# pulseEKKO PRO

## USER'S GUIDE

2005-00040-05

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**Sensors & Software Inc.**

1040 Stacey Court

Mississauga, Ontario

Canada L4W 2X8

Tel:(905) 624-8909

Fax:(905) 624-9365

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# 1   Overview

This manual describes how to set up and run a pulseEKKO PRO LF (low frequency) Ground Penetrating Radar (GPR) system connected to a Digital Video Logger (DVL) for data display and storage.

**Basic Components Assembly**
Section 2 Assembly of Basic Components on page 3 details the step by step procedure for assembling the major components of the pulseEKKO PRO system.

The modular design of the pulseEKKO PRO GPR makes the system very flexible and readily field-portable in a number of configurations. The final assembly of the particular configuration is covered in the next sections.

**Full Bistatic System Assembly**
Section 3 Full Bistatic System Assembly on page 19 details the additional steps to assemble the Full Bistatic System.

**One Man System Assembly**
Section 4 One-Man System Assembly on page 21.

**Antenna SmartCart Assembly**
Section 5 Antenna SmartCart System Assembly on page 23.

**Borehole System**
Section 6 Borehole System on page 29**.**

**Hand Towed System Assembly**
Section 7 Hand Towed System Assembly on page 31.

**Transducer SmartCart Assembly**
Section 8 Transducer SmartCart System Assembly on page 37.

**TR1000 System Assembly**
Section 9 TR1000 Transducer System on page 41.

**Multi-Channel System Assembly**
Section 10 Multi-Channel System on page 49.

**Accessories**
Section 11 Adding Accessories on page 51 describes how accessories can be added to the various configurations described in the above sections. This includes items like Beeper/Triggers, odometers, carriers and GPS.

**Starting the System**
Section 12 Starting the pulseEKKO PRO System on page 59 describes how to power the system, start up the DVL and navigate around the menus.

**Setting Data Collection Parameters:**
Section 13 System Setup Parameters on page 65 covers the procedure for selecting appropriate data collection parameters. Although every effort has been made to make the software as transparent and user friendly as possible, this section explains in greater detail each of the options and menu items in the data collection program.

To get up and running quickly see Section 13.1 System Parameters for a Quick Start to Data Collection on page 66.

**Scope Mode:**            Section 14 Running in Scope Mode on page 101 describes how to set
                           timezero to ensure the system is ready for data collection.

**Data Collection:**       Section 15 Data Collection Mode on page 105 describes running the radar
                           system and collecting data.

**Surveying Techniques:**  Section 16 Surveying Techniques on page 119 describes system configura-
                           tions and offers hints for properly collecting data in field conditions.

**Troubleshooting:**       Section 17 Troubleshooting on page 137 presents some simple steps the
                           user should go through when things do not work as they should.

**File Management:**       Section 18 File Management on page 147 describes how to transfer data
                           from the DVL to a PC and how to delete files and directories from the DVL.

**Care and Maintenance:**  Section 19 Care and Maintenance on page 153 discusses procedures for the
                           care and maintenance of your pulseEKKO PRO system.

**Helpful Hints:**         Section 20 Helpful Hints on page 161 lists some helpful hints, based on years
                           of experience, to help make data collection and field operations run as
                           smooth as possible.

# 2    Assembly of Basic Components

There are four essential components to the pulseEKKO PRO radar system: the Digital Video Logger (DVL), the control module, the transmitting unit and the receiving unit. This section describes how each of these components are assembled. It also describes how the transmitter and receiver assemblies are connected to the control module via either fibre optic cables or transducer cables.

Section 2.1: P3 describes the DVL and Control Module, components common to all system configurations.

Section 2.2: P6 describes the assembly of the low frequency antenna (12.5 to 200 MHz) transmitter and receiver assemblies.

Section 2.3: P13 describes the assembly of the high frequency transducers (250 to 1000 MHz).

Later sections describe how these basic system components are assembled into the different system configurations.

## 2.1    DVL and Control Module

The DVL and Control Module are common to all configurations.

### 2.1.1    Attaching the Control Module to the DVL

The control module unit must be attached to the back of the DVL (Figure 2-1). This may already have been done at the factory. Proceed to the next section (Section 2.1.2: P5), if this is the case.



*Figure 2-1:  The DVL with the control module attached to the back.*

*Figure 2-2: Remove the 4 yellow caps and the 4 screws from the back of the DVL (left) and place the control module on the back of the DVL (right). Make sure that the 37 pin connector is aligned properly with the 37 socket connector on the control module.*



*Figure 2-3: Attach the control module to the DVL using the 4 screws supplied (left) and a Phillips screwdriver (not supplied). Tighten the 37 pin connectors into place (right) with a small slotted screwdriver (not supplied).*

## 2.1.2  Attaching the Fibre Optic Converters for Low Frequency Antennas

Low frequency, unshielded antennas in the frequency range from 12.5 to 200 MHz require fibre optic cables to connect the transmitter and receiver to the control module. Higher frequency, shielded antennas use electrical cables to connect the transmitter and receiver to the control module. The control module is designed to accept both types of cables.

For low frequency antennas, the Electronic to Fibre Optic Converters must be attached to the control module and secured using the latches (Figure 2-4).



*Figure 2-4:  Low frequency antennas (12.5 to 200 MHz) require the electrical to fibre optic converters to be attached to the control module and secured using the latches.*

## 2.2 Low Frequency Transmitter, Receiver and Antenna Assembly

### 2.2.1 Low Frequency Antennas

The pulseEKKO PRO can be used with many different antennas. There are 5 low frequency, unshielded, bistatic antennas available: 12.5, 25, 50, 100 and 200 MHz (Figure 2-5). The best frequency of antenna to use on a survey depends on the survey objectives (Section 13.2.1: P68).
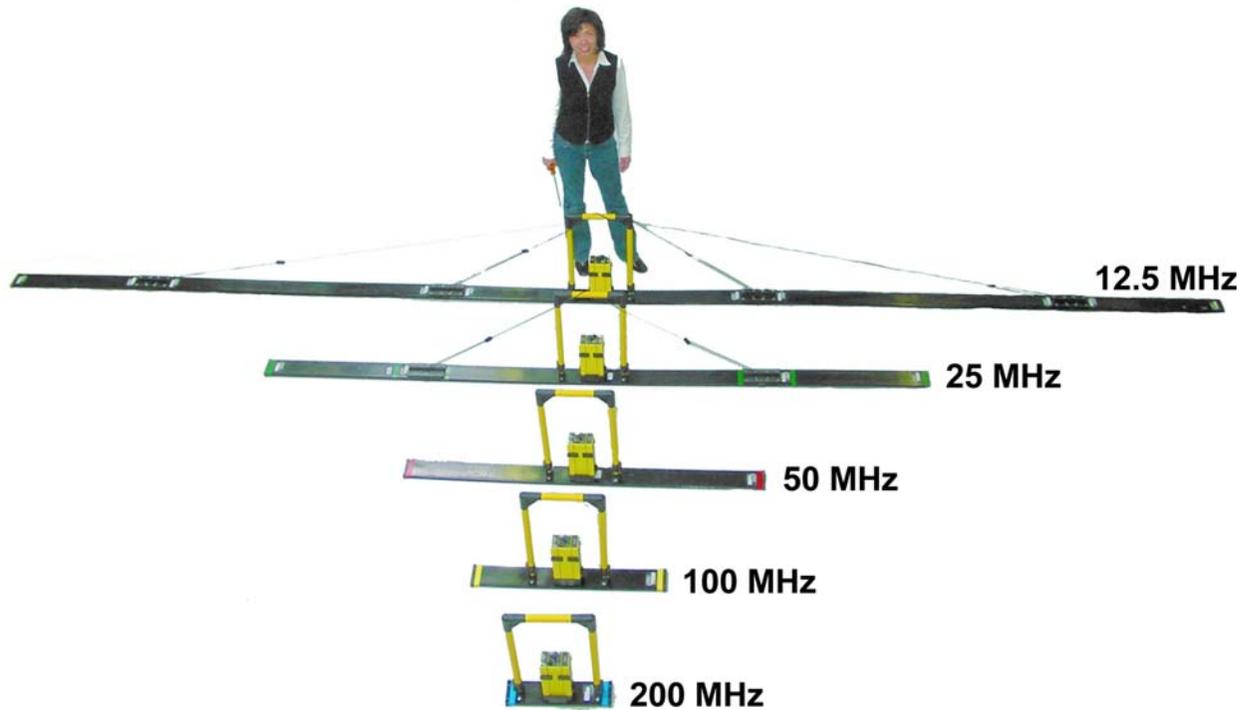


*Figure 2-5: Low frequency, unshielded, bistatic antennas available for the pulseEKKO PRO. The antennas come in pairs; one transmitting antenna and one receiving antenna. The shortest antennas, the 200 MHz, are 0.5 metres long while the longest, the 12.5 MHz are 8 metres long.*

The procedure for attaching the transmitter and receiver to any low frequency antenna is outlined below.

## 2.2.2  Attaching the Sockets to the Transmitter and Receiver

Insert and tighten the two female brass antenna sockets into the bottom of the transmitter and receiver electronic boxes (Figure 2-6). Tighten the sockets finger-tight. DO NOT APPLY UNDUE FORCE!

*Figure 2-6:  Hand tighten the brass sockets into the bottom of the transmitter and receiver.*

## 2.2.3  Inserting Pins into the Antennas

Insert the two male brass antenna pins into the two threaded holes in the center of the antennas. Tighten the pins finger-tight (Figure 2-7). DO NOT APPLY UNDUE FORCE!

*Figure 2-7:  Insert the male brass antenna pins into the holes on the top of the antenna and finger-tighten.*

## 2.2.4  Attaching the Mounting Blocks to the Antennas

Attach the antenna mounting blocks to the antennas by using the flathead screwdriver to tighten the 4 (four) quarter-turn fasteners, ensuring that the male brass antenna pins protrude up the center holes of the mounting blocks (Figure 2-8). Quarter-turn fasteners work by aligning the screw in the socket and then pressing downward and tightening a quarter of a turn. DO NOT APPLY UNDUE FORCE. It is usually best to have all four of the quarter-turn fasteners properly aligned in their sockets before tightening them. To do this, put slight pressure on the quarter-turn fastener and rotate it until you feel it drop into the socket. Then align the other three quarter-turn fasteners in the same manner. Once complete, go back and tighten all of them.



*Figure 2-8:  Attach the mounting blocks to the top of the antenna using the 4 quarter-turn fasteners. Before doing so, make sure that the 2 male brass antenna pins have been screwed into the top of the antenna first.*

## 2.2.5   Latching the Transmitter and Receiver to the Mounting Blocks

Carefully place the transmitter and receiver electronic boxes down onto the mounting blocks such that both brass pins fully connect (Figure 2-9 Left). Then use the 2 plastic draw latch connectors to hold the electronics boxes onto the mounting block (Figure 2-9 Right).
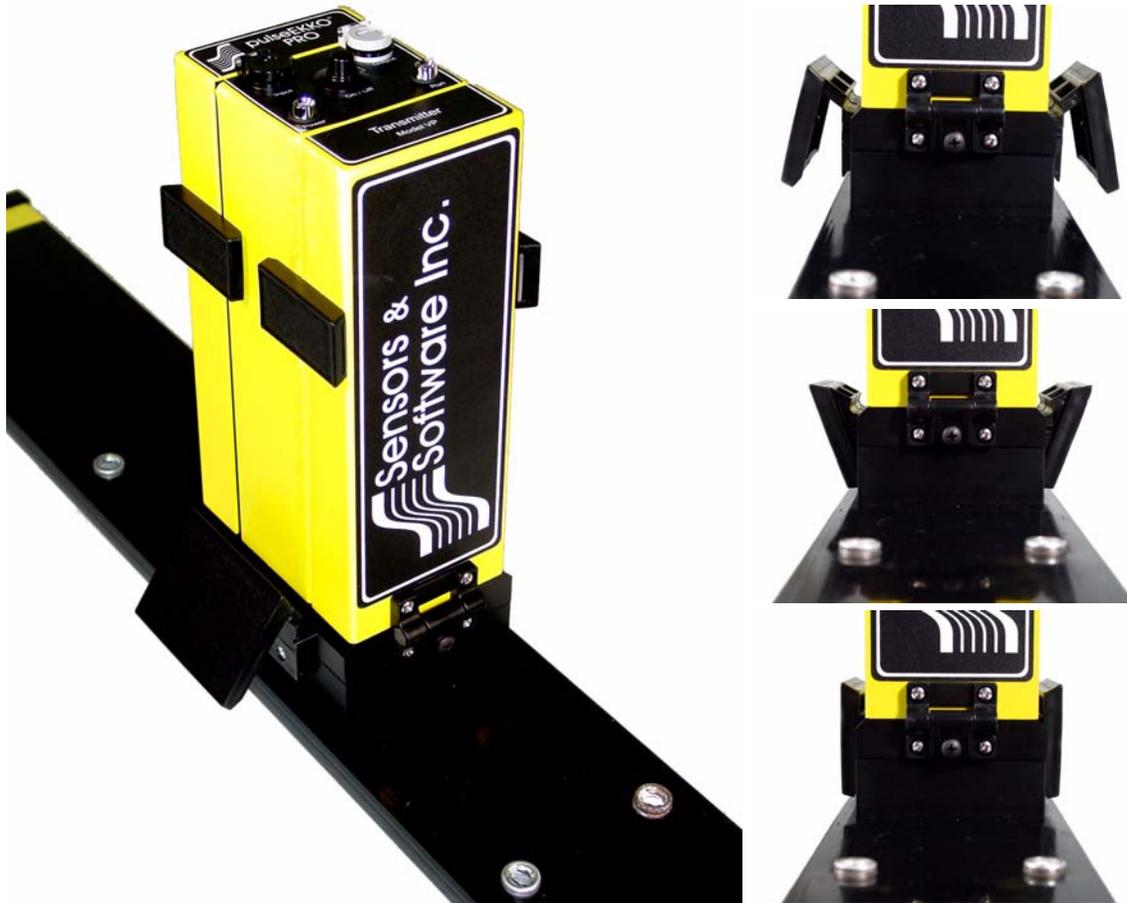


*Figure 2-9:  Attaching the Transmitter and Receiver to the antennas.*

## 2.2.6   Inserting Batteries into the Transmitter and Receiver

With the transmitter and receiver power switched OFF, unlatch the 2 battery covers on the sides of the electronics and open (Figure 2-10). Place one 12-volt battery on each side on the electronics boxes making sure the positive (+) terminal faces inward toward the electronics (Figure 2-11). The battery is "keyed" with a notch in one side so it only fits properly in this orientation. Close and latch the battery covers.



*Figure 2-10:  Opening the battery compartment doors.*



*Figure 2-11:  Insert the 12 Volt battery into the battery compartment making sure that battery polarity is correct. The positive (+) terminal faces inward. The battery is "keyed" so it will only seat properly in the compartment if it is in the correct orientation.*

### 2.2.7  Connecting the Fibre Optic Cables

The next step is to connect the transmitter and receiver to the control module.

a)  The pulseEKKO PRO low frequency system uses 2 dual fibre optic cables like the one shown in Figure 2-12. These cables typically come in lengths of 2.5, 5 and 20 metres. The 5 metre cables are standard for the Full Bistatic system (Section 3: P19). The 2.5 metre cables are usually used on the Antenna SmartCart (Section 5: P23) while the 20 metre cables are used with the 12.5 and 25 MHz antennas or when collecting low frequency CMP data (Section 16.11: P132).

   The fibre optic cables should be properly cared for (Section 19.6: P155), tested periodically (Section 17.2: P141) and inspected for kinks or signs of damage and repaired if necessary (Section 19.7: P156).



*Figure 2-12:  Dual fibre optic cable used with the transmitter and receiver. The black and grey strain reliefs on the end of the cable (left) plug into the same coloured fibre optic receptacles on the top of the transmitter and receiver (see Figure 2-13). The connection on the other end of the cable (right) connects to either fibre optic receptacle on the control module (see Figure 2-14).*

b)  To connect the pulseEKKO PRO in the standard configuration shown in Figure 3-1, plug the dual fibre optics cable into the transmitter making sure the colour on the strain relief jacket matches the colour of the receptacle door, black to black and grey to grey (Figure 2-13). Confirm that the fibre optic connection is seated properly by pushing down gently until the connection "clicks" into place.



*Figure 2-13:  Attaching the fibre optic cables to the transmitter and receiver. Make sure to match the connector colour to the door colour (grey to grey and black to black). Push the fibre optic cable down until you can feel it "click" into place.*

c)   The pulseEKKO PRO system can be used with a pulseEKKO 100 transmitter (Section 13.2.8: P76). If the transmitter is a pulseEKKO 100 transmitter, the fibre optic **Output** connection on the transmitter should **NOT** be connected. Also, see the information about the low battery warning message when data are collected with a pulseEKKO 100 transmitter (Section 17.1.3.1: P140).

d)   After attaching the dual fibre optic cables to the transmitter and receiver, the other end of the fibre optic cables are attached to the fibre optic converters on the control module (Figure 2-14). The fibre optic cable from the transmitter connects to the fibre optic converter labelled 4. The fibre optic cable from the receiver connects to the fibre optic converter labelled 5. Note that the fibre optic connection at the control module is keyed and will only attach properly in one orientation.



*Figure 2-14:  The dual fibre optic cable from the transmitter and receiver attaches to the electrical to fibre optic converters on the control module. The fibre optic cable from the transmitter connects to the control module receptacle labelled 4 while the fibre optic cable from the receiver connects to the control module receptacle labelled 5. This connection is keyed so it will only attach when the fibre optic cable is in the orientation shown.*

## 2.3    Bi-Static Transducer Assembly

### 2.3.1   High Frequency Bi-Static Transducers

The pulseEKKO PRO can be used with many different antennas. Low frequency antennas in the range from 12.5 to 200 MHz were shown earlier (see Figure 2-5).

There are also 3 high frequency, shielded, bistatic antennas available: 250, 500 and 1000 MHz (Figure 2-15). Each antenna box is really a "transducer" because it consists of both an antenna and the electronics. The transmitting transducer is indicated with a "T" on the label, e.g. T500, while the receiving transducer is indicated with an "R" on the label, e.g. R500.

The best frequency of antenna to use on a survey depends on the survey objectives (see Antenna Frequency, Section 13.2.1: P68)
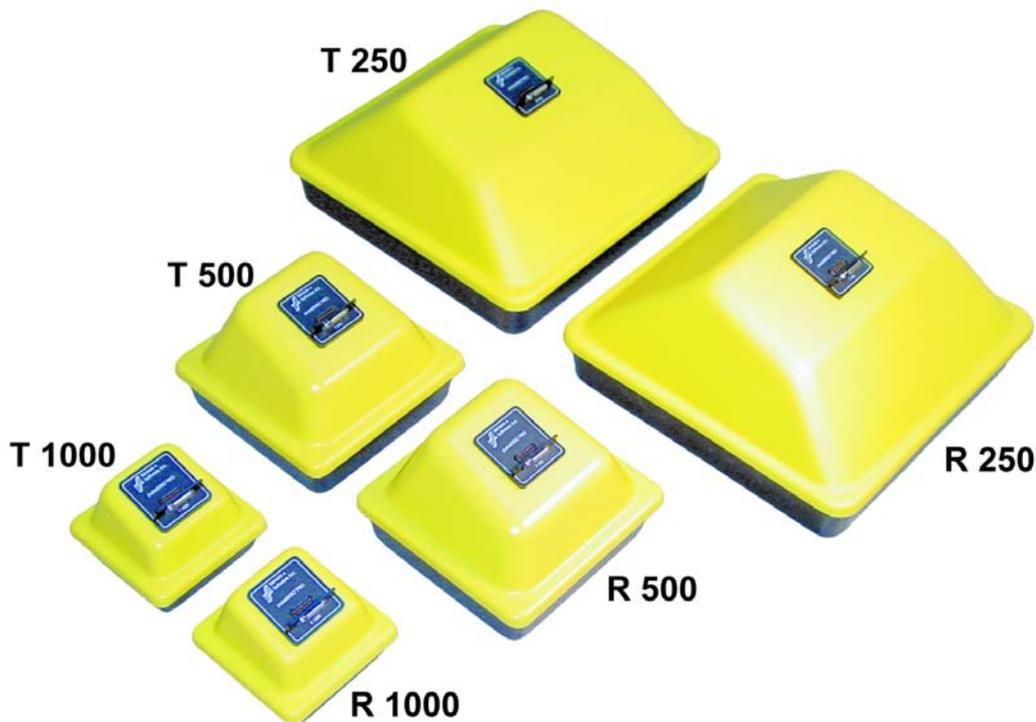


*Figure 2-15:  High frequency, shielded, bistatic antennas available for the pulseEKKO PRO. The antennas come in pairs, one transmitting transducer and one receiving transducer. These are indicated by an "T" and "R" on the labels. The 1000 MHz transducers are 14.5 cm (6 in) across, the 500 MHz transducers are 22.5 cm (9 in) across and the 250 MHz transducers are 38 cm (15 in) across and all are square.*

The procedure for attaching the transducers to the skid plate and attaching to the adjustable tow handle is described below.

