

For those who wish to get more detailed information, they should acquire copies of the following documents available from ETSI.

ETSI EN 302 066-1 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 1: Technical characteristics and test methods

ETSI EN 302 066-2 V1.2.1 (February 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive

ETSI TR 101 994-2 V1.1.2 (March 2008) Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Ground- and Wall- Probing Radar applications; System Reference Document

Industry Canada Regulations - English

Industry Canada published it regulations for ground penetrating radar (GPR) on Mar 29 2009 as part of the RSS-220 titled 'Devices Using Ultra-Wideband (UWB) Technology'.

Industry Canada has made a unique exception for GPR by not requiring user licensing. The user does have to comply with the following directives:

> *This Ground Penetrating Radar Device shall be operated only when in contact with or within 1 m of the ground.*
>
> *This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.*

Should the ground penetrating radar be used in a wall-penetrating mode then the following restriction should be noted by the user:

> *This In-wall Radar Imaging Device shall be operated where the device is directed at the wall and in contact with or within 20 cm of the wall surface.*
>
> *This In-wall Radar Imaging Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.*

Since operation of GPR is on a license-exempt basis, the user must accept the following:

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Règlement d'Industrie Canada - Français

Industrie Canada a publié des règlements pour les appareils géoradar (GPR) le 29 mars 2009, dans le cadre du RSS-220 intitulé "Dispositifs utilisant la bande ultra-large (UWB)".

Industrie Canada a faite une exception unique pour GPR en n'exigeant pas de licence par utilisateur. L'utilisateur doit se conformer aux directives suivantes:

> *Ce géoradar périphérique doit être utilisé que lorsqu'il est en contact avec ou moins de 1 m du sol.*
>
> *Ce géoradar périphérique doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.*

Si le géoradar est utilisé dans un mode de pénétration au mur, la restriction suivante est à noter par l'utilisateur:

> *Ce dispositif d'imagerie radar doit être utilisé lorsque l'appareil est orienté vers le mur et en contact avec ou dans les 20 cm de la surface du mur.*
>
> *Ce dispositif d'imagerie radar doit être utilisé que par les organisations d'application de la loi, les instituts de recherche scientifique, des sociétés minières commerciales, entreprises de construction et de secours d'urgence ou des organisations de lutte contre les incendies.*

Parce que l'exploitation de GPR est sur une base exempte de licence, l'utilisateur doit accepter le texte suivant:

La fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositif.

Appendix C

Instrument Interference

Immunity regulations place the onus on instrument/apparatus/device manufacturers to assure that extraneous interference will not unduly cause an instrument/apparatus/device to stop functioning or to function in a faulty manner.

Based on independent testing house measurements, Sensors & Software Inc. systems comply with such regulations in Canada, USA, European Community and most other jurisdictions. GPR devices can sense electromagnetic fields. External sources of electromagnetic fields such as TV stations, radio stations and cell phones, can cause signals detectable by a GPR which may degrade the quality of the data that a GPR device records and displays.

Such interference is unavoidable but sensible survey practice and operation by an experienced GPR practitioner can minimize such problems. In some geographic areas emissions from external sources may be so large as to preclude useful measurements. Such conditions are readily recognized and accepted by the professional geophysical community as a fundamental limitation of geophysical survey practice. Such interference being present in the GPR recordings is not considered as an equipment fault or as a failure to comply with immunity regulations.

Appendix D

Safety Around Explosive Devices

Concerns are expressed from time to time on the hazard of GPR products being used near blasting caps and unexploded ordnance (UXO). Experience with blasting caps indicates that the power of Sensors & Software Inc.'s GPR products are not sufficient to trigger blasting caps. Based on a conservative independent testing house analysis, we recommend keeping the GPR transmitters at least 5 feet (2m) from blasting cap leads as a precaution. Some customers do experimental trials with their particular blasting devices to confirm with safety. We strongly recommend that GPR users routinely working with explosive devices develop a systematic safety methodology in their work areas.

The UXO issue is more complex and standards on fuses do not exist for obvious reasons. To date, no problems have been reported with any geophysical instrument used for UXO. Since proximity and vibration are also critical for UXO, the best advice is to be cautious and understand the risks.