### 2.3.2   Mounting Transducers to the Skid Plate

Skid plates are sized to fit a pair of transducers positioned side by side. The completed transducer - skid plate assembly attaches readily to the Hand Tow Handle (Section 7.1: P32), Big and Little Wheel Odometers (Section 7.2: P33) and the SmartCart (Section 8: P37).



*Figure 2-16:  Mounting the transducers onto the skid plate. The skid plate assembly consists of the bottom piece and two side flanges (top). The transducers are placed onto the bottom skid plate with the labels facing the same direction (middle). While the transducers can go in either the front or back position, data quality is slightly improved if the receiving transducer is placed in the back position when hand towing the transducers or using them on a SmartCart. The transducers are held onto the skid plate by placing the two flanges over the mounting posts. The above images show the assembly of the 500 MHz transducers onto the 500 MHz skid plate. The procedure for the 250 and 1000 MHz transducers onto their skid plates is exactly the same.*

### 2.3.2.1    Connecting the Transducer Cables

Transducer cables connect the transducers to the control module. They come in lengths of 2, 3, 10 and 30 metres.



*Figure 2-17:  Standard transducer cable used with 250, 500 and 1000 MHz transducers. The female end of the cable connects and latches to the transducer (Figure 2-18), while the male end connects to the control module (Figure 2-19).*



*Figure 2-18:  Connecting the transducer cables to the transducers. The connections are secured with latches.*

*Figure 2-19: Connecting the transducer cables to the Control Module. The transducer cables from the transmitting and receiving transducers connect to the control module into either the receptacle labelled 4 or 5. The "smart" electronics figures which device is connected to which receptacle. The cable attachments are secured with latches.*

Review the section on cable care (Section 19.2: P153) for more information about working with GPR system cables.

### 2.3.2.2 Transducer Cables with Odometer and Beeper/Trigger Receptacles

Some transducer cables have receptacles at the transducer connection to support accessory items like odometers and remote beeper\triggers.



*Figure 2-20: Transducer cable with odometer or beeper/trigger receptacle at the transducer end of the cable (circled). Along with the standard transducer cable, some system configurations, like the Hand Towed system, come with transducer cables that support odometer input (Section 7: P31) and beeper/trigger input.*

The odometer transducer cable has a receptacle at the transducer end of the cable that allows an odometer to be connected to the system. The most common use of this cable is with the Hand Towed system (Section 7: P31).

Review the section on cable care (Section 19.2: P153) for more information about working with GPR system cables.

## 2.4    TR1000 Transducer

The pulseEKKO PRO has a second 1000 MHz transducer available. It is a mono-static, shielded transducer with a built-in odometer wheel called the TR1000. The assembly of the system with the TR1000 transducer is described in Section 9: P41

# 3    Full Bistatic System Assembly

This section describes the assembly of the Full Bistatic system pictured in Figure 3-1.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) and the transmitter and receiver assemblies (Section 2.2: P6), has been completed.

Complete system configurations for data acquisition are shown later (Section 16.1: P119).
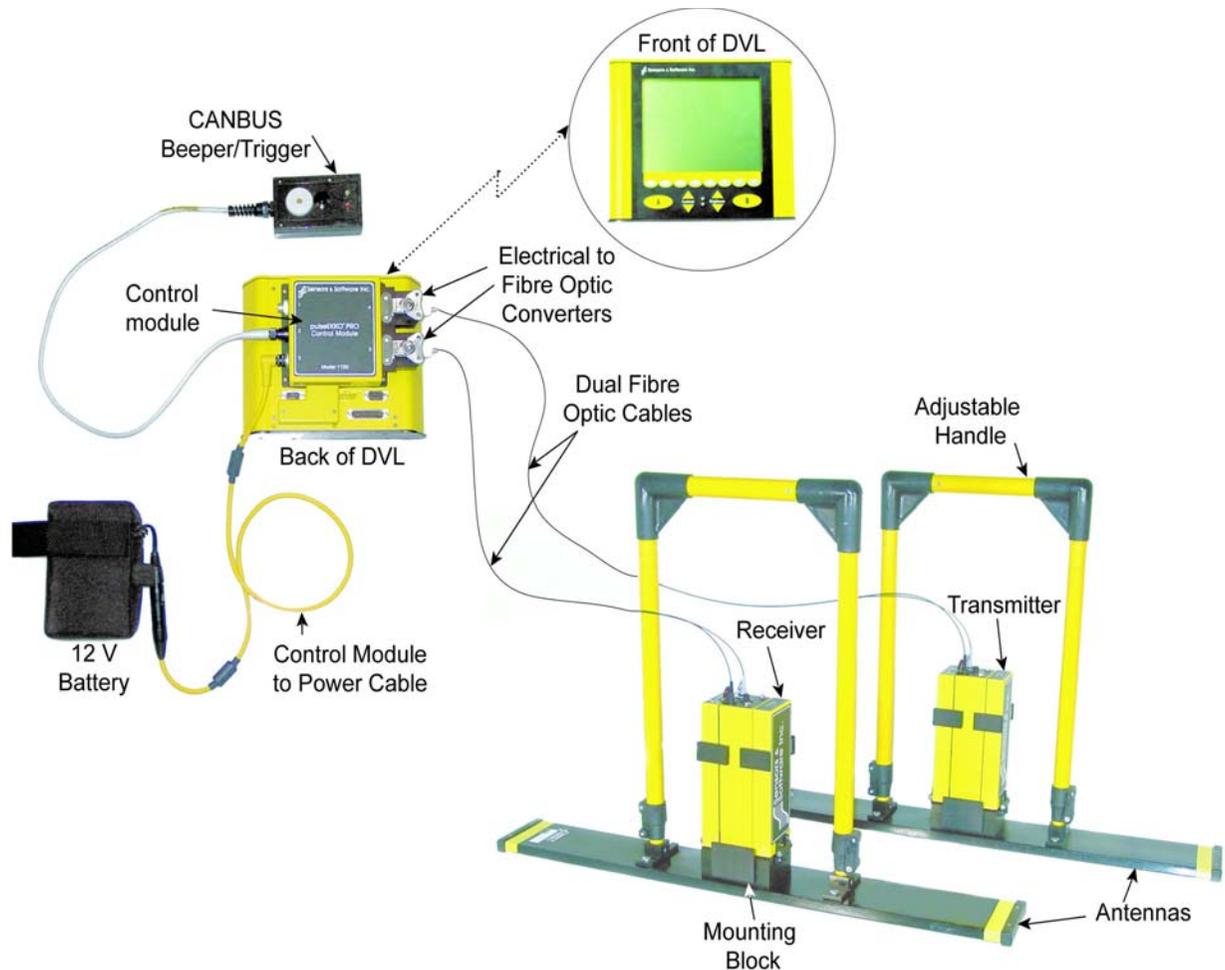


*Figure 3-1:  The complete low frequency pulseEKKO PRO hand held Assembly*

# 3.1   Attaching Handles

## 3.1.1   Attaching the Adjustable Handles

Attach the adjustable handle to the antenna using the flat head screwdriver to tighten the 4 quarter-turn fasteners as with the mounting block (Figure 3-2).

This handle can then be adjusted for height by loosening the 2 levers by hand, moving the handle to the desired height and retightening the levers (Figure 3-3).

*Figure 3-2:  Attach the adjustable handles to the antennas by tightening the 4 quarter-turn fasteners. Adjust the height of the handle by loosening the levers at the base of the handles (right) and pulling the handles up to the correct height.*
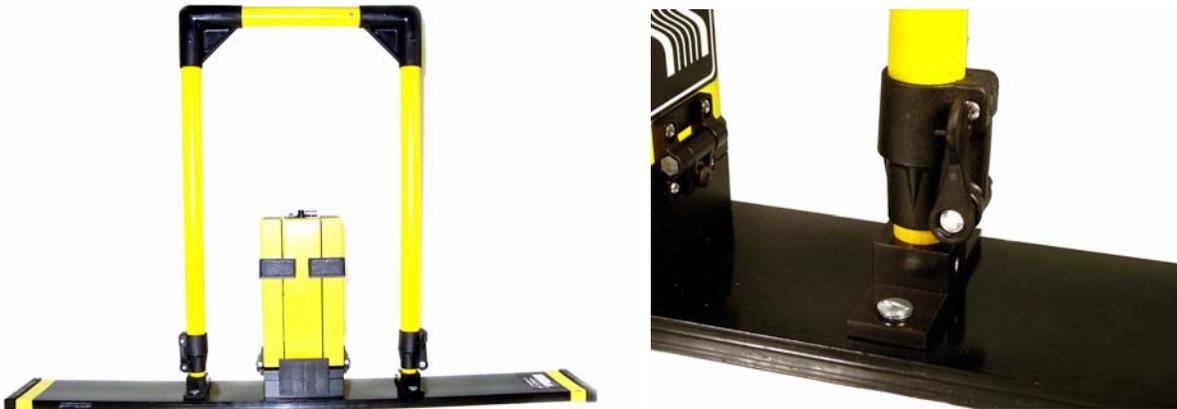
*Figure 3-3:  Once the handles have been adjusted to the correct height, lock them into place by tightening the levers as shown on the right.*

# 4    One-Man System Assembly

This section describes the assembly of the One Man system pictured in Figure 4-2. It is very similar to the Full Bistatic system pictured in Figure 3-1 except for the different handles.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) and the transmitter and receiver assemblies (Section 2.2: P6), has been completed.

Complete system configurations for data acquisition are shown later (Section 16.1: P119).

## 4.1    Attaching the One-Man Handles

Attach the optional one-man handle to the antennas using the flat head screwdriver to tighten the 4 quarter-turn fasteners as with the mounting block (Figure 3-2).

The DVL tray can be added to the one-man handles as shown in Figure 4-2. Note that the DVL, like all computers, generates electromagnetic noise. While it was designed to minimize these effects, if banding is observed in the data, moving the DVL further from the receiver may alleviate this problem.



*Figure 4-1:  The One-man handles attach to the antennas using quarter-turn fasteners.*

*Figure 4-2:  Complete One-Man Handle Assembly. The DVL tray can be attached to the middle bar (as shown), the top bar or the DVL can be carried by a second operator. In the configuration shown, the DVL can be a source of noise so, if you see banding in the data, this may be alleviated by moving the DVL away from the receiver.*

# 5    Antenna SmartCart System Assembly

This section describes the assembly of the SmartCart with low frequency antennas pictured in Figure 5-1. The 200, 100 and 50 MHz antennas can be attached to the SmartCart to allow rapid data acquisition in areas that are flat and smooth like roads and golf courses.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) and the transmitter and receiver assemblies (Section 2.2: P6), has been completed.

Complete system configurations for data acquisition are shown later (Section 16.1: P119).
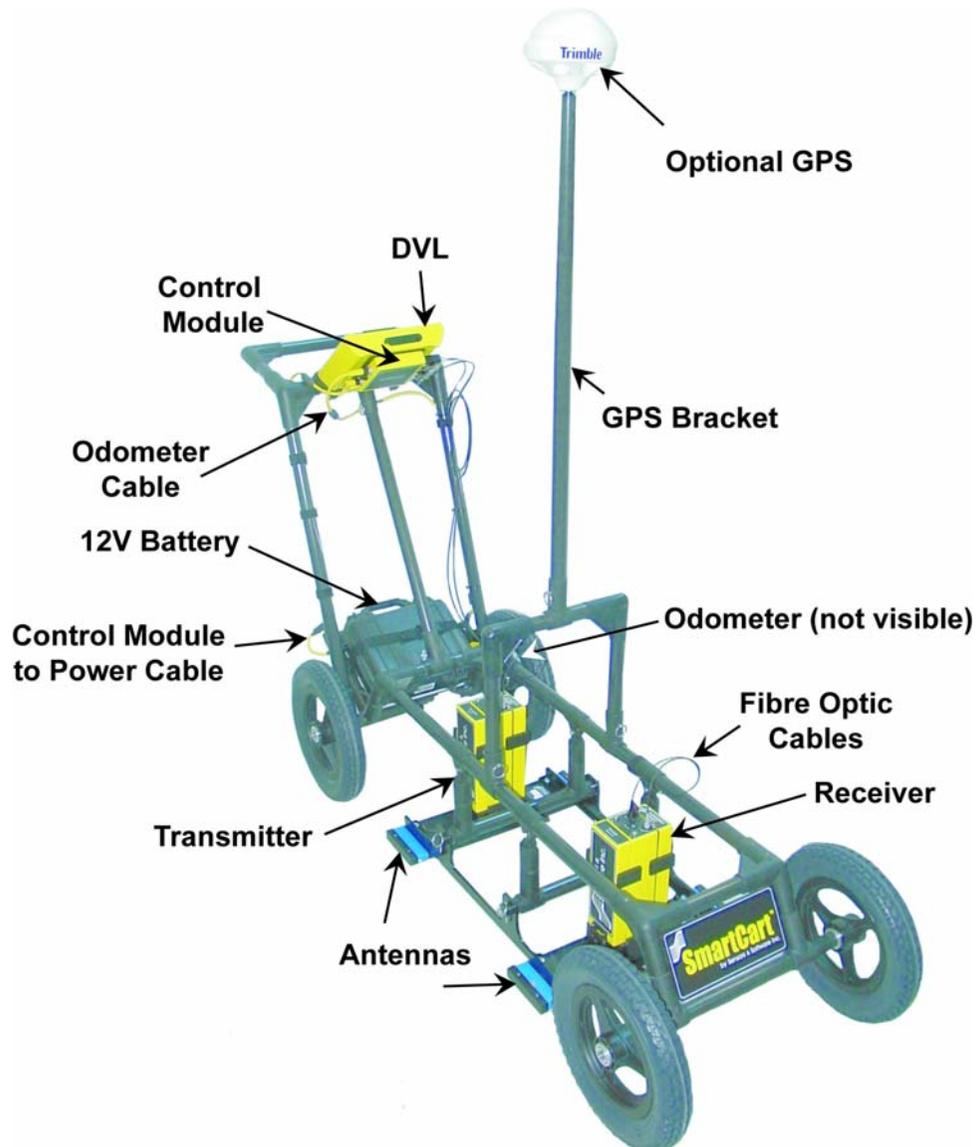


*Figure 5-1:  The complete low frequency antenna SmartCart configuration including the optional GPS. To reduce noise, it is recommended that the receiver go in the front of the SmartCart, furthest away from the DVL. The odometer cable connects to receptacle 1 on the control module. This configuration typically uses the 2.5 m fibre optic cables, although cables of any length can be coiled up and used. Cables should be secured to the frame of the cart using velcro strips or electrical tape.*

The SmartCart has 0.5m separation bars for the 200 MHz antennas and 1m separation bars for the 50 MHz antennas. The 100 MHz antennas can be used with either separation bar. The assembly of the 0.5m separation bars is shown in Figure 5-2 and the complete assembly attached the SmartCart is shown in Figure 5-3.
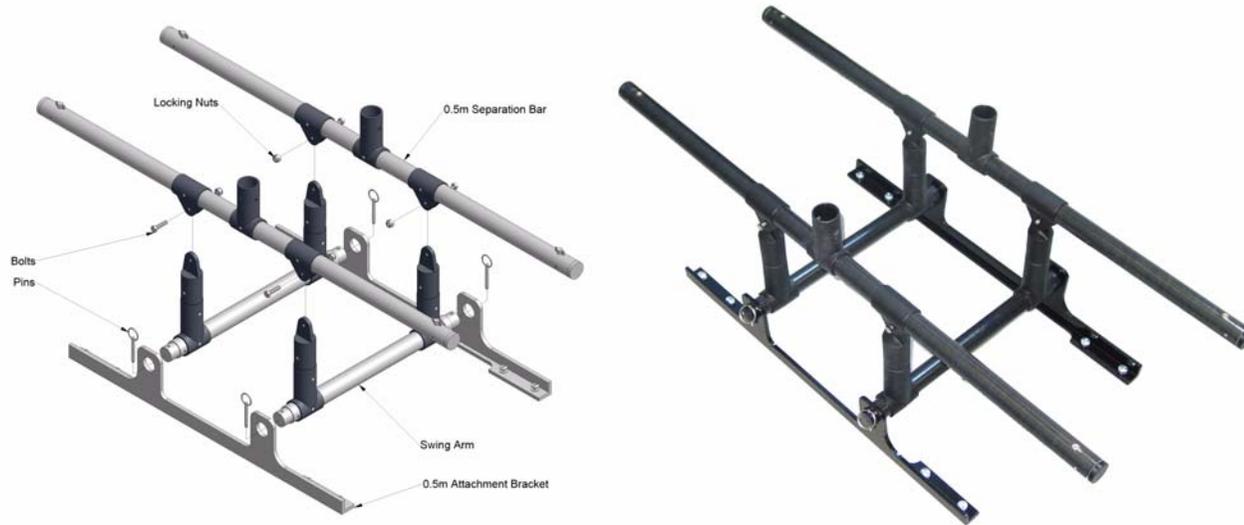


*Figure 5-2:  Assembling the 0.5m separation bars. The 1m separation bars are assembled in a similar way.*



*Figure 5-3:  Attach the separation bars to the front and rear axle assemblies of the SmartCart using the finger screws (left). Be careful to align the screws so they go in straight. If the screws are forced in the threads can be stripped. The SmartCart with the 0.5m separation bars attached is shown on the right.*

## 5.1    Attaching Antennas

The antennas are attached to the bottom of the separation bars using quarter-turn fasteners. Figure 4-1 shows how this is done. It is best to attach the antennas to the SmartCart BEFORE attaching the transmitter and receiver (with batteries inside) to the antennas.

Data quality is highest when the receiver is placed in the front of the SmartCart, furthest away from the DVL.

## 5.2    Attaching the Battery

The SmartCart comes with one of two different sized batteries: a larger, heavier 17 Amp-hr battery in a black box and a smaller, lighter 9 Amp-hr battery in a grey box (Figure 5-4).



*Figure 5-4:  SmartCart 12V batteries. The black case holds a 17 Ah battery and the grey case holds a 9 Ah battery. The SmartCart can come with either battery.*

The battery is placed in the angled frame on the back of the SmartCart behind the rear axle. The battery should be secured into place with the belt (Figure 5-5).



*Figure 5-5:  The 12 volt battery sits on a mounting tray behind the rear axle. The larger black battery (left) is secured using the belt from the side to side. The smaller grey battery (right) is secured using the belt from front to back.*

## 5.3   Attaching DVL and Control Module

The DVL and Control Module are attached to the DVL tray on the SmartCart (Figure 5-6).



*Figure 5-6:  Attaching the digital video logger (DVL). Step 1: Depress flexible clip. Step 2: Slide DVL onto shelf. Make sure the DVL is secure in the tray before letting go.*

## 5.4   Connecting the Odometer

The SmartCart odometer cable attaches to receptacle 1 on the control module.



*Figure 5-7:  The SmartCart odometer connects to receptacle 1 on the control module.*

To acquire data with the SmartCart odometer, the Trigger Method must be set to Odometer (Section 13.3.1.2: P78).

When collecting data with an odometer, data quality can be increased using the DynaQ stacking option (Section 13.2.7.1: P75)

Ensure that it is properly calibrated for accurate distance measurement (Section 13.3.5.1: P84).

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value (Section 13.3.5.2: P84).

# 6    Borehole System

The pulseEKKO PRO can also use borehole antennas to conduct crosshole surveys. These surveys are described under Survey Types (see Section 13.4.5: P87) and Borehole GPR (see Section 16.12.1: P134). Appendix I: pulseEKKO PRO Borehole Data Acquisition has details about borehole GPR surveys.

# 7    Hand Towed System Assembly

This section describes the assembly of the Hand Towed system pictured in Figure 7-1.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) and transducer assembly (Section 2.3: P13), has been completed.

Complete system configurations for data acquisition are shown later (Section 16.1: P119).
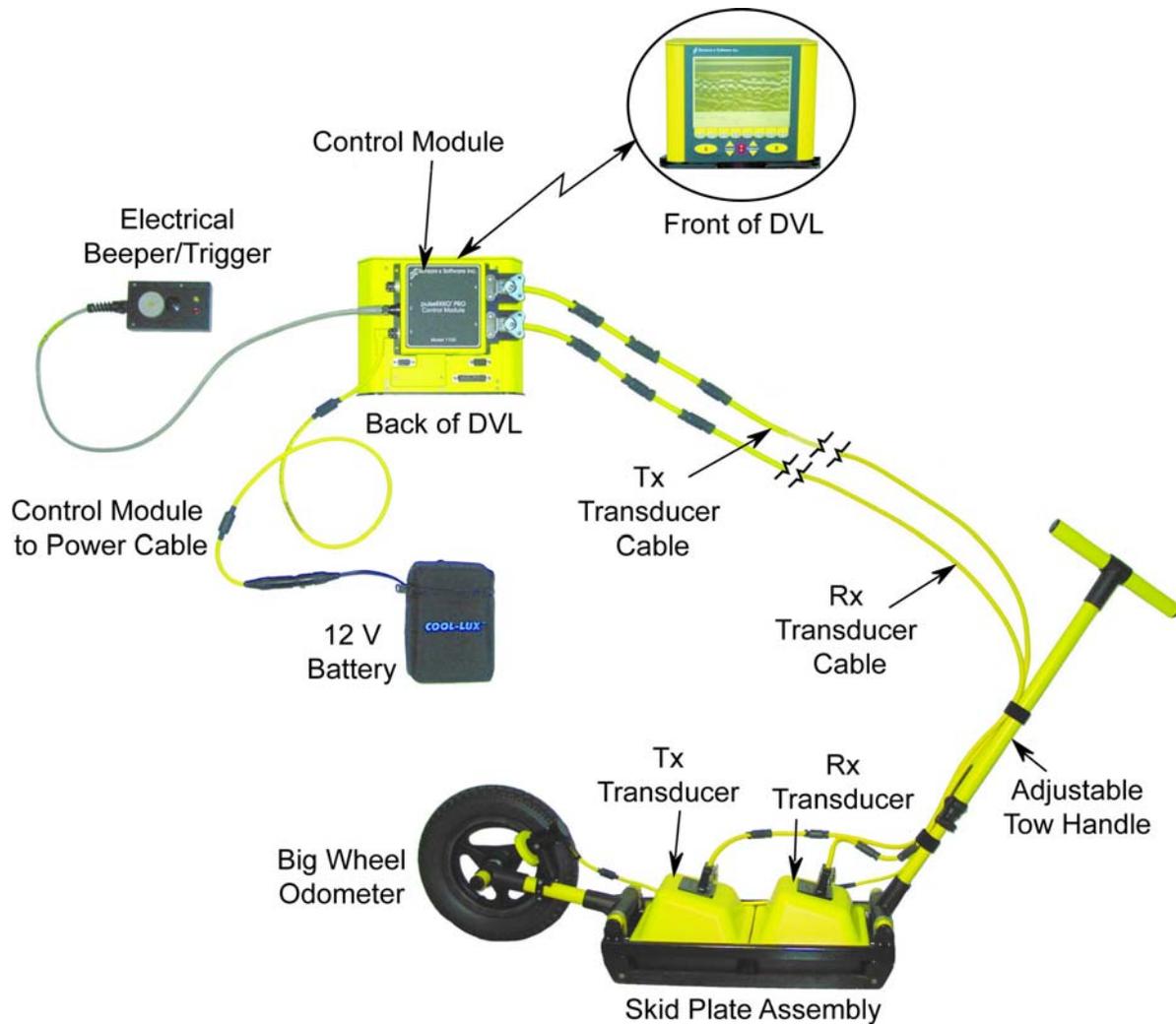


*Figure 7-1:  The complete high frequency pulseEKKO PRO tow mode assembly. The odometer cable connects to the odometer receptacle on the transducer cable.*

## 7.1   Attaching the Adjustable Tow Handle



*Figure 7-2: To attach the adjustable tow handle to the skid plate assembly, place the T end of the handle into the trough on the end of the skid plate assembly where the receiving transducer label is facing. The T end of the handle is attached to the skid plate assembly by placing the U-bracket over the top and into the vertical slots. The handle is secured into place by inserting the metal pins into the holes at the bottom of the U bracket.*

## 7.2   Attaching a Wheel Odometer

The Hand Tow system can collect data in Free Run mode or odometer mode (Section 13.3.1: P77). Two different wheel odometers are available. This section describes how to attach the odometers to the Hand Tow system.



*Figure 7-3:  The Hand Tow system has two different odometers for collecting data with an equal step size between traces. In rough conditions the Big Wheel Odometer (top) can be used. In flat, smooth areas the Small Wheel Odometer (bottom) can be used.*

### 7.2.1   Attaching the Big Wheel Odometer



*Figure 7-4:  The big wheel odometer. Ensure that the small yellow odometer is tightly pressed against the rim of the wheel so that it spins when the big wheel is rotated.*



*Figure 7-5:  The big wheel odometer attaches to the skid plate assembly exactly the same way as the adjustable tow handle is attached. Place the T end of the odometer into the trough on the end of the skid plate assembly. The labels on the transmitting transducer should be facing away from this end. The T end of the odometer is attached to the skid plate assembly by placing the U-bracket over the top and into the vertical slots. The odometer is secured into place by inserting the metal pins into the holes at the bottom of the U bracket.*

### 7.2.2  Attaching the Small Wheel Odometer



*Figure 7-6:  The small wheel odometer (top) attaches to the skid plate assembly by inserting the metal post into the hole on the end of the skid plate (middle). The odometer is secured into place by inserting the metal pin into the vertical hole on the edge of the skid plate (bottom).*

## 7.2.3  Odometer Settings

To acquire data with a Big Wheel or Small Wheel odometer, the Trigger Method must be set to Odometer (Section 13.3.1.2: P78).

When collecting data with an odometer, data quality can be increased using the DynaQ stacking option (Section 13.2.7.1: P75).

Ensure that it is properly calibrated for accurate distance measurement (Section 13.3.5.1: P84).

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value (Section 13.3.5.2: P84).

# 8    Transducer SmartCart System Assembly

This section describes the assembly of the SmartCart system with transducers pictured in Figure 16-11.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) and transducer assembly (Section 2.3: P13), has been completed.

## 8.1   SmartCart Assembly

The SmartCart has separation bars for the 250, 500 and 1000 MHz transducers. The 500 MHz separation bars are shown in Figure 8-1.



*Figure 8-1:  Assembling the 500 MHz separation bars. The 250 and 1000 MHz separation bars are assembled in a similar way.*



*Figure 8-2:  Attach the separation bars to the front and rear axle assemblies of the SmartCart using the finger screws (left). Be careful to align the screws so they go in straight. If the screws are forced in the threads can be stripped. The SmartCart with the 500 MHz separation bars attached is shown on the right.*

## 8.2    Attaching Transducers

The skid plate with the transducers attaches to the bottom of the separation bars in the same manner as it attaches to the transducer handle and big wheel odometer, using U brackets and pins. See Figure 7-2 and Figure 7-5.

Data quality is highest when the receiving transducer is placed in the front of the SmartCart, furthest away from the DVL.

## 8.3    Attaching the Battery

The SmartCart comes with one of two different sized batteries: a larger, heavier 17 Amp-hr battery in a black box and a smaller, lighter 9 Amp-hr battery in a grey box (Figure 8-3).



*Figure 8-3:  SmartCart 12V batteries. The black case holds a 17 Ah battery and the grey case holds a 9 Ah battery. The SmartCart can come with either battery.*

The battery is placed in the angled frame on the back of the SmartCart behind the rear axle. The battery should be secured into place with the belt (Figure 8-4).



*Figure 8-4:  The 12 volt battery sits on a mounting tray behind the rear axle. The larger black battery (left) is secured using the belt from the side to side. The smaller grey battery (right) is secured using the belt from front to back.*

## 8.4   Attaching DVL and Control Module

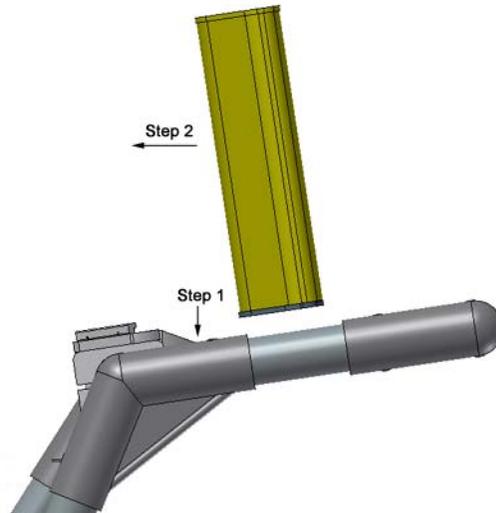The DVL and Control Module are attached to the DVL tray on the SmartCart (Figure 5-6).
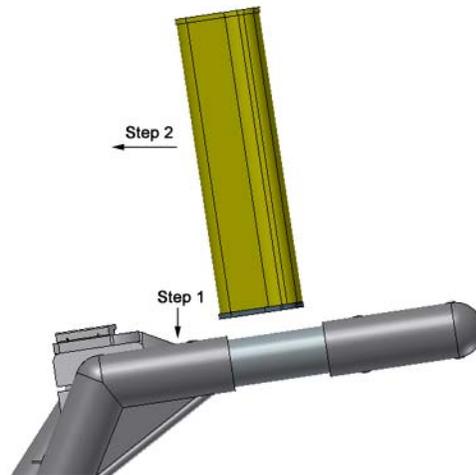


*Figure 8-5:  Attaching the digital video logger (DVL). Step 1: Depress flexible clip. Step 2: Slide DVL onto shelf. Make sure the DVL is secure in the tray before letting go.*

## 8.5   Connecting the Odometer

The SmartCart odometer cable attaches to receptacle 1 on the control module.



*Figure 8-6:  The SmartCart odometer connects to receptacle 1 on the control module.*

To acquire data with the SmartCart odometer, the Trigger Method must be set to Odometer (Section 13.3.1.2: P78).

When collecting data with an odometer, data quality can be increased using the DynaQ stacking option (Section 13.2.7.1: P75)

Ensure that it is properly calibrated for accurate distance measurement (Section 13.3.5.1: P84).

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value (Section 13.3.5.2: P84).

# 9    TR1000 Transducer System

This section describes the assembly of the TR1000 Transducer system pictured in Figure 9-1.

Before assembling this configuration, ensure the assembly of the DVL and Control module (Section 2.1: P3) has been completed.

Complete system configurations for data acquisition are shown later (Section 16.1: P119).
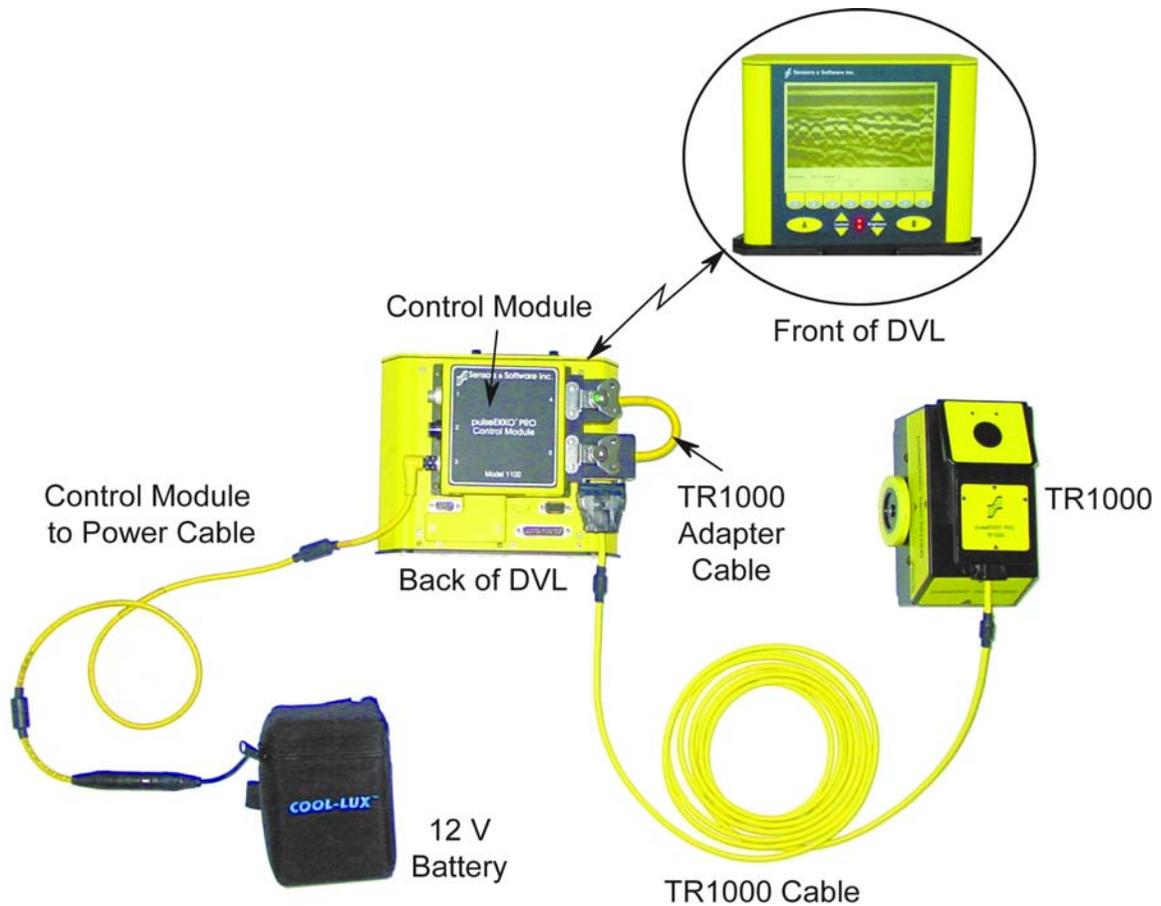


*Figure 9-1: The complete setup of the TR1000 system.*

## 9.1    TR1000

The TR1000 transducer contains 1000 MHz transmitting and receiving antennas, electronics, an electrical beeper/trigger and an odometer wheel, all in one housing. The odometer wheel is spring-loaded so the unit must be pushed down so it makes good contact with the surface during data acquisition. The bottom of the TR1000 has a replaceable wear pad.

The TR1000 cable receptacle is located under the handle.
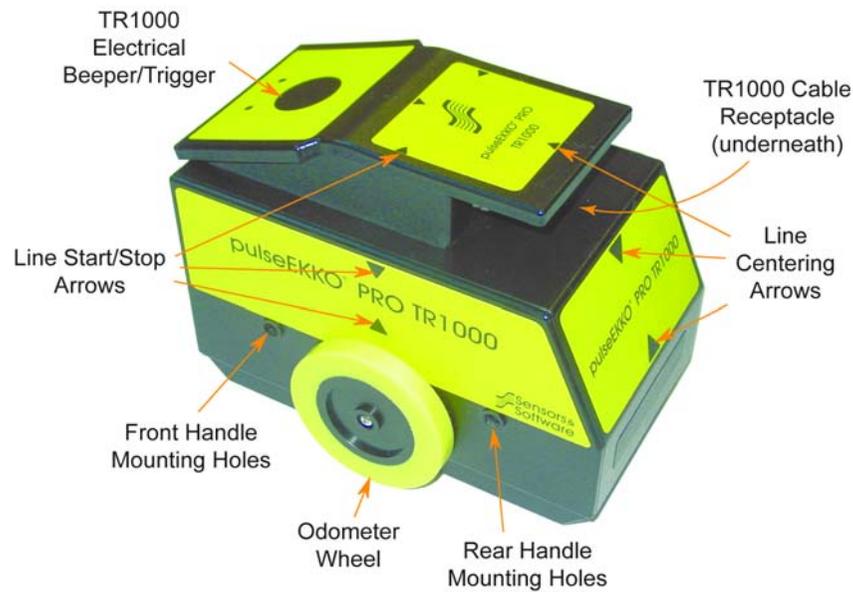
*Figure 9-2: Features of the TR1000. This view shows the back of the unit with the front on the left.*

Survey lines should start and stop based on the arrows above the odometer wheel. Similarly, survey lines should be centered on the arrows on the front and back.

The electrical beeper/trigger button on the TR1000 can serve two functions:

1) When the Trigger Method is set to Odometer (Section 13.3.1: P77), the button can be pressed to add fiducial markers during data collection (Section 15.4: P109) or,

2) When the Trigger Method is set to Electrical Trigger (Section 13.3.1: P77), the button can be pressed to collect one trace of data.

Note that the standard electrical beeper/trigger (Section 11.1: P51) will not operate if it is attached to the control module when using the TR1000. The beeper/trigger functions can only be performed by the TR1000 electrical beeper/trigger.

The TR1000 has 2 sets of holes for mounting the optional handle (Section 9.3: P46) at different positions.

## 9.2    Connecting the Cables

### 9.2.1   TR1000 Adapter Cable

The TR1000 Adapter Cable connects the two transducer cable receptacles on the control module together. Ensure the end of the cable with the extra receptacle is connected to the lower receptacle on the control module as shown in Figure 9-4.



*Figure 9-3:  TR1000 Adapter Cable. The left end has an extra receptacle for the TR1000 cable to connect to.*



*Figure 9-4:  Connecting the TR1000 Adapter cable to the Control Module. The end with the extra receptacle on the side needs to be attached to the bottom receptacle on the Control Module.*

## 9.2.2  TR1000 Cable

The TR1000 cable is available in lengths of 5 or 10 meters (16 and 33 feet).
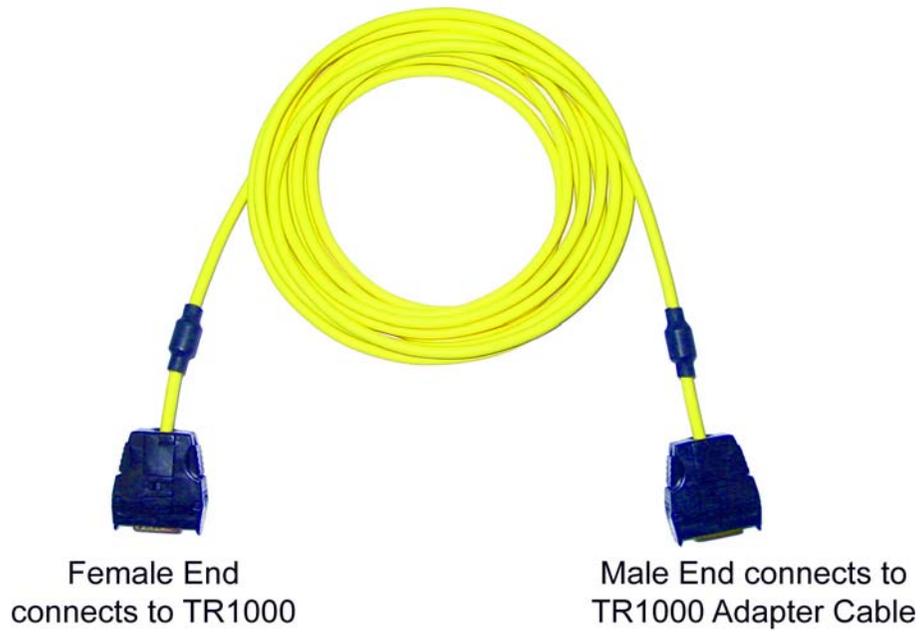


*Figure 9-5:  TR1000 transducer cable.*
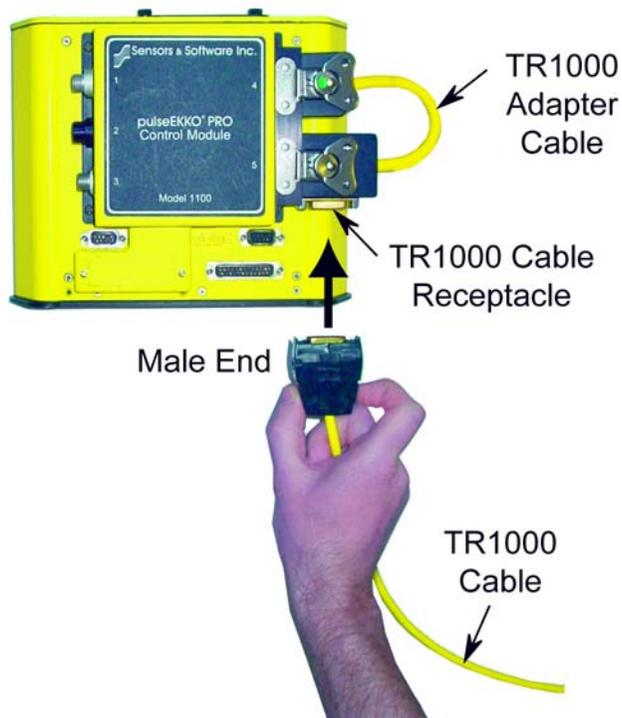


*Figure 9-6:  Connecting the male end of the TR1000 cable to the receptacle on the TR1000 Cable Adapter.*
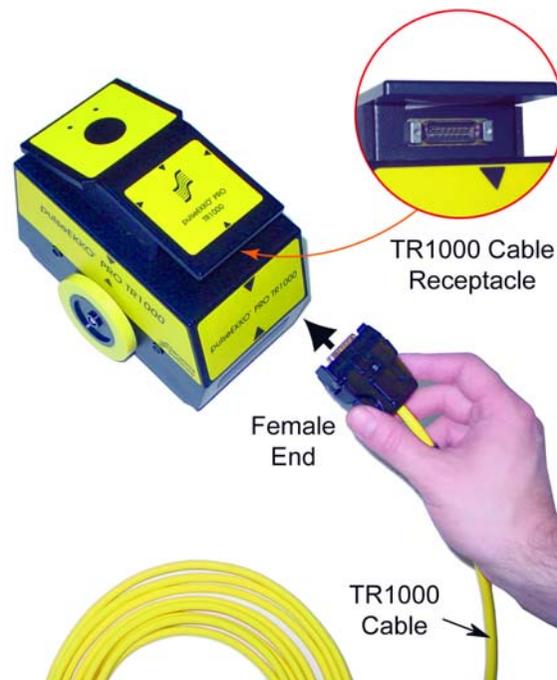
*Figure 9-7:  Connecting the female end of the TR1000 cable to the TR1000.*

When disconnecting the TR1000 cable from the TR1000 or the TR1000 Adapter Cable, it is necessary to squeeze the connector release tabs on either side of the connector.

Review the section on cable care (Section 19.2: P153) for more information about working with GPR system cables.

## 9.3   TR1000 Handle

The TR1000 has an optional handle to allow the user to stand up during data collection.

The handle usually attaches to the TR1000 using the rear mounting holes. To attach the handle, retract the spring-loaded knobs on the end of the handle, align to the two mounting holes and release the knobs to lock them into position.



*Figure 9-8:  Attaching the handle to the rear mounting holes (left) allows the TR1000 to be deployed from a standing position (right).*

There is an additional set of handle mounting holes at the front of the TR1000 which can be used when scanning a vertical surface or in confined spaces when it is preferable to pull the TR1000 towards the user rather than pushing it.



*Figure 9-9:  Attach the handle to the front mounting holes when scanning vertical walls or for situations when it is preferable to collect data by pulling the TR1000 towards the operator.*

## 9.4   TR1000 Odometer Setup

To acquire data with the TR1000 odometer, the Trigger Method must be set to Odometer (Section 13.3.1.2: P78).

Ensure that it is properly calibrated for accurate distance measurement (Section 13.3.5.1: P84).

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value (Section 13.3.5.2: P84).

# 10   Multi-Channel System

The pulseEKKO PRO allows multi-channel data collection. These types of surveys are described in Appendix J: pulseEKKO PRO Multi-Channel Data Acquisition.

# 11   Adding Accessories

There are several accessories that can be connected to the pulseEKKO PRO system. These include two types of beeper/triggers, odometers, GPS and the DVL Carrier. These are described below.

## 11.1  Electrical Beeper/Trigger Unit

The Electrical Beeper/Trigger is an optional accessory with the pulseEKKO PRO system.

To connect the electrical beeper/trigger unit, attach it to receptacle 2 on the control module (Figure 11-1). This connector will only attach to the number 2 receptacle on the control so there is no chance of error.

**The electrical beeper/trigger must be connected to the control module BEFORE the DVL is turned on.** It is only on bootup that the control module senses the presence of the electrical beeper/trigger.
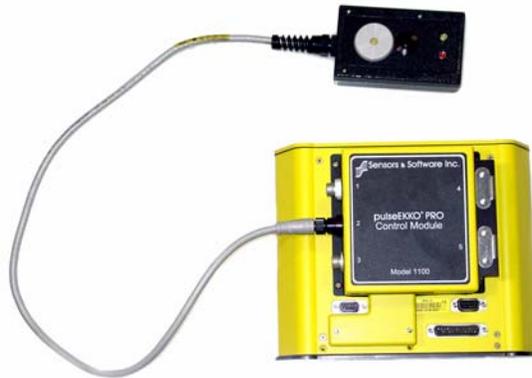


*Figure 11-1:  Attach the electrical Remote Beeper/ Trigger unit to the control module receptacle labelled 2.*

The Electrical Beeper/Trigger has 2 lights; one yellow and one red. The yellow light will be on when the beeper/trigger is communicating properly with the system and flash if there is no communication. The red light is normally off but starts flashing to indicate that the power to the control module is getting low.

Depending on the setting of the Trigger Method (Section 13.3.1: P77), the electrical beeper/trigger is used in different ways:

**Electrical:** When the radar system is run with the Trigger Method set to Electrical (Section 13.3.1.1: P78), data acquisition of individual traces can be controlled using the button on the electrical beeper/trigger unit. As well, during data acquisition, the beeper will emit a sound as data are being collected, as long as the Beeper Activated option (Section 13.3.2: P79) is set to Electrical.

**DVL Button:** Another method of triggering the system is to set the Trigger Method to DVL button (Section 13.3.1.1: P78) and the Beeper Activated option to Electrical (Section 13.3.2: P79). Pressing the B button the DVL will trigger the system to acquire a data trace and an audible beep from the electrical beeper/ trigger unit will indicate when a data trace is being collected.

**Free Run:** If the Trigger Method is set to Free Run (Section 13.3.1.1: P78) and the Beeper Activated option to Electrical (Section 13.3.2: P79) data are collected continuously after a user-defined time delay (Section 13.3.3: P79). During data acquisition, there is an audible beep from the electrical beeper/trigger unit to indicate when a data trace is being collected. Pressing the button on the electrical beeper/trigger will save a fiducial marker with the next acquired trace (Section 15.4: P109).

**Odometer:** If the Trigger Method is set to Odometer (Section 13.3.1.2: P78) and the Beeper Activated option to Electrical (Section 13.3.2: P79) data are collected based on the turning of the odometer wheel and the Step Size (Section 13.2.5: P72). During data acquisition, there is an audible beep from the electrical beeper/trigger unit to indicate when a data trace is being collected. Pressing the button on the electrical beeper/trigger will save a fiducial marker with the next acquired trace (Section 15.4: P109).

If the DVL carrier is included as part of the system (see Section 11.2 DVL Carrier on page 55), the user may find it convenient to attach the electrical Beeper/Trigger to the frame of the DVL carrier.

## 11.1.1 Fibre Optic Beeper/Trigger Unit

The Fibre Optic Beeper/Trigger unit is an optional component for triggering the low frequency system to collect data. It serves the same function as the standard Electrical Beeper/Trigger (Figure 11-1) unit but can attach to the handle of the transmitting antenna so that the antenna operator can control the data collection.

To attach the Fibre Optic unit to the pulseEKKO PRO handles, insert the end of the hand screw through the hole in the adjustable handle attached to the transmitting antenna and tighten it into the unit (Figure 11-2).



*Figure 11-2:  Attaching the Fibre Optic Remote Beeper/Trigger unit to the transmitter handle.*

To connect the fibre optic remote beeper/trigger unit you should have the dual fibre optic cable for the control module to transmitter connection plus a short single fibre optic cable (Figure 11-3). One of the two cables on the dual fibre optic cable should already be connected to the **Input** (black) receptacle on the transmitter.

Figure 11-3 illustrates the proper connection of the Fibre Optic Remote Beeper/Trigger unit. Ensure that:

1) The second fibre optic cable of the dual cable connects to the **Output** (grey) fibre optic connector on the remote trigger and beeper unit. This connection enables the trigger part of the remote beeper/trigger unit to work.

2) The short single fibre optic cable connects from the **Input** (black) fibre optic connector on the remote trigger and beeper unit to the **Output** (grey) receptacle on the transmitter. This connection enables the beeper part of the remote beeper/trigger unit to work.

**Note that if you have a pulseEKKO 100 transmitter (Section 13.2.8: P76) you cannot use the pulseEKKO PRO fibre optic beeper/trigger.**
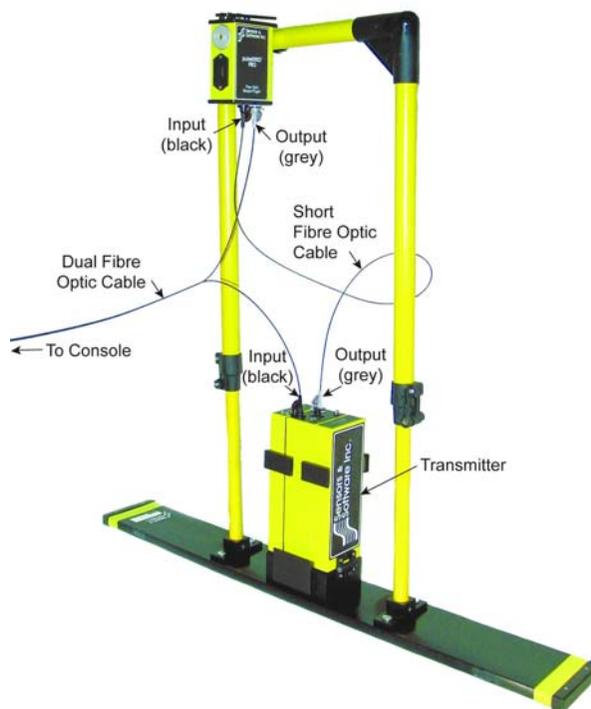


*Figure 11-3: Fibre optic cabling details for the Fibre Optic Remote Beeper/Trigger unit.*

The Fibre Optic Remote Beeper/Trigger unit is powered by one 9 Volt battery that slides into the battery compartment (Figure 11-4). Please note the proper polarity of the battery. An alkaline 9V battery will normally power the unit for 3-5 hours of heavy use so it is a good idea to have spare 9 Volt batteries available. Lithium 9V batteries are also available that will power the unit for approximately 20 hours. When the voltage from the battery is gets too low, the red light on the top of the Fibre Optic Remote (not visible in the figures) will start to flash. This indicates that the battery should be replaced within approximately 30 minutes.

*Figure 11-4: The Fibre Optic Remote Beeper/Trigger unit operates with a 9 Volt battery that can be accessed by opening the battery compartment on the side of the unit.*

To turn the Fibre Optic Remote Beeper/Trigger unit on, depress the thumb lever on the top of the unit and hold it down for 3 seconds. The red light will come on and start to flash. After 3 seconds the unit will beep 3 times and the red light will stop flashing and stay on. This indicates that the unit is ready for data collection.

To turn the Fibre Optic Remote Beeper and Trigger unit off, depress the thumb lever and hold it down for 3 seconds. After 3 seconds the unit will beep once and the red light will go out.

The fibre optic beeper/trigger will automatically turn off after 7 minutes of non-use.

Depending on the setting of the Trigger Method (Section 13.3.1: P77), the fibre optic beeper/trigger is used in different ways:

**Fibre Optic:** When the radar system is run with the Trigger Method set to Fibre Optic (Section 13.3.1.1: P78), data acquisition of individual traces can be controlled using the thumb lever on the fibre optic beeper/ trigger unit. As well, during data acquisition, the beeper will emit a sound as data are being collected, as long as the Beeper Activated option (Section 13.3.2: P79) is set to Fibre Optic.

**DVL Button:** Another method of triggering the system is to set the Trigger Method to DVL button (Section 13.3.1.1: P78) and the Beeper Activated option to Fibre Optic (Section 13.3.2: P79). Pressing the B button the DVL will trigger the system to acquire a data trace and an audible beep from the fibre optic beeper/ trigger unit will indicate when a data trace is being collected.

**Free Run:** If the Trigger Method is set to Free Run (Section 13.3.1.1: P78) and the Beeper Activated option to Fibre Optic (Section 13.3.2: P79) data are collected continuously after a user-defined time delay (Section 13.3.3: P79). During data acquisition, there is an audible beep from the fibre optic beeper/trigger unit to indicate when a data trace is being collected. **However, unlike the electrical beeper/trigger, pressing the button on the fibre optic beeper/trigger will NOT save a fiducial marker with the next acquired trace (Section 15.4: P109).**

**Odometer:** If the Trigger Method is set to Odometer (Section 13.3.1.2: P78) and the Beeper Activated option to Fibre Optic (Section 13.3.2: P79) data are collected based on the turning of the odometer wheel and the Step Size (Section 13.2.5: P72). During data acquisition, there is an audible beep from the fibre optic beeper/trigger unit to indicate when a data trace is being collected. **However, unlike the electrical beeper/trigger, pressing the button on the fibre optic beeper/trigger will NOT save a fiducial marker with the next acquired trace (Section 15.4: P109).**

## 11.2  DVL Carrier

For convenience during data acquisition, the DVL and control module can be carried using the optional DVL Carrier shown in Figure 11-5.



*Figure 11-5:  The DVL and control module can be attached to the optional DVL Carrier for hands-free operation. The DVL can be adjusted to optimize the view angle.*

## 11.3  Odometers

The pulseEKKO PRO system can accept an odometer input to trigger the system to acquire data at equal distance intervals (Step Sizes). An odometer eliminates the necessity of using a tape measure or survey makers.

The pulseEKKO PRO is designed to work with a number of different odometers. This includes the Big Wheel Odometer (See Figure 7-1 on page 31), the Small Wheel Odometer (See Figure 7-6 on page 35), the SmartCart odometer (Figure 11-6 below), the TR1000 Odometer (See Figure 9-2 on page 42) as well as vehicle odometers available from Sensors & Software.

All odometers except the TR1000 odometer can connect to receptacle 1 on the control module (Figure 11-6). When an odometer is used with transducers, it can also connect to the odometer receptacle on the transducer cables (See Figure 2-20 on page 16).

The Big Wheel Odometer can be used with the low frequency antennas but requires the use of a custom-length odometer cable extension to allow it to connect to receptacle 1 on the control module (Figure 11-6).

*Figure 11-6:  The pulseEKKO PRO accepts input from various odometers including the wheel odometer shown, which is from the SmartCart. Odometers attach to receptacle 1 on the control module or to the transducer end of the transducer cables. When using the Big Wheel Odometer with low frequency antennas, use a long extension cable (not shown) to attach to receptacle 1 on the control module*

To acquire data with an odometer, the Trigger Method must be set to Odometer (Section 13.3.1.2: P78).

When collecting data with an odometer, data quality can be increased using the DynaQ stacking option (Section 13.2.7.1: P75).

For more information about data collection with an odometer see Section 16.6: P129.

If an odometer is being used for data collection, ensure that it is properly calibrated for accurate distance measurement (Section 13.3.5.1: P84).

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value (Section 13.3.5.2: P84).

## 11.4  GPS

The DVL has a serial port on the back for attaching a GPS receiver. This port will accommodate any GPS receiver that has a standard NMEA string output through the serial port.

The DVL settings will need to be changed to accommodate the input of GPS data (Section 13.3.4: P79).



*Figure 11-7:  Attaching a GPS to the serial port on the back of the DVL.*

Figure 16-15 shows GPS being used with various pulseEKKO PRO system configurations.

# 12   Starting the pulseEKKO PRO System

## 12.1  Powering the DVL and Control Module

Connect the Control Module to Power Supply Cable to the receptacle labelled 3 on the control module (Figure 12-1) This cable will only fit on the number 3 receptacle. Note that the other end of this cable has an XLR connector. Power can be supplied to the DVL by using a battery (normally supplied by Sensors & Software) with the mating XLR connector.

If powering the DVL with a user-supplied standard 12 Volt battery, connect the optional Power Cable Extension with Alligator Clips to the end of the Control Module to Power Supply Cable (Figure 12-1). The alligator clips can then be connected to a 12 Volt battery. Make sure that the black clip is attached to the negative (-) and the red clip is attached to the positive (+) battery terminals. If the alligator clips are connected to the wrong terminals of the battery, the DVL will not be powered. When the DVL is receiving power the upper red light on the front of the DVL will be illuminated.
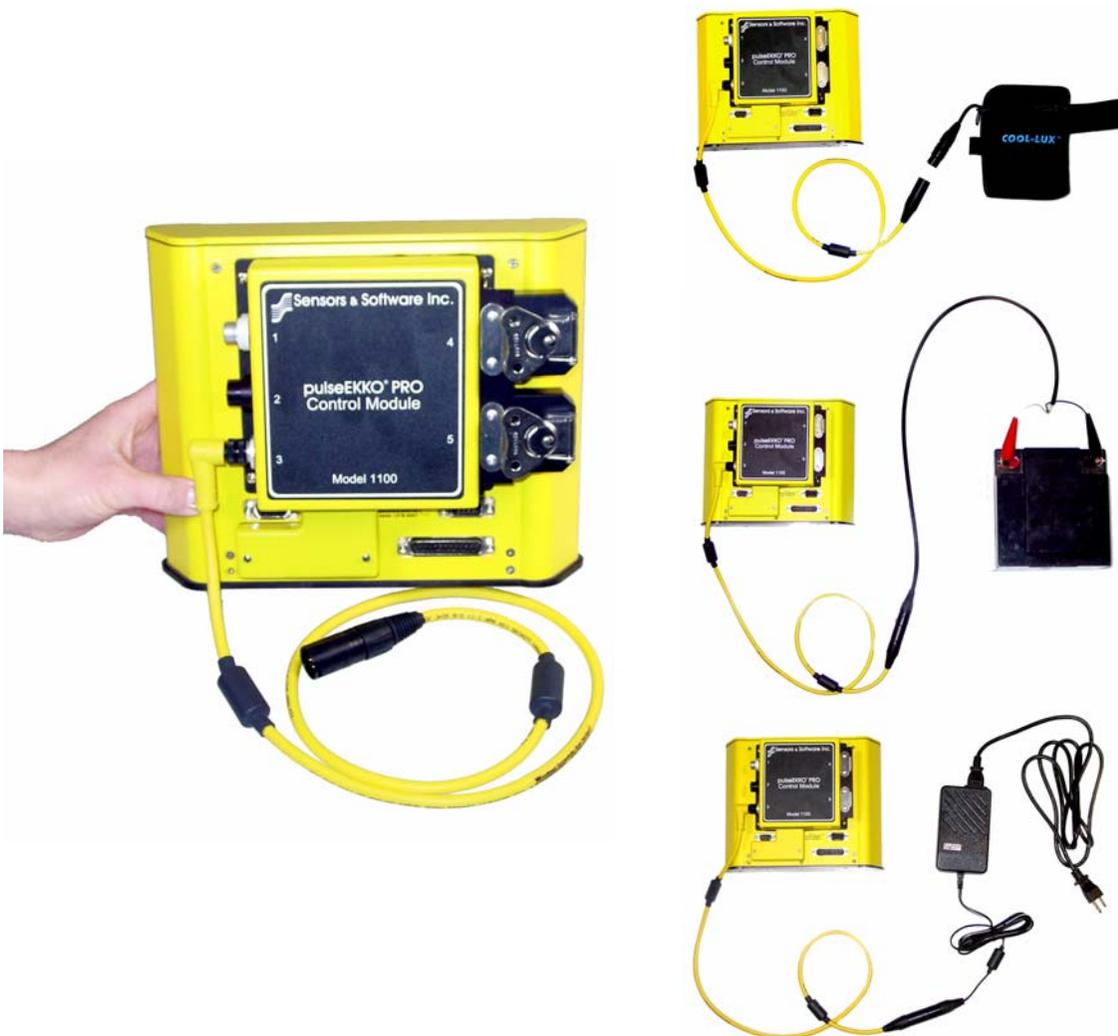


*Figure 12-1: Attach the Control Module to Power Supply Cable to receptacle 3 on the control module (left). The DVL and control module can then be powered using the battery with the XLR connector supplied by Sensors & Software (top right). This battery may be a belt battery (shown) or a larger SmartCart battery (not shown, see Figure 5-1). Using the optional alligator clip cable, the DVL and control module can also be powered using any standard 12 Volt battery (middle right). The DVL and control module can also be powered using the optional AC mains (bottom right).*

## 12.2 Powering the Low Frequency Transmitter and Receiver

Turn the transmitter and receiver ON by pressing the button on the top of each unit. The red Power LED on the top of the unit will flash 5 times and then stay on to indicate the unit is ready for operation. If not, check that the batteries inside the Transmitter and Receiver are fully charged and have been inserted the right way.

When not collecting data, the transmitter and receiver should be turned OFF to increase the life of the batteries.

## 12.3 Digital Video Logger

Once all the cable connections are made between the control module, transmitter, receiver, the Digital Video Logger (DVL) and the battery, the upper red LED light on the DVL panel should be lit. If the battery voltage is too low, the LED light will flash for about 30 seconds and go out. If the light flashes or does not appear, check the connections and make sure the battery is fully charged.

The low voltage indicator can be helpful for identifying when the battery needs to be recharged. If the battery voltage drops too low the DVL will cease to operate.

The front of the DVL is shown in Figure 12-2. To start the system, press any button on the front panel. The lower red LED on the front panel should illuminate.



*Figure 12-2:  Digital Video Logger (DVL) face*

The water-resistant membrane keypad has a number of buttons that can be pressed to perform various tasks.

**Menu Buttons**: The buttons labelled 1 to 8 correspond to menu choices that appear listed on the screen or along the bottom of the screen when the Digital Video Logger is turned on.

In addition, there are two general-purpose buttons labelled A and B. All buttons are DVL software application dependent and roles change. The operation will be self-explanatory from the display screen.

**Screen**: The DVL screen is a grey scale LCD selected for its wide temperature range and visibility in sunlight. Visibility can be a major problem with viewing GPR data displays outdoors and considerable effort has been expended on getting a readily visible outdoor display.

**Brightness**: The yellow Brightness control arrows are used to increase and decrease the screen brightness. Increasing the Brightness setting may improve the visibility of the screen in dark conditions.

**Contrast**: The yellow Contrast control arrows are used to increase and decrease the screen contrast. Increasing the Contrast setting may improve the visibility of the screen on a bright, sunny day.

Temperature sensors within the DVL automatically compensate the screen setting so that manual adjustments of Brightness and Contrast should seldom be needed after initial setup.

**Compact Flash Drives**: The DVL has both an internal and a removable compact flash drive. The DVL firmware resides on the internal drive. Data can be saved to either the internal or removable drive (see Section 18.6: P151). The removable compact flash drive is accessible by opening the door on the top of the DVL. **Make sure that the DVL is powered down before removing or inserting the compact flash drive.** Loosen the finger screws on the top of the DVL, swing the door open and press the button to eject the drive.

The DVL comes with a removable compact flash drive but the user has the option to purchase additional drives for data storage. For best results, purchase an industrial grade compact flash drive with higher transfer rates and temperature ranges. We strongly recommend the Sandisk Extreme III and IV. These are widely available in consumer electronics stores. The DVL can use cards up to a maximum of 2 GB in size.

To transfer data from the removable drive to a PC the user will need to purchase a card reader (see Section 18.1: P147). These are widely available in consumer electronics stores.



*Figure: 12-3 The DVL has a removable compact flash drive for data storage.*

## 12.3.1 DVL Temperature Requirements

The internal temperature of the DVL must be kept above -10 C so the LCD screen is not damaged. If you are using the DVL in cold temperatures, ensure the DVL has sufficient protection, especially from the cooling effects of the wind. A soft-sided cooler bag with extra insulating material inside has been used successfully by many customers in Arctic and Antarctic regions. If possible, power up the DVL at a warm temperature. With adequate insulation, the internal electronics will generate enough heat to keep the DVL warm.

## 12.3.2 Main Menu

Once all components are properly connected, the radar is ready to operate under DVL control. Turn the DVL on by pressing any button on the front. After the DVL boots up the main menu is displayed (Figure 12-4). There is also a flow chart of the complete menu system on the DVL shown in Figure 12-5.
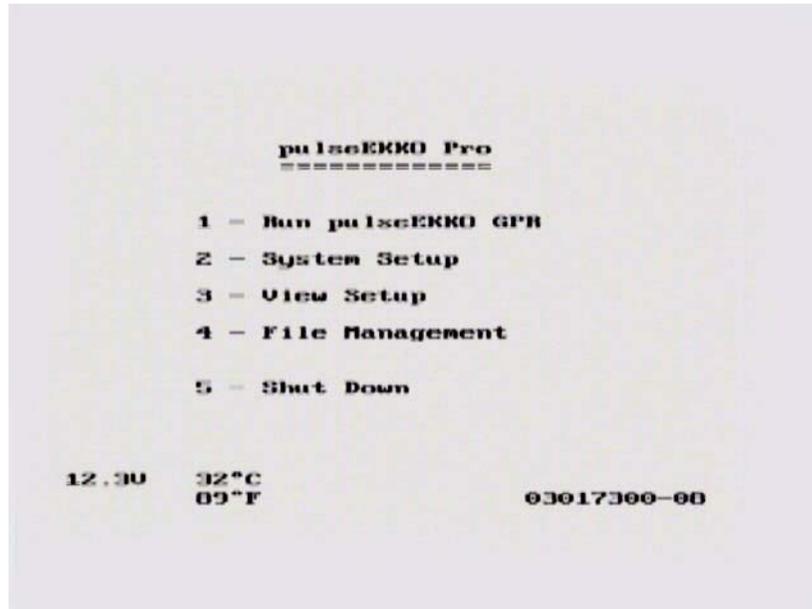


*Figure 12-4: pulseEKKO PRO main menu screen on the DVL.*

To begin acquiring data, press button number 1 for **Run pulseEKKO GPR**. Details about data collection are given in Section 14 on page B-101.

To setup data collection parameters, press button number 2 for **System Setup**. Details about setting data collection parameters are given in Section 13 System Setup Parameters on page 65.

The current system setup parameters can be viewed by pressing button number 3 for **View Setup**.

Data files collected can be transferred to an external PC and deleted from the DVL using the **File Management** menu item. File Management can be selected by pressing button 4 from the main menu. Details about using File Management are given in Section 18 on page B-147.

The DVL can be shut down by pressing button number 5. Exit also serves an important function. Before exiting, the program saves all the current parameters. This process enables the system to start up with the same settings as before it was last powered off. Therefore, the user should NOT shut off the DVL by only removing the power.

The two numbers displayed in the lower left corner of the main menu are the internal temperature of the DVL in Celsius and Fahrenheit and the voltage of the power supply running the DVL. When the DVL voltage drops to 10.2 Volts or less, the DVL will shut down. If this occurs in the middle of a data file, that file will be lost.

MAIN MENU

**1** Run pulseEKKO GPR  |  **2** System Setup  |  **3** View Setup  |  **4** File Management  |  **5** Shut Down

**A-B** Select Data Folder Number

**1** Collect Line Data

**A-B** Select Line Number

**1** Run

**2** Setup Menu (shortcut)

**8** Return

**2** Collect Grid Data

**A-B** X or Y Grid (if GPR Grid Type is set to XY)

**A-B** Select X or Y Line Number
**1** Run
**2** Setup Menu (shortcut)
**8** Setup Menu

**8** Return

**3** Collect Data (No Save)

**4** Scope Mode

**8** Return

**1** GPR Parameters

Antenna Frequency
Time Window
Sampling Interval
Antenna Separation
Antenna Step Size
Radar Velocity
System Stacking
Pulser Setting

**2** Acquisition Control

Trigger Method

CANBUS
Fibre Optic
DVL Key (B)
Free Run
Odometer

Beeper Activated
Free Run Trace Delay
GPS Parameter Menu

GPS Recording Mode
GPS Transfer Baud Rate
GPS Transfer Parity
GPS Transfer Stop Bits
GPS Transfer Data Bits
GPS Last NMEA String
Test GPS with Listing
Test GPS with Plotting

Odometer Setup Menu

**1** Odometer Calibration
**2** Set Calibration Manually
**3** Odometer Direction
**8** Return

Fibre Optic Testing

**3** Survey Parameters

Start Position
Antenna Step Size
Positional Units
Data Directory No.
Survey Type
GPR Grid Type
X Line Spacing
Y Line Spacing

**4** Display Parameters

Trace Plotting Type
Gain Type Applied
Gain Applied

**5** DVL Setup Menu

**1** Set DVL Time & Date
**2** Set DVL Transfer Mode
**3** Set DVI into Upgrade Mode
**4** Select Display Info Mode
**8** Return

**6** View Complete Setup

**8** Return

**1** Transfer Directory

**A** Up
**B** Down
**1** Tag
**2** Send
**8** Exit

**2** Transfer File

**1** Next Line
**2** Transfer Line
**A** Prev Directory
**B** Next Directory
**8** Exit

**3** Delete Directory

**A** Up
**B** Down
**1** Tag
**2** Delete
**8** Exit

**4** Delete File

**1** Next Line
**2** Delete Line
**A** Prev Directory
**B** Next Directory
**8** Exit

**5** View Disk Space

*Figure 12-5:  Flow chart of the complete pulseEKKO PRO DVL menu system.*

## 12.3.3 Using the Software Menus

Menu items can be selected in one of two ways:

1) If the menu item has a number listed beside it, that item can be selected by pressing the corresponding button number on the DVL. For example, in the above menu (See Figure 12-4 on page 62), pressing the number 1 will select the option for running a pulseEKKO GPR system.

2) On a menu with items that are not numbered, one of the menu items will be flashing to indicate that it is currently selected. Pressing the button immediately below the word "Up" or "Down" to choose another option. Once the menu item is flashing, it can be changed to preset values by pressing the A or B buttons. Pressing the button under Return will take the user up to the previous menu level.

The above explanation may sound complicated but having used it a few times, the whole procedure will become intuitive after a few usages.

# 13   System Setup Parameters

The **System Setup** option from the main menu (See Figure 12-4 on page 62) is used to set up the data collection parameters.



*Figure 13-1:  The System Setup main menu is used to access and change any parameter used for data collection. Related parameters are grouped under different menu headings, for example, GPR Parameters list the variables specific to the GPR system. Select View Complete Setup from this menu to quickly locate the desired parameter and the heading it is listed under.*

Selecting **View Complete Setup** from this menu or **View Setup** from the main menu (See Figure 12-4 on page 62) displays all the current parameter settings for the pulseEKKO PRO system. A screen display similar to the one in Figure 13-2 will be seen:
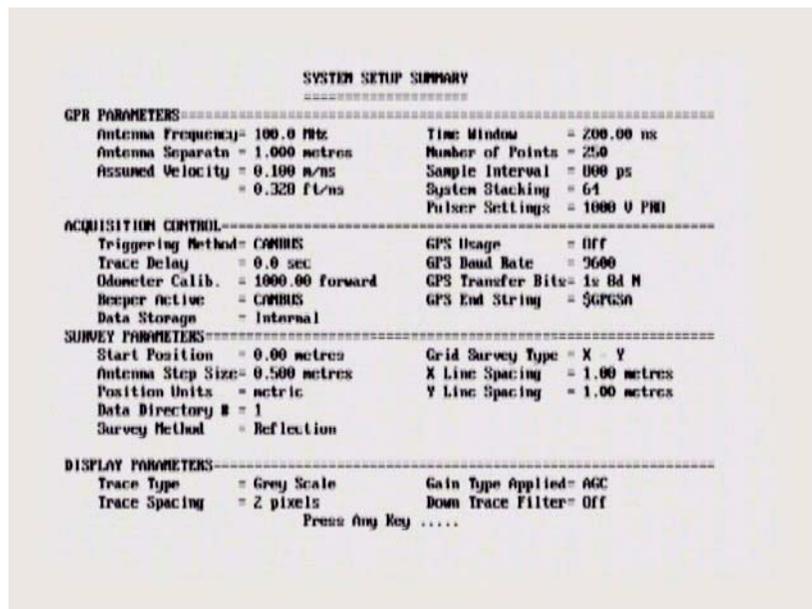


*Figure 13-2:  The **View Setup** option displays all the current settings and indicates which System Setup headings to select to change individual parameters. For example, select Acquisition Control to change the Triggering Method.*

Figure 13-2 illustrates how many parameters must be set before data collection can start. While intimidating, many of the parameters can use the default values while many others are rarely changed at all.

## 13.1  System Parameters for a Quick Start to Data Collection

All the system parameters are detailed in this section but for a quick start to data collection, the most important parameters to consider before proceeding to the next section, Running in Scope Mode, and starting data collection are:

1)  Frequency (Section 13.2.1: P68)

2)  Time Window (Section 13.2.2: P69)

3)  Sampling Interval (Section 13.2.3: P70)

4)  Antenna Separation (Section 13.2.4: P71)

5)  Antenna Step Size (Section 13.2.5: P72)

6)  System Stacking (Section 13.2.7: P74)

7)  Trigger Method (Section 13.3.1: P77)

## 13.2  GPR Parameters

Selecting the GPR Parameters menu option will display a screen similar to Figure 13-3. This section describes, in detail, each parameter listed in this menu.
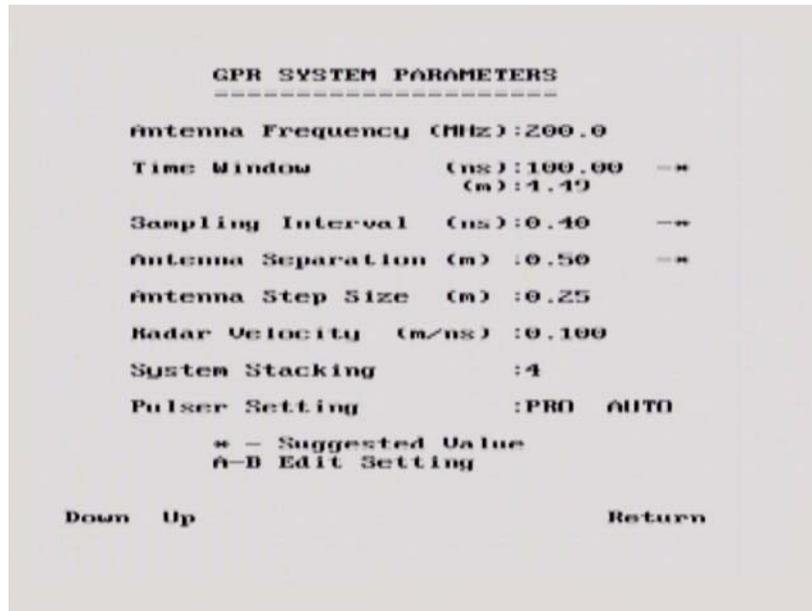


*Figure 13-3:  The GPR System Parameters menu. Use the Up and Down buttons to move to the desired parameter and edit the value by pressing the A and B buttons. Several of the parameters have suggested values, indicated by an asterisk (\*), but these values can still be changed by the user.*

## 13.2.1 Antenna Frequency

Deciding which antenna frequency to use for a survey depends on the objectives of the survey.  As frequency decreases the depth of investigation generally increases but spatial resolution decreases. Therefore, the ideal survey will be one that uses the highest frequency that adequately penetrates to the target depth.  This is not always easy to determine and often field experimentation with several different frequencies is necessary.

This parameter is set under System Setup - GPR Parameters - Antenna Frequency.

The following table offers a guide to frequency selection.  It is based on the assumption that spatial resolution of the target is about 25% of the target depth.  The values are based on practical experience and should be used as a quick guide only.

| Depth (m) | Center Frequency (MHz) |
|-----------|------------------------|
| 0.5 | 1000 |
| 1.0 | 500 |
| 2.0 | 200 |
| 5.0 | 100 |
| 10 | 50 |
| 30 | 25 |
| 50 | 10 |

Note that the hardware cannot determine which antenna is attached. The <u>user must</u> correctly enter this parameter.

It is important that the correct frequency be entered since this value is used in many computations including pulse width, used in the DEWOW correction (Appendix B: on page B-1), and for several default settings such as sampling interval (Section 13.2.3: P70).

## 13.2.2 Time Window

The Time Window setting determines how long (and therefore how deep) the radar system will probe the subsurface.  It is important that it is set to a value appropriate for the depth of the survey target. An entire survey could fail if the window is not sufficiently long enough to sample to the depth of the target. Conversely, too long a time window increases the data volume and decreases productivity.

This parameter is set under System Setup - GPR Parameters - Time Window.

The Time Window value will be set to a default value based on the antenna frequency selected (Section 13.2.1: P68) as shown in the table below.

| Frequency (MHz) | Default Time Window (ns) | Approximate Depth (m) with V=0.1m/ns | Approximate Depth (ft) with V=0.328ft/ns |
|:---:|:---:|:---:|:---:|
| 12.5 | 1600 | 80 | 262 |
| 25 | 800 | 40 | 131 |
| 50 | 400 | 20 | 66 |
| 100 | 200 | 10 | 33 |
| 200 | 100 | 5 | 16 |
| 250 | 100 | 5 | 16 |
| 500 | 50 | 2.5 | 8 |
| 1000 | 25 | 1.25 | 4 |

**Note:** The default Time Window value may not be appropriate for the survey at hand. If not, the value can be changed by the user.

Since the radar system really measures time, and survey targets are at a specific depth, an estimate of velocity can be used to relate depth to time to obtain a good time window value. The DVL automatically calculates and displays a depth value based on the Time Window value and the current Radar Velocity value (Section 13.2.6: P73).

### 13.2.2.1   How Depth is Determined

Ground penetrating radar systems record the time for a radio wave to travel to a target and back. The depth to that target is calculated based on the velocity at which the wave travels to the target. In ideal reflection operation, depth is calculated as:

$$D = V \times T/2$$

Where          D is Depth (m)

               V is Velocity (m/ns)

               T is Two-way travel time (ns)

The wave velocity depends on the properties of the material. The menus allows the user to input different velocities, which changes the total depth range displayed on the screen. A value of 0.1 m/ns (or 0. 33 ft/ns) is a good average value for geologic materials; a table of the velocities of common geologic materials is listed below (Section 13.2.6: P73).

## 13.2.3 Temporal Sampling Interval

The pulseEKKO PRO system samples the GPR signals returning to the receiver. The resulting GPR data is a series of numbers that represent signal amplitude at equally spaced time intervals. The time interval between points on the trace is called the Temporal Sampling Interval.

The sampling interval is dependent on the frequency of the antennas being used.  Higher frequencies need to be sampled at a finer time sampling interval than lower frequencies.
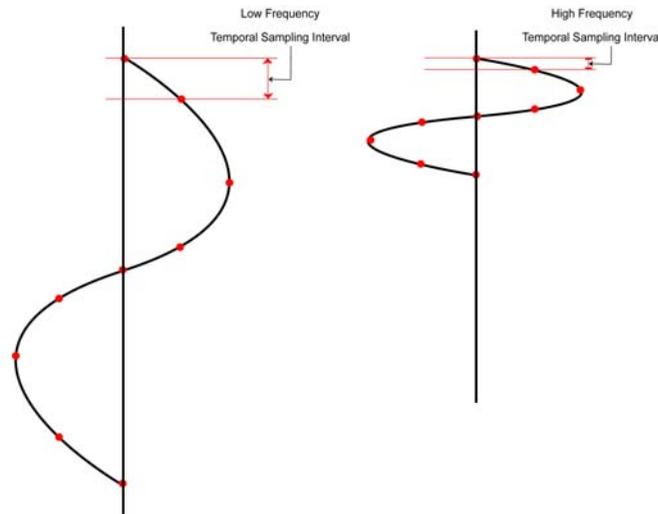


*Figure 13-4:  The temporal sampling interval is set to properly sample the GPR signal waveform. It varies with the antenna frequency since properly sampling high frequency signals (right) requires a smaller sampling interval than longer, low frequency signals (left).*

This parameter is set under System Setup - GPR Parameters - Sampling Interval.

The Sampling Interval value will be set to a default value based on the antenna frequency selected (Section 13.2.1: P68) as shown in the table below. It can, however, be changed. **In general, the default Sampling Interval should NOT be changed by the user.**

The recommended temporal sampling interval versus antenna frequency is reproduced below:

| Center Frequency (MHz) | Recommended Sampling Interval (ns) |
|:---:|:---:|
| 12.5 | 6.4 |
| 25 | 3.2 |
| 50 | 1.6 |
| 100 | 0.8 |
| 200 | 0.4 |
| 250 | 0.4 |
| 500 | 0.2 |
| 1000 | 0.1 |

It is important not to choose a sampling interval that is too large for a particular frequency otherwise the data may be aliased (undersampled and thus not very representative of the real signal). Choosing a sampling interval too small will increase the data volume unnecessarily and may slow down the data collection process.

### 13.2.3.1 Determining the Number of Points per Trace

The number of points per trace is displayed in the View Setup screen (See Figure 13-2 on page 65). Points are calculated based on the time window length and the sampling interval. For example, using a time window of 300 ns and a sampling interval of 0.8 ns, the number of points is calculated as follows:

$$\text{points} = \text{time window/sampling interval}$$
$$= 300 \text{ ns} / 0.8 \text{ ns}$$
$$= 375$$

## 13.2.4 Antenna Separation

As the transmitting and receiving antennas are moved along a survey line, it is important that a separation be maintained between them. When the antennas are mounted on a cart the antenna separation is fixed, but when the antennas are not fixed in position, it is common to use a rope or measuring tape to maintain the proper separation (See Figure 16-4 on page 121).

This parameter is set under System Setup - GPR Parameters - Antenna Separation.

The Antenna Separation value will be set to a default value based on the antenna frequency selected (Section 13.2.1: P68) as shown in the table below.

| Frequency (MHz) | Minimum Antenna Separation (metres) | Minimum Antenna Separation (feet) |
|:---:|:---:|:---:|
| 12.5 | 8 | 26 |
| 25 | 4 | 13 |
| 50 | 2 | 6 |
| 100 | 1 | 3 |
| 110 | 1 | 3 |
| 200 | 0.5 | 1.5 |
| 250 | 0.38 | 1.25 (15 in) |
| 500 | 0.225 | 0.75 (9 in) |
| 1000 | 0.15 | 0.5 (6 in) |

The rule of thumb is that the minimum antenna separation should equal the antenna length. For example, 100 MHz antennas are 1 metre long and should be kept about 1 metre apart during a survey. If the antenna spacing is too small, receiver electronics may be overloaded by the transmit signal resulting in data clipping (see Appendix B: on page B-1 for a discussion of this problem).

Note that this parameter has no meaning for any mode of operation where the antenna separation changes such as when collecting a CMP/WARR profile.

## 13.2.5 Antenna Step Size

This specifies the distance the antenna pair will be moved each time to collect a new trace during a Reflection mode survey (Section 13.4.5: P87).

To properly resolve subsurface targets spatially, it is important that a proper Antenna Step Size be selected.  Too coarse a Step Size may result in missed subsurface targets while too fine a Step Size will result in large data volumes and slow survey productivity.

This parameter is set under System Setup - GPR Parameters - Antenna Step Size.

The Antenna Step Size value will be set to a default value based on the antenna frequency selected (Section 13.2.1: P68) as shown in the table below.

| Frequency (MHz) | Recommended Antenna Step Size (metres) | Recommended Antenna Step Size (feet) |
|---|---|---|
| 12.5 | 2 | 6 |
| 25 | 1 | 3 |
| 50 | 0.5 | 1.5 |
| 100 | 0.25 | 1 |
| 200 | 0.1 | 0.33 (4 in) |
| 250 | 0.05 | 0.166 (2 in) |
| 500 | 0.025 | 0.0833 (1 in) |
| 1000 | 0.01 | 0.042 (0.5 in) |

Note that the default values can be overridden by changing the Step Size value directly.

When using an odometer to collect data, make sure that odometer has been properly calibrated (Section 13.3.5.1: P84), otherwise positional information will be incorrect.

In CMP mode (Section 16.11: P132), the step size is interpreted to be the total increment in separation between each trace. Therefore, if each antenna is moved 0.25 metres then the Step Size is 0.5 metres.

## 13.2.6 Radar Velocity

If an accurate depth axis on the real-time display is desired, or the user wishes to see the approximate depth of penetration while setting the time window value (Section 13.2.2: P69), the user should supply the program with the average radar wave propagation velocity (in m/ns or ft/ns).

The best way to determine the radar velocity of the survey area is to extract the velocity using the Hyperbola Curve Fitting routine (Section 15.5.4.1: P111) or a Common Mid Point (CMP) survey (Section 16.11: P132).

*Note that having an incorrect radar velocity value does NOT affect the quality of the GPR data collected. It will only affect the depth scale on the display. This can be changed later.*

If it is not possible to determine the radar velocity directly, refer to the chart below which lists the radar velocities of various materials.

| Material | Velocity (m/ns) | Velocity (ft/ns) |
|:---:|:---:|:---:|
| Air | 0.30 | 0.98 |
| Ice | 0.16-0.17 | 0.52 |
| Dry Soil | 0.15 | 0.49 |
| Dry Sand | 0.15 | 0.49 |
| Granite | 0.13 | 0.43 |
| Dry Salt | 0.13 | 0.43 |
| Dry Rock | 0.12 | 0.39 |
| Limestone | 0.12 | 0.39 |
| Wet Rock | 0.10 | 0.33 |
| Concrete | 0.08-0.12 | 0.26-0.39 |
| Pavement | 0.10 | 0.33 |
| Shales | 0.09 | 0.30 |
| Silts | 0.07 | 0.23 |
| Wet Soil | 0.06 | 0.20 |
| Wet Sand | 0.06 | 0.20 |
| Clays | 0.06 | 0.20 |
| Fresh Water | 0.033 | 0.11 |
| Sea Water | 0.033 | 0.11 |

A velocity of 0.1 m/s or 0.33 ft/ns is a good value to use when uncertain about the velocity of the material being surveyed.

## 13.2.7 System Stacking

In noisy environments, one way of improving signal to noise is to collect more than one trace at each survey position, average them and record the average trace. This is known as "trace stacking" or "stacking". Data quality improves because the noise, which is usually a random addition to the trace, tends to zero when averaged while the GPR signal is constant, thus increasing the "signal-to-noise ratio".
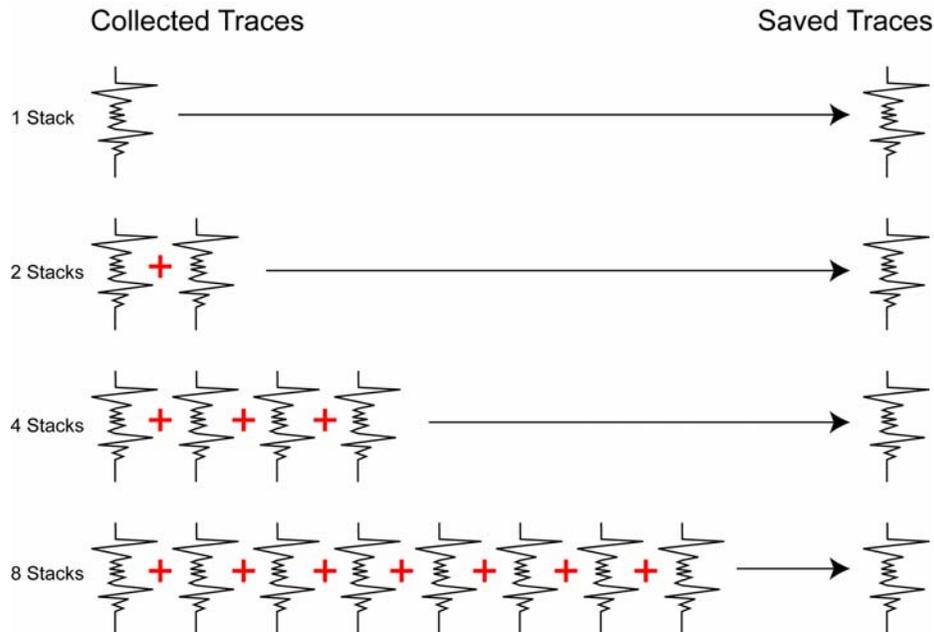


*Figure 13-5: The concept of "stacking" data. At each data collection point, the trace is collected multiple times. These traces are averaged together to calculate the data trace that is actually saved. Stacking improves the data quality by improving the signal-to-noise ratio.*

While stacking improves data quality, it may slow down survey production. The more stacks, the longer it takes to collect data at each survey position. Therefore, it is important to find the optimum number of stacks that still reveal the target adequately.

This parameter is set under System Setup - GPR Parameters - System Stacking.

While stacks can be set from 1 to 32767, for most surveys, stacking 4 to 64 times is suitable.

Stacking is normally reduced when: 1) the survey objective is looking for very strong responses or 2) production speed is vital, such as measurements made from a rapidly moving vehicle.

When the system is run in Free Run mode (Section 13.3.1.3: P78), the user can control the speed the system collects data by increasing or decreasing the number of stacks. Increasing the number of Stacks has the effect of slowing down the data collection speed of the system. Decreasing the number of Stacks has the effect of speeding up the data collection speed of the system.

### 13.2.7.1 Increasing Data Quality with DynaQ

If the Trigger Method (Section 13.3.1: P77) is set to odometer, one of the options for Stacking is to set it to DynaQ.

DynaQ is an advanced, patented technology that dynamically adjusts stacking as the system movement speed varies. In most situations, moving the system at a comfortable speed stacks enough to generate data of good quality. In situations where target resolution or maximum penetration depth is critical, moving slower increases the number of stacks and increases the data quality.

As the system moves during data collection, the DVL screen displays a DynaQ scale bar from L (Low) to H (high) to indicate data with enhanced signal-to-noise are being attained.
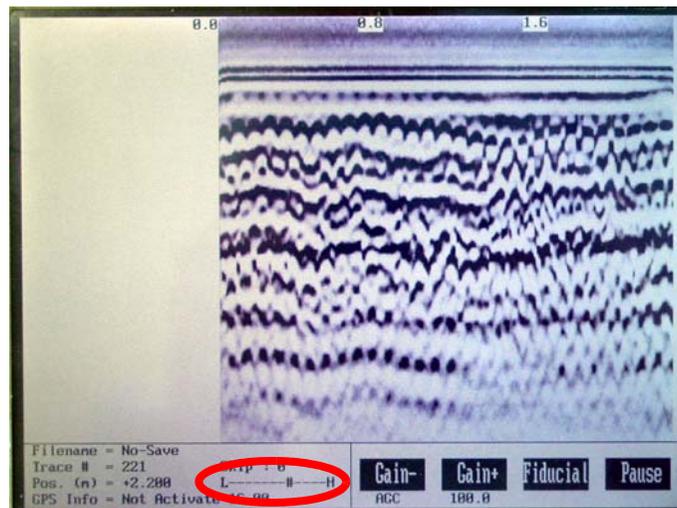


*Figure 13-6: When collecting data with an odometer, stacking can be set to DynaQ so the number of stacks for each trace is dynamically adjusted depending on the speed the system is moving. Moving the system slower increases the number of stacks and increases data quality. The number of stacks is indicated on the DynaQ scale bar from Low (L) to High (H).*

The DynaQ information for each data line is written to the header (.HD) file.

Currently, DynaQ cannot be used for multi-channel data acquisition (see Appendix J: pulseEKKO PRO Multi-Channel Data Acquisition).

## 13.2.8 Pulser Setting

This setting allows the user to specify which transmitter (or pulser) is being used for data collection. Several different transmitters can be used with a pulseEKKO PRO system.

In general, if you have a pulseEKKO PRO transmitter, set Pulser Setting to **PRO Auto**. This will automatically set the transmitter to the highest voltage available for that transmitter. For example, a 400 Volt transmitter will be set to 400 Volts and a 1000 Volt transmitter will be set to 1000 Volts.

The only time that PRO Auto is not the correct setting for a pulseEKKO PRO transmitter is if you have a 400 to 1000 variable voltage transmitter and you want to set the pulser voltage to a value lower than 1000 Volts. As mentioned above, using the PRO Auto setting for this transmitter will result in the voltage being set to the highest value, in this case 1000 volts. To set the transmitter to a different value, say 500 volts, it is necessary to edit the Pulser Setting until PRO 500V is displayed.

Note that if you have a 400 volt or 1000 volt transmitter and you try to set it to a voltage other than the correct one, an error will occur when you try to collect data.

The 1000 volt pulser is recommended when using 12.5 to 100 MHz antennas, while the 400 volt pulser is recommended for 50 to 200 MHz antennas.  Both pulsers can, however, be used for all antennas.

**pulseEKKO 100 Transmitter:** The pulseEKKO PRO can also be run using pulseEKKO 100 transmitters. The three options are PE100 400 for the 400 volt transmitter, PE100 1K for the 1000 volt transmitter and PE100 5K for the 5000 volt transmitter.

See Section 2.2.7: P11 describing the proper way of connecting the fibre optic cables to the pulseEKKO 100 transmitter.

Also, see the information about the low battery warning message when data are collected with a pulseEKKO 100 transmitter (Section 17.1.3.1: P140).

## 13.3  Acquisition Control

Selecting the Acquisition Control parameters menu option from the System Setup main menu (See Figure 13-1 on page 65), will display a screen similar to Figure 13-7. This section details each parameter listed in this menu.
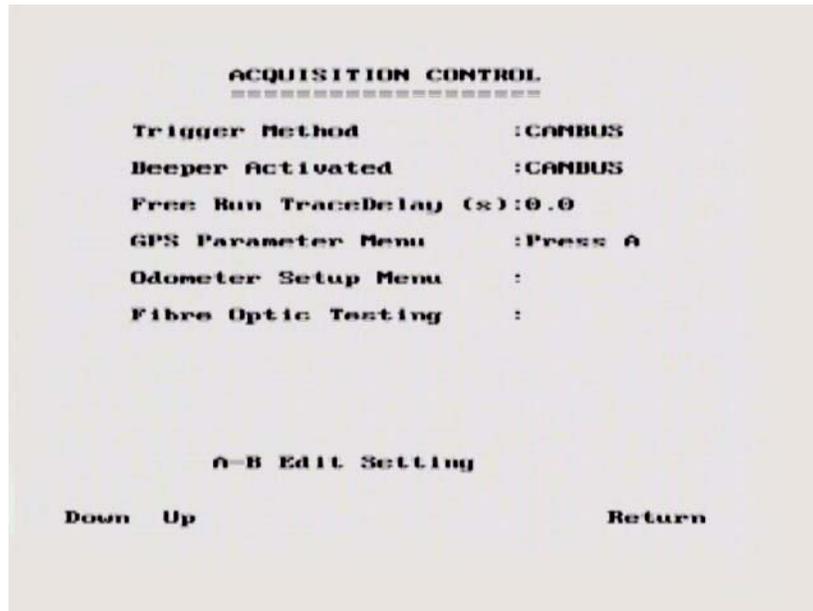


*Figure 13-7:  The Acquisition Control menu. Use the Up and Down buttons to move to the desired parameter and edit the value by pressing the A and B buttons. Selecting any of the last three options opens sub-menus to edit these parameters.*

### 13.3.1 Trigger Method

The Trigger Method determines what device is going to trigger the transmitter to fire and collect a data trace.

This parameter is set under System Setup - Acquisition Control - Trigger Method.

There are 5 ways to trigger the transmitter to fire:

1) DVL B Button

2) Electrical Trigger

3) Fibre Optic Trigger

4) Odometer

5) Free Run

The Trigger Method to use is best determined by the user after examination of the site to assess the ease with which the radar can be moved from position to position.

### 13.3.1.1 Triggers

Triggering the system with an electrical, Fibre Optic or DVL B Button trigger (options 1 -3) is best for surveying in difficult terrain where antennas cannot be moved easily or at regular time intervals. For the position of each measurement point, the system assumes the operator has moved the antennas one step size along the survey line. This is also the mode to select when an odometer is used to trigger the system at specific distance intervals.

In Trigger mode, the user presses the B button on the DVL screen or an external trigger button to collect the next trace. The user is prompted with "READY" or "HIT TRIGGER" on the DVL screen to indicate the system is ready to collect the next trace.

Note that when data are collected with the electrical or the fibre optic trigger, the device may emit a beeping sound after the button is pressed, indicating data collection is taking place. The beeping sound will only occur if the corresponding Beeper Activated option is selected (Section 13.3.2: P79).

### 13.3.1.2 Odometer

Selecting this option means that the system will be triggered to collect data using the input from the odometer (Section 11.3: P55). See Section 16.6 Odometer Data Acquisition on page 129 for more details about data acquisition with an odometer.

### 13.3.1.3 Free Run

Selecting this option means that the system is not triggered by a particular device but runs continuously in time.

The system automatically collects data at regular, user-determined time intervals. This is called "Free Run" mode and is best for surveys in flat, unobstructed terrain where antennas can be moved easily. For the position of each measurement point, the system assumes the operator has moved the antennas one step size along the survey line. True position can also be controlled by the user adding markers at known positions along the survey line and Rubberbanding the data in post-processing.

When Free Run operation is used, it is necessary to slow the data collection down by increasing the number of stacks (Section 13.2.7: P74) and the time delay between data traces (Section 13.3.3: P79). These options allow the user to control the speed of the data acquisition.

The number of stacks and time delay should be set to values that, when combined with the system tow speed, provide an appropriate Step Size interval. This may take a little experimenting to determine the optimal values for stacks, time delay and the actual speed that the system is moving.

To determine the towing speed to collect data at approximately the desired step size, do the following calculation:

1) Set the GPR Parameters for Time Window/Depth and Sampling Interval.

2) Set the Trigger Method to Free Run (Section 13.3.1 Trigger Method on page 77).

3) Set the Free Run Trace Delay to zero (0.0) seconds (Section 13.3.3 Free Run Trace Delay on page 79).

4) Set the number of Stacks to 1 (Section 13.2.7 System Stacking on page 74).

5) Without moving the system, using a stopwatch, time the system to collect and save data in Line Mode (Section 15.3 Data Collection on page 106) for 120 seconds (2 minutes) and pause the data collection.

6)   Record the number of traces that were collected in the 120 second time period. This will be visible on the bottom of the data collection screen beside "Trace #".

7)   Divide the number of traces by the time in seconds to calculate the number of trace per second (trcs/sec) that were recorded.

8)   To calculate the towing speed necessary to collect traces at approximately the desired step size, perform the following calculation:

   For kilometers/hour:        trcs/sec * step size(m) * 3.6

   For miles/hour              trcs/sec * stepsize(ft) * 0.68

9)   If the calculated towing speed is too fast, increase the number of stacks in Step 4 and repeat the calculation.

10)  Create a speed chart by doing this calculation at different numbers of stacks and different time windows/depths.

To avoid confusion, it is usually best to set the Step Size to 1.0 so that it the "position" that is saved with each trace is actually the trace number.

Data collected in this manner uses another means of determining the actual position of each trace, typically by collecting GPS data in parallel or by adding fiducial markers into the data at known locations during data collection and rubberbanding the data in post-processing.

## 13.3.2 Beeper Activated

The Electrical and Fibre Optic Beeper/Trigger units are designed to emit a beeping sound as a trace of GPR data is being collected. However, they will only beep if they have been activated to do so with this menu.

The available settings in this menu are: Electrical, Fibre Optic, Both or None.

Selecting None means that even if a Beeper/Trigger is present and is the Trigger Method being used (Section 13.3.1: P77), it will not beep.

## 13.3.3 Free Run Trace Delay

When the system is run in Free-Run mode (Section 13.3.1.3: P78), this option allows the user can specify a time delay (in seconds) between traces. This delay allows time for the user to set up the antennas at the new position. The computer automatically collects the next trace after the elapsed time has passed.

The Trace Delay is input in tenths of seconds, between each data collection point. To run the system as quickly as possible, set this value to 0.0 seconds.  For a longer time delay, use the buttons to set the value.

Factors as the radar site, operator experience, weather, etc. will determine how long the delay time should be. Trial and error will decide the appropriate setting.

## 13.3.4 GPS Parameter Menu

The Global Positioning System (GPS) uses special satellites around the Earth to determine the position of a GPS receiver located anywhere on the surface of the Earth.  GPS receivers can be purchased from a number of manufacturers.

The DVL has a serial port on the back for attaching a GPS receiver (Section 11.4: P57). This port will accommodate any GPS receiver that has a standard NMEA string output through the serial port.

The GPS receiver can be set up to send one or more types of data strings.  These strings are called NMEA-0183 strings and each contains positional or other information in specific formats.  Each type of string is specified by a 5-character prefix. ***Note that Sensors & Software GPR data can only be integrated with GPS data if at least one of the NMEA strings output by the GPS are GPGGA, GPRMC or GPGLL.*** These are the only strings that have the positional information required.
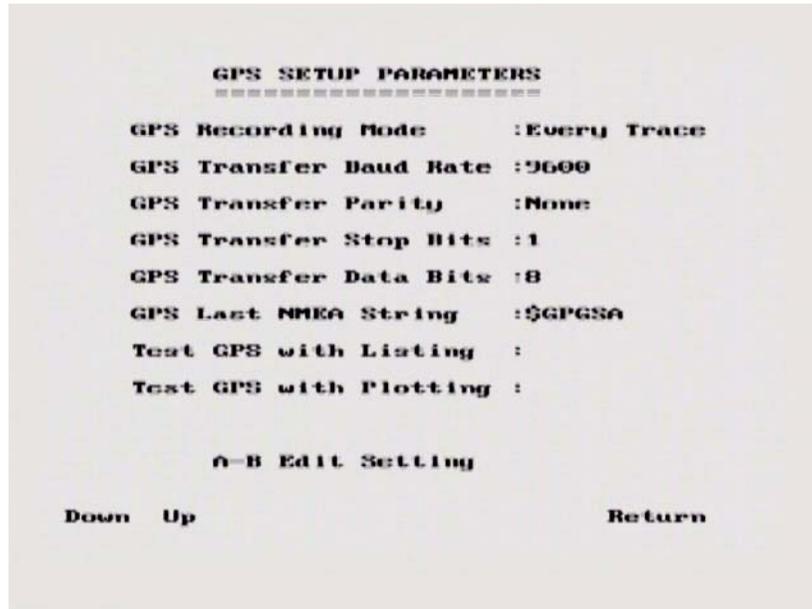


*Figure 13-8:  The GPS Setup Parameter screen.*

This feature allows GPS information to be recorded while collecting GPR data. The GPS information may be useful for mapping where GPR surveys have been performed (see Reading Every X Traces below) or determining where a specific target of interest is located in GPS co-ordinates (see Tagging mode below).

The DVL can be set up to read and log GPS information collected during data acquisition with the GPR system.  GPS information can be logged in two different ways:

  1)  For every trace collected by the GPR system, or

  2)  Every time the user adds a fiducial to the data by pressing the Fiducial button or the A button (Section 15.4: P109).

This feature provides a means of capturing GPS information to an independent file.  ***Note that the GPS information is NOT automatically integrated with the GPR data.*** After data acquisition is complete, the data can be downloaded to a PC and the EKKO_View Deluxe software can be used to integrate the GPS data with the GPR data.

In order for the DVL to read the GPS data string, the GPS settings for the specific GPS receiver must be input into this menu.  There are 4 important items that must be input correctly for the DVL to display the GPS strings: Baud Rate, Stop Bits, Data Bits and Parity.  These are discussed in more detail below.  The default values listed below are the values that are typically used.  Read the GPS Receiver User's Guide or experiment with the settings to find the correct ones.

Once these 4 items are set correctly you should be able to run Test GPS with Listing and have GPS information written to the screen.

When the logging of GPS information is enabled, during data acquisition, a message will appear in the bottom left-hand corner of the DVL screen indicating whether GPS data is successfully being received.

### 13.3.4.1   GPS Recording Mode

There are three GPS Recording Modes available:

**Off** mode means that a GPS receiver is not connected to the DVL so no GPS information is being logged. This should be the setting if you do not have a GPS receiver.

**Reading every x traces** mode means that every time the GPR collects 1, 5, 10, 20 or 50 traces of GPR data, a data string of GPS information will be added to a file. This file has the same name as the data file i.e. LINE6, but with a GPS extension. This file can be accessed after transferring the GPR data files to an external PC (Section 18: P147).

For example, if the number of traces is set to 1, the LINE6.GPS may look like this:

```
Trace #1 at position 0.00
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
Trace #2 at position 0.05
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
Trace #3 at position 0.10
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
Trace #4 at position 0.15
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
```

Note that when the Reading per Trace option is on, it is still possible to add fiducial markers to the GPS file.  These will appear as F1, F2 etc. between the trace numbers. For example, a portion of LINE6.GPS may look like this:

```
Trace #85 at position 4.20
$GPGGA,134850.00,4338.204868,N,07938.429003,W,2,06,2.1,152.60,M,-35.09,M,4.2,0118*74
$GPVTG,152.6,T,,,002.3,N,004.3,K,D*43
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.7*37
F1
$GPGGA,134850.00,4338.204868,N,07938.429003,W,2,06,2.1,152.60,M,-35.09,M,4.2,0118*74
$GPVTG,152.6,T,,,002.3,N,004.3,K,D*43
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.7*37
Trace #86 at position 4.25
$GPGGA,134851.00,4338.204362,N,07938.428362,W,2,06,2.1,152.40,M,-35.09,M,5.2,0118*72
$GPVTG,136.9,T,,,002.8,N,005.2,K,D*45
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.7*37
```

**On a Tag** mode means that whenever a fiducial marker (F1, F2 etc.) is added to the data by pressing the Fiducial button or the A button on the DVL (Section 15.4: P109), a data string of GPS information will be added to a file. This file has the same name as the data file i.e. LINE6, but with a GPS extension. This file can be accessed after transferring the GPR data files to an external PC.

For example, LINE6.GPS may look like this:

```
F1
$GPGGA,134218.00,4338.190204,N,07938.438411,W,2,05,2.6,154.60,M,-35.09,M,4.0,0118*7B
$GPVTG,356.8,T,,,000.2,N,000.4,K,D*4B
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F2
```

```
$GPGGA,134219.00,4338.190294,N,07938.438409,W,2,05,2.6,154.45,M,-35.09,M,5.0,0118*7C
$GPVTG,1.3,T,,,000.4,N,000.7,K,D*44
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F3
$GPGGA,134221.00,4338.190261,N,07938.438285,W,2,05,2.6,154.05,M,-35.09,M,5.2,0118*79
$GPVTG,10.0,T,,,000.2,N,000.4,K,D*72
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F4
$GPGGA,134222.00,4338.190397,N,07938.438255,W,2,05,2.6,153.95,M,-35.09,M,5.0,0118*73
$GPVTG,9.8,T,,,000.3,N,000.5,K,D*42
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
```

If the GPS mode is set to Reading per Trace or Fiducial Tagging AND the GPR is Run Without Saving Data (Section 15.8: P117), it is still possible to log GPS data strings. Every time a fiducial marker is added to the data by pressing the Fiducial button or the A button on the DVL (Section 15.4: P109), a data string of GPS information is added to a file. This file is called TAGGED.GPS and can be exported using the File Management option (Section 18: P147).

An example of a TAGGED.GPS file is shown below.

```
New File 09-18-2000  13:53:38
F1
$GPGGA,134227.00,4338.190520,N,07938.438280,W,2,05,2.6,153.98,M,-35.09,M,4.6,0118*7E
$GPVTG,347.7,T,,,000.3,N,000.5,K,D*44
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F2
$GPGGA,134228.00,4338.190238,N,07938.438286,W,2,05,2.6,153.87,M,-35.09,M,4.4,0118*75
$GPVTG,5.4,T,,,000.2,N,000.4,K,D*42
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F3
$GPGGA,134229.00,4338.190277,N,07938.438273,W,2,05,2.6,153.76,M,-35.09,M,5.4,0118*7A
$GPVTG,23.4,T,,,000.1,N,000.2,K,D*73
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
F4
$GPGGA,134231.00,4338.190127,N,07938.438362,W,2,05,2.6,154.59,M,-35.09,M,5.0,0118*7A
$GPVTG,20.2,T,,,000.2,N,000.3,K,D*74
$GPGSA,A,3,30,10,13,24,06,,,,,,,,4.3,2.6,3.4*36
*******************************************************************************
New File 09-18-2000  13:55:36
F1
$GPGGA,134259.00,4338.192453,N,07938.449096,W,2,06,2.4,153.14,M,-35.09,M,5.4,0118*75
$GPVTG,310.9,T,,,000.5,N,001.0,K,D*4A
$GPGSA,A,3,04,30,10,13,24,06,,,,,,,3.2,2.4,2.1*32
F2
$GPGGA,134301.00,4338.192559,N,07938.449176,W,2,06,2.4,153.17,M,-35.09,M,5.0,0118*7A
$GPVTG,314.4,T,,,000.6,N,001.1,K,D*41
$GPGSA,A,3,04,30,10,13,24,06,,,,,,,3.2,2.4,2.1*32
F3
```

### 13.3.4.2  Baud Rate

The baud rate is the speed that data is sent from the GPS receiver to the serial port of the DVL.  The available options are: 2400, 4800, 9600 (default) or 19200. Often, the baud rate for GPS units is 4800. If you are having a problem getting the GPS to work with the DVL, the Baud Rate is the most likely problem.

### 13.3.4.3  Stop Bits

The available settings for Stop Bits are: 1 (default) or 2.

### 13.3.4.4  Data Bits

The available settings for Data Bits are: 7 or 8 (default).

### 13.3.4.5  Parity

The available settings for Parity are: none (default), odd or even.

### 13.3.4.6  Last NMEA String

The GPS receiver can be set up to send one or more types of data strings.  These strings are called NMEA-0183 strings and each contains positional or other information in specific formats.  Each type of string is specified by a 5-character prefix. There are numerous NMEA strings but examples of three different NMEA strings (GPGGA, GPVTG and GPGSA) are shown below.

```
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
$GPGGA,134713.00,4338.221086,N,07938.421365,W,2,06,2.1,152.51,M,-35.09,M,5.0,0118*79
$GPVTG,34.0,T,,,001.4,N,002.5,K,D*70
$GPGSA,A,3,30,26,10,13,24,06,,,,,,,4.2,2.1,3.6*36
```

Before using the GPS with the GPR, the DVL software needs to know the prefix of the LAST string being sent in each group.  In the example above, three strings are being sent each time (GPGGA, GPVTG and GPGSA).  Since GPGSA is the last one being sent in each group, the End String needs to be specified as GPGSA.

To see what the End String is for your particular GPS, run Test GPS with Listing and note the first 5 characters on the last line after each series of strings is written to the screen.  These are the 5 characters that need to be filled in under Last NMEA String.

The Last NMEA String option allows the user to fill in the necessary 5 character GPS prefix.  Use the numbered buttons to change the letters forward in the alphabet. Use the Change Direction button make the letters go backward in the alphabet.

See the GPS Receiver User's Guide for details on how to set up the receiver to output specific NMEA strings or groups of NMEA strings.

### 13.3.4.7  Test GPS with Listing

After all the settings above have been input and the GPS receiver is attached to the serial port on the DVL, the test option allows the user to check that the DVL is receiving the GPS output.

If the NMEA strings are successfully being read by the DVL they will appear on the DVL screen.  This is a good time to note the prefix of the last NMEA string in the list and input it in the End String setting above.

If the NMEA strings do not appear, check that the port settings are correct.  It is also possible that a crossover cable is required between the output cable of the GPS receiver and the serial port on the DVL.

### 13.3.4.8  Test GPS with Plotting

Once the GPS system is running successfully, selecting Test GPS with Plotting can be used to graphically display the GPS data.  This screen displays the GPS Time, Latitude, Longitude and Altitude as well as other values indicating the accuracy of the GPS reading.  The GPS position is also displayed in a square that can be Zoomed from 2 metres square to 16384 metres square.

## 13.3.5 Odometer Setup Menu
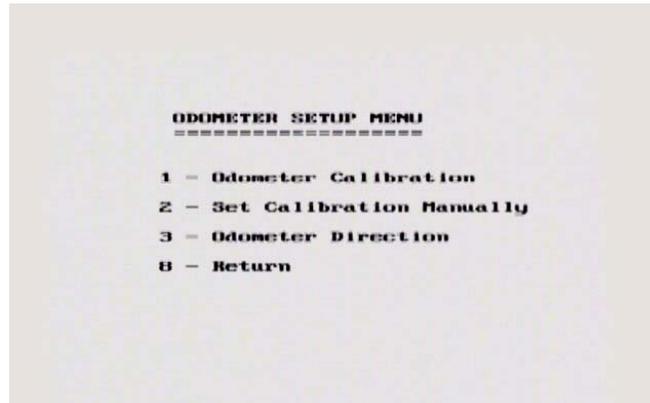


*Figure 13-9: Odometer Setup Menu.*

### 13.3.5.1   Odometer Calibration

The odometer should be calibrated periodically to ensure accuracy.

When Odometer Calibration is selected, the user is prompted to select the length of the line to calibrate on. There are 8 different choices in metres and 8 choices in feet.  To toggle the units between metres and feet, press the B button.  Pressing the A button on this screen gives the additional option to select a user defined value.  The user-defined value can range from 0.01 to 5000 metres or 0.01 to 26400 feet.

When the calibration distance has been selected follow the directions on the screen:

Set the system at zero and press A

Move the system the selected distance and press B

Press A to exit.

Typical calibration values for the various odometers are:

> SmartCart: 1160
>
> Big Wheel: 1080
>
> Small Wheel: 1540
>
> TR1000: 2315

### 13.3.5.2   Set Odometer Manually

When Odometer Calibration is selected, the user is prompted to manually enter the odometer calibration value.

If you use more than one odometer and often switch odometers, it may be a good idea to calibrate each odometer on the type of surface being surveyed and record the calibration values. This way, when changing odometers, rather than having to recalibrate the odometer you want to use, you can simply manually enter the recorded calibration value.

### 13.3.5.3   Odometer Direction

This setting determines whether data are collected as the system is rolled forward or reverse. The back up arrow (Section 16.6.2: P130) will work in the direction opposite to this setting. The available options are: Forward and Reverse.

## 13.3.6 Fibre Optic Testing

As part of troubleshooting a problem with the system, the fibre optic cables can be tested for damage (Section 17.2: P141).

## 13.4 Survey Parameters

Selecting the Survey Parameters menu option from the System Setup main menu (See Figure 13-1 on page 65), will display a screen similar to Figure 13-10. This section details each parameter listed in this menu.
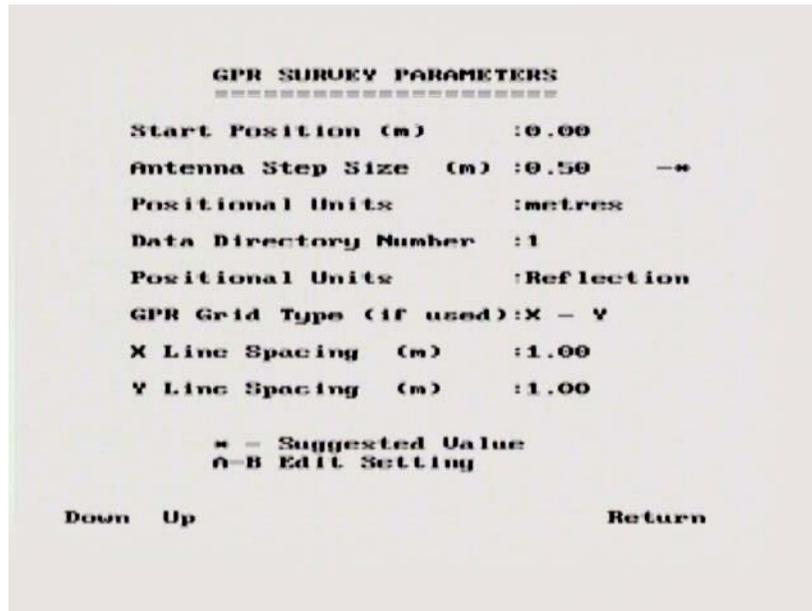


*Figure 13-10: The GPR Survey Parameters menu. Use the Up and Down buttons to move to the desired parameter and edit the value by pressing the A and B buttons.*

### 13.4.1 Start Position

This is the starting position for the first trace. Normally, most lines start at position zero (0.0) and the position of each trace increments by the Antenna Step Size (Section 13.2.5: P72). The Start Position value can be changed to a non-zero and even a negative value if necessary.

It is assumed that the units for all position and distance quantities are the units specified under Positional Units (Section 13.4.3: P86).

For a CMP/WARR measurement, the start position is the initial antenna separation.

### 13.4.2 Antenna Step Size

The Antenna Step Size can be changed in this menu as well as the menu under System Setup - GPR Parameters (Section 13.2.5: P72).

### 13.4.3 Positional Units

Two distance units are available: metres or feet.  This information is stored in the header file and is used in plotting scales.  All distance parameters in the other menus will be interpreted based on the setting of this item.

### 13.4.4 Data Directory Number

This option is used to determine the directory that the data files will be saved to. The idea is that related data files are saved in the same directory.

The Data Directory Number can be changed in this menu or under the Run pulseEKKO menu (Section 15.1: P105).

The user has access to 20 different directories for data storage.

### 13.4.5 Survey Type

Ground penetrating radar has been used in many different survey modes to gather information.  Three of the more common modes are:

   a)  Reflection mode, which is by far the most common mode used to map underlying stratigraphy, (See Figure 16-1 on page 119).

   b)  CMP (Common Mid Point) or WARR (Wide Angle Reflection and Refraction), useful in deducing information on wave propagation velocity versus depth (Section 16.11: P132) and

   c)  Transillumination where the transmitting and receiving antennas are situated at opposite sides of a partition to study the transmission properties of the dividing material (Section 16.12: P134). The options available here are Trans., Trans - ZOP, Trans - MOG and Trans - VRP. Calibration files are also related to Transillumination surveys. **Borehole transillumination surveys are detailed in Appendix I: pulseEKKO PRO Borehole Data Acquisition.**

### 13.4.6 GPR Grid Type

The grid parameter settings in the Survey Parameters menu allow the user to modify settings specific to collecting data in organized grids.  This includes the grid type and line spacing.

Data are normally collected on a grid if the user is interested in displaying the data as a 3D volume (using the EKKO_3D software) or as a plan map (using the EKKO_Mapper software).  Producing accurate 3D volumes or plan maps is easier if the field survey is properly designed and data are collected correctly.

Positional accuracy of each line is vital if the user wants to be able to relocate targets of interest after the data have been processed.

For linear targets like pipes and utilities, the best GPR response occurs when the GPR survey line crosses the target at right angles. If possible, it is always best to run GPR survey lines perpendicular to the direction of linear targets.

Sensors & Software's EasyGrid makes laying out an accurate, square grid simple. Contact Sensors & Software for more details.

The Grid Type determines the way that the area of the grid is to be covered by the survey lines. Survey lines can be either a set of parallel lines in the X axis direction (Figure 13-11), a set of parallel lines in the Y axis direction (Figure 13-12), or, for complete coverage, parallel lines in both the X and Y direction (Figure 13-13).

**X Lines Only**

Set up a first-quadrant XY grid. Data lines run in the X direction, distance increasing from the Y axis baseline. Line numbers increase in the positive Y direction (see Figure 13-11). Lines must be equally spaced. It is not critical that all the lines are the same length. However, it does make processing easier if all the lines start at the same baseline position (usually defined as zero (0.0)).



*Figure 13-11:  The line configuration for lines collected in X Lines Only mode. The convention is that X lines are parallel to the X axis. For seamless integration into data processing software like EKKO_Mapper, note that the lines are assumed to be collected with X positions increasing as the line moves away from the Y baseline. Line numbers start at line 0 and increment as the lines move away from the X axis. The Line Spacing distance needs to be specified in the grid settings and lines should be equally spaced.*

**Y Lines Only**

Set up a first-quadrant XY grid. Data lines run in the Y direction, distance increasing from the X axis baseline. Line numbers increase in the positive X direction (see Figure 13-12). Lines must be equally spaced. It is not critical that all the lines are the same length. However, it does make processing easier if all the lines start at the same baseline position (usually defined as zero (0.0)).



*Figure 13-12:  The line configuration for lines collected in Y Lines Only mode. The convention is that Y lines are parallel to the Y axis. For seamless integration into data processing software like EKKO_Mapper, note that the lines are assumed to be collected with Y positions increasing as the line moves away from the X baseline. Line numbers start at line 0 and increment as the lines move away from the Y axis. The Line Spacing distance needs to be specified in the grid settings and lines should be equally spaced.*

**X and Y Lines**

Set up a first-quadrant XY grid. X data lines run in the X direction, distance increasing from the Y axis baseline. Line numbers increase in the positive Y direction (see Figure 13-13). Lines must be equally spaced. Y data lines run in the Y direction, distance increasing from the X axis baseline. Line numbers increase in the positive X direction. Lines should be equally spaced. The line spacing of the X lines and Y lines can be different.

It is not critical that all the lines are the same lengths. However, it does make processing easier if all the lines start at the same baseline position (usually defined as zero (0.0)).
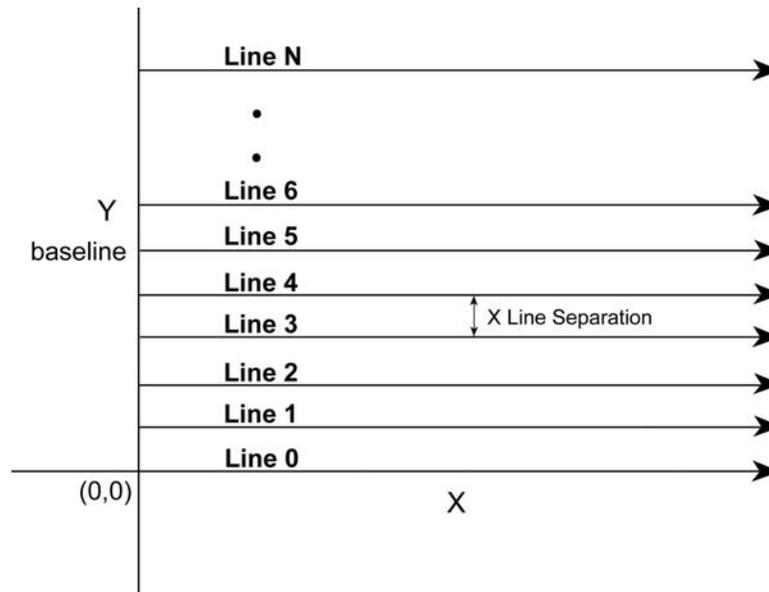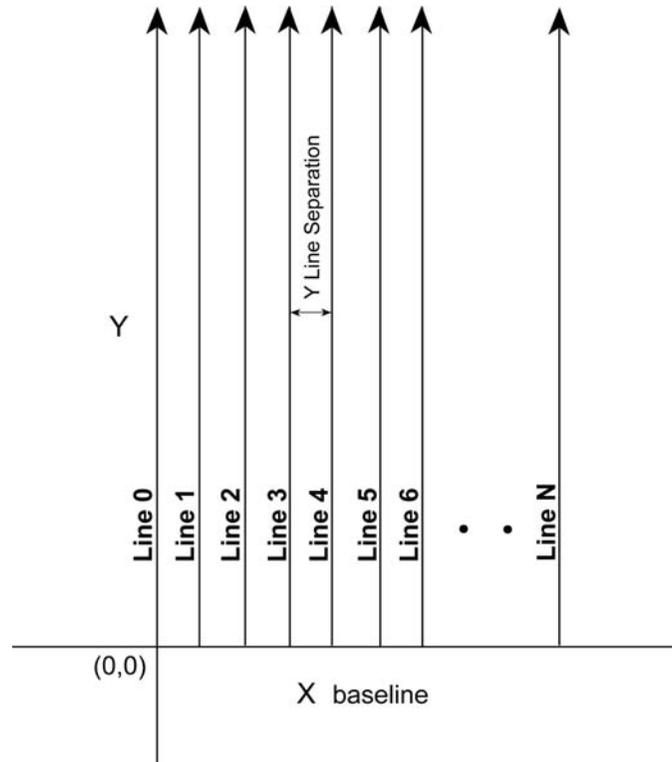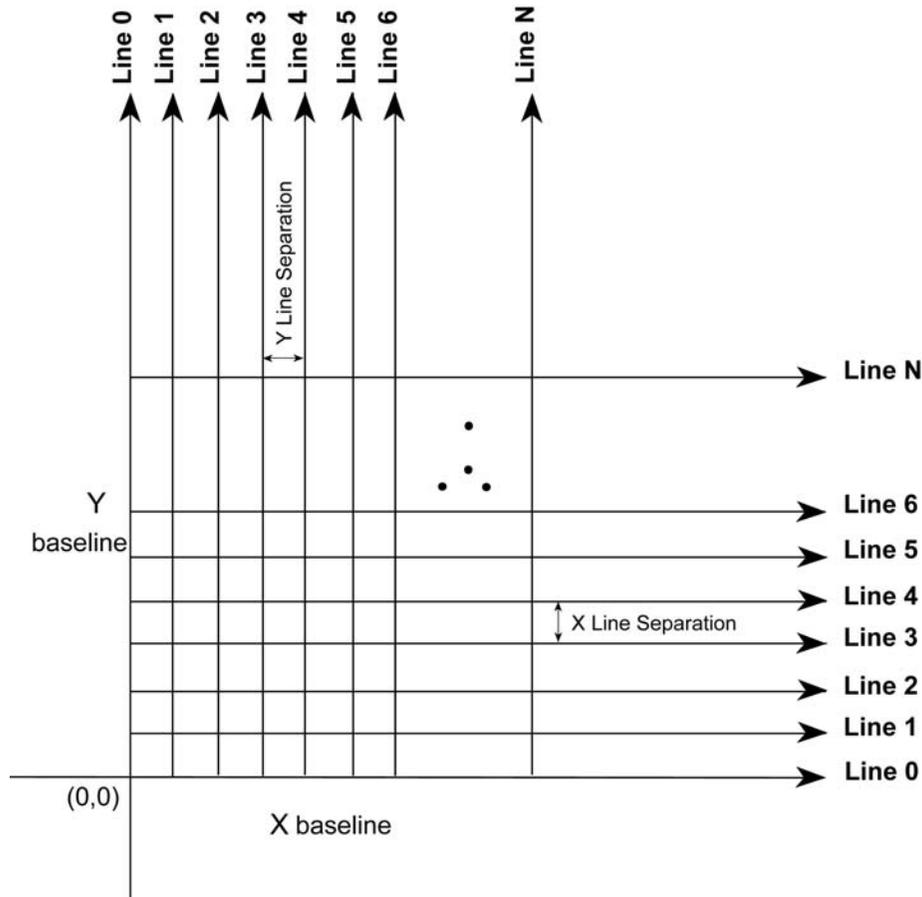


*Figure 13-13: The line configuration for lines collected in XY Lines mode. The convention is that X lines are parallel to the X axis and Y lines are parallel to the Y axis. For seamless integration into data processing software like EKKO_Mapper, note that the lines are assumed to be collected with X positions increasing away from the Y baseline and the Y positions increasing away from the X baseline. Line numbers start at line 0 and increment as the lines move away from the axes. The Line Spacing distances needs to be specified in the grid settings and lines should be equally space, although the X line spacing and Y line spacing can be different.*

### 13.4.7 X Line Spacing

For X Only or XY grid data acquisition, the distance between the X survey lines needs to be specified in this menu (Figure 13-11 and Figure 13-13). The distance units are assumed to be the same as those specified in Positional Units (Section 13.4.3: P86)

If an XY grid is being collected, note that the line spacing of the X lines and Y lines can be different.

### 13.4.8 Y Line Spacing

For Y Only or XY grid data acquisition, the distance between the Y survey lines needs to be specified in this menu (Figure 13-12 and Figure 13-13). The distance units are assumed to be the same as those specified in Positional Units (Section 13.4.3: P86)

If an XY grid is being collected, note that the line spacing of the X lines and Y lines can be different.

### 13.4.9 GFP Files

When data are collected in a grid, a special file, called a GFP file, is generated. GFP stands for "GPR Files and Processing" and this file saves information about the grid including the positions and geometry of the GPR line data files. The GFP file is saved in the same grid folder on the DVL as the grid data files. When the grid folder is transferred to a PC (Section 18.1: P147), the GFP file is present.

The GFP file allows the grid data to be quickly read and plotted in Sensors & Software PC-based software like **EKKO_Mapper**.

The GFP file can be viewed and edited using the **GFP_View** program. GFP_View is used to add and delete line data files and change the positions of the data lines. See the **GFP_View User's Guide** for more information.

## 13.5  Display Parameters

Selecting the Display Parameters menu option from the System Setup main menu (See Figure 13-1 on page 65), will display a screen similar to Figure 13-14. This section details each parameter listed in this menu.



```
            GPR DISPLAY PARAMETERS
            ------------------------

    Trace Plotting Type      :Grey 1-P

    Gain Type Applied        :Constant

    Gain Applied    (mult) :200.00




            A-B Edit Setting


 Down   Up                            Return
```
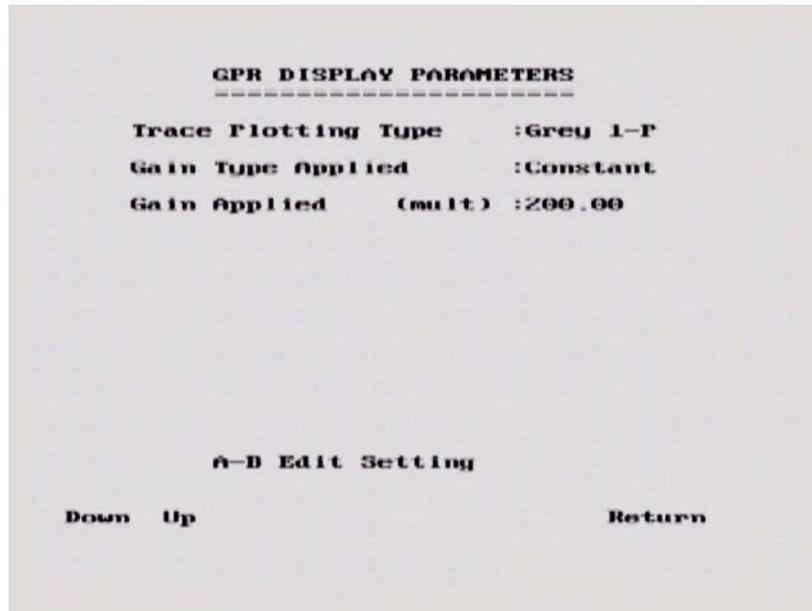
*Figure 13-14:  The Display Parameters menu. Use the Up and Down buttons to move to the desired parameter and edit the value by pressing the A and B buttons.*

### 13.5.1 Trace Plotting Type

The data traces can be plotted in two ways: Grey scale or Wiggle.

**Grey** means each data point is plotted as a grey strip based on its amplitude (Figure 13-15).

If traces are plotted in grey scale, the trace width, in pixels, can also be specified.  The choices are 1, 2, 4 or 8 pixels with 2 or 1 pixels being the usual setting.  For example, the VGA screen on the DVL with a resolution width of 640 pixels can display:

80  traces 8 pixels wide

160 traces 4 pixels wide

320 traces 2 pixels wide

640 traces 1 pixel  wide

The narrower the trace width, the more data that can be displayed on one screen.
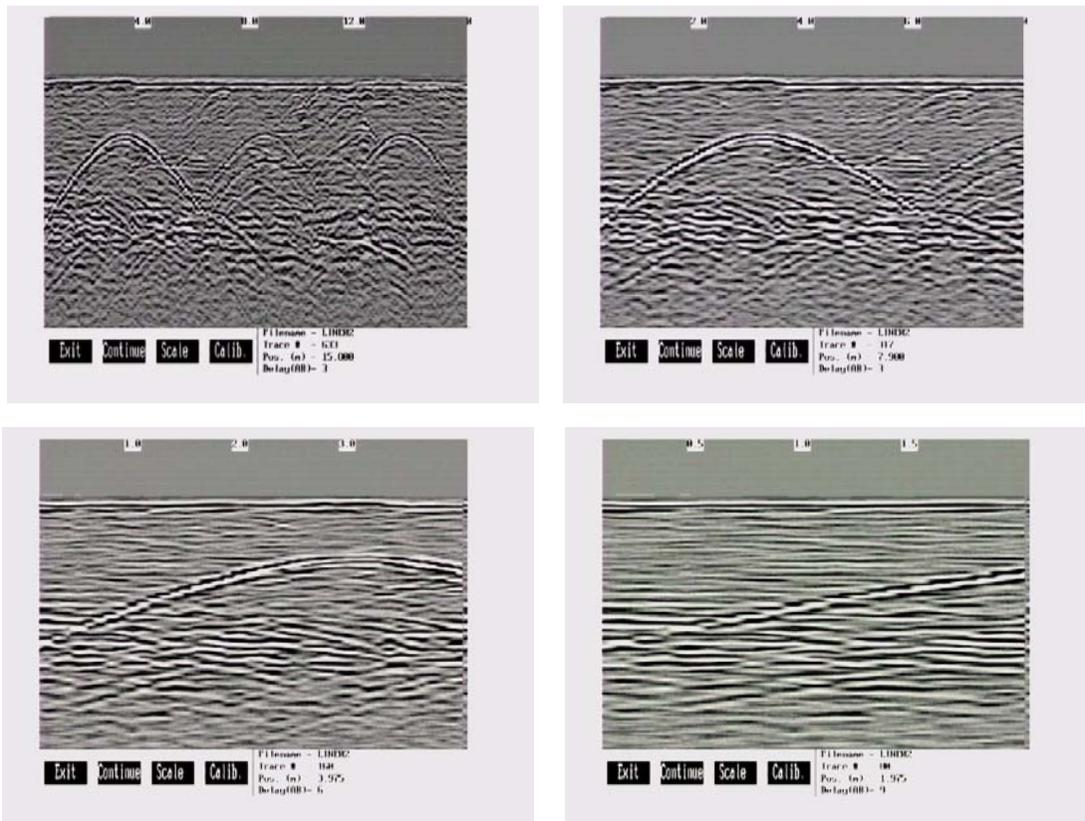
*Figure 13-15:  Grey scale traces depict the signal amplitude as shades of grey from white to black. Data traces can be plotted to the screen with a width of 1 pixel (top left), 2 pixels (top right), 4 pixels (bottom left) or 8 pixels (bottom right). The narrower the trace width, the more data that can be plotted on one screen. In this example, plotting the data 1 pixel wide results in 16 metres of data displayed on one screen while 2 pixels results in 8 metres of data, 4 pixels results in 4 metres of data and 8 pixels results in 2 metres of data.*

**Wiggle** means the traces will be plotted as a curved line with the amplitude determining the size of the curve (Figure 13-16). The wiggle traces can be plotted with shading on the Left side or negative amplitude side of the trace (Wiggle - L), the Right side or positive amplitude side of the trace (Wiggle - R) or with no shading (Wiggle - N). The normal default is to shade on the right (positive amplitude) side.



*Figure 13-16:  Wiggle trace plots show signal strength with a curved line. The left (or negative) side of the curve or the right (or positive) side of the curve can be shaded (left image). The right image shows the wiggle traces with no shading.*

## 13.5.2 Gain Type Applied and Gain Applied

Since the radar signal strength normally decreases with increasing time, it is usually necessary to apply some sort of gain function to boost the weaker signals at later times.

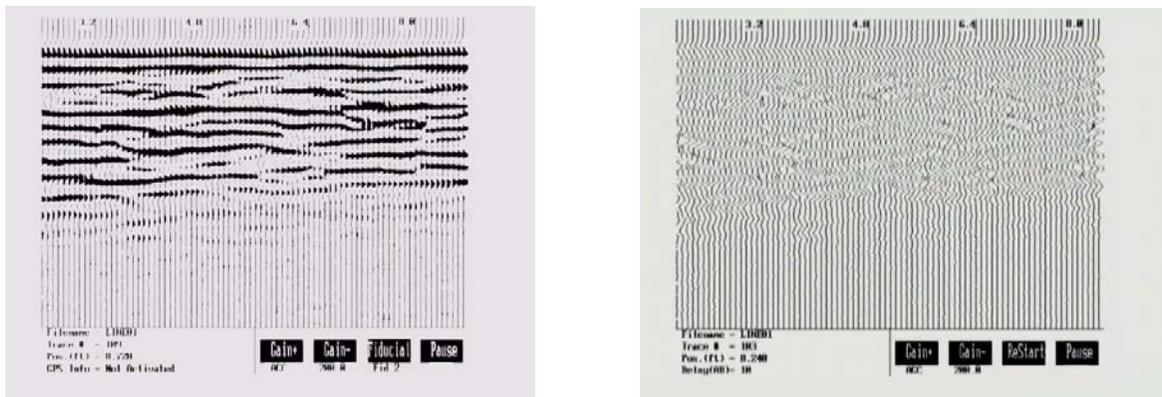The raw, ungained data shows little signal except for the strong near-surface reflectors (Figure 13-17).   No gain may be useful in areas where the radar signal is very strong or in areas where the targets are very shallow.

Four gains are available: AGC, SEC, Constant, and None. These are each described below.

*No matter which gain function has been selected, the data are ALWAYS stored WITHOUT any gain applied.  Gain is only applied for real-time display purposes.*

For data collection in the field, AGC and constant gains are often the most practical to show that the system is working properly and to show a range of reflectors in the material. Other more sophisticated gains, like SEC functions, can be applied later when plotting the data in the office.
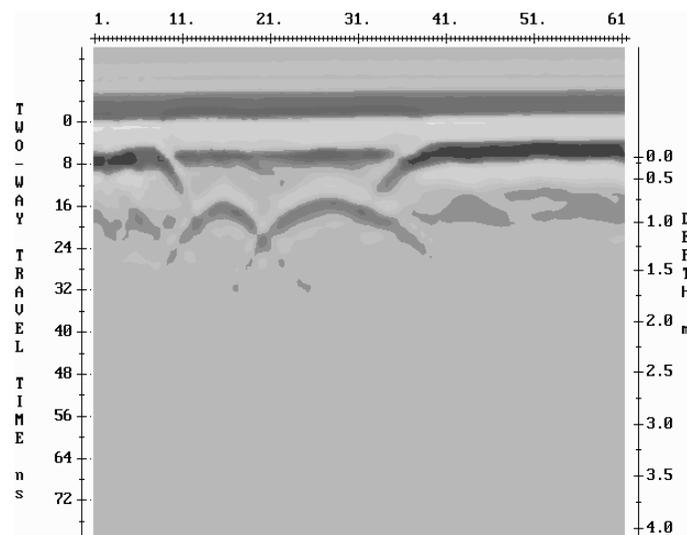


*Figure 13-17:  Display of a data section over buried tanks.  No gain was applied before plotting.*

Note that none of the gain functions are permitted to boost a data point value to greater than 32767 or less than -32767.  Values where this occurs are trapped and forced to 32767 or -32767.

### 13.5.2.1   AGC Gain

The AGC (Automatic Gain Control) gain attempts to equalize all signals by applying a gain which is inversely proportional to the signal strength (Figure 13-18). This type of gain is most useful for defining continuity of reflecting events. The user should realize that AGC does not preserve relative amplitude information. Hence once the data have been AGC'ed, the user can no longer make reliable deductions concerning the strength of any particular reflector relative to other reflectors (Figure 13-19).

Since the AGC gain is inversely proportional to the signal strength, very small signals can produce very large gains.  Therefore some type of gain limiting scheme must be applied. The user enters the maximum gain which can be applied to the data.  This maximum gain is then fixed for the whole data set.

Note that if a data point multiplied by the gain exceeds 32767, the absolute value of the new data point value becomes 32767 or -32767.
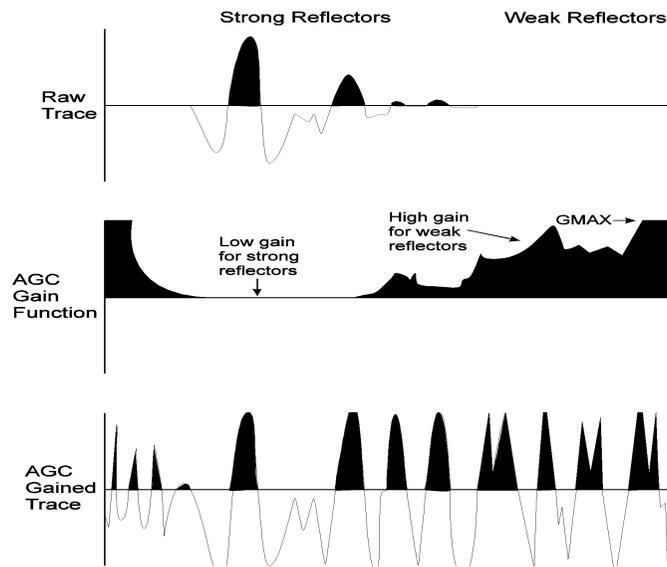
*Figure 13-18:  Shows how the AGC function (middle) is inversely related to reflector strength of the raw trace (top).  The AGC gained trace (bottom) is a result of multiplying each point in the raw trace with the equivalent point in the AGC function.*



*Figure 13-19:  Display of a data section over buried tanks.  An AGC gain was applied before plotting.*

The only user variable for the AGC gain is the **Max Gain Applied** value. This is a number between 1 and 32767 which determines the maximum gain that can be applied to any data point.  This maximum gain is fixed for the whole data set. A typical value would be 50 - 2000 depending on the noise and average signal levels.

### 13.5.2.2 SEC Gain

The SEC (Spreading & Exponential Compensation) gain is a composite of a linear time gain and an exponential time gain. This gain compensates for the spherical spreading losses and the exponential dissipation of energy in the data being collected. Since radar data is attenuated exponentially and the SEC is an exponential gain (Figure 13-20), it tends to be the gain closest to physical reality. Therefore, unlike the AGC gain, reflections can be compared for relative signal strength (Figure 13-21 and Figure 13-22).

This gain is essentially an exponential function. This exponential function could, in fact, go to infinity. Therefore, as with the AGC gain some gain limiting factor must be applied. This gain limiting factor is identical to the one used in the AGC gain (see AGC above).
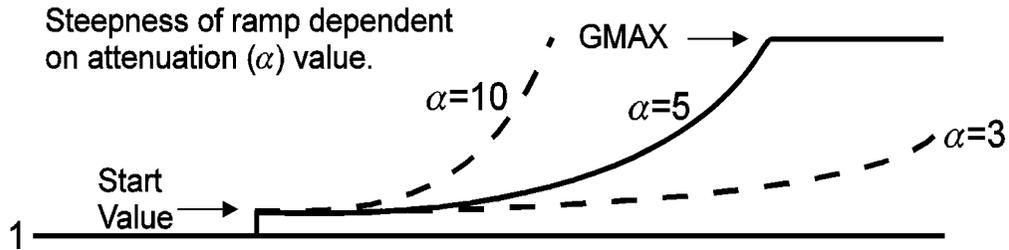


*Figure 13-20: The SEC function has one parameters that must be specified. GMAX is a limiting value on the function. The Attenuation (alpha) value determines the steepness of the ramp. When data are collected in areas with high attenuation, a higher Attenuation (alpha) value may be necessary to reveal weaker signals.*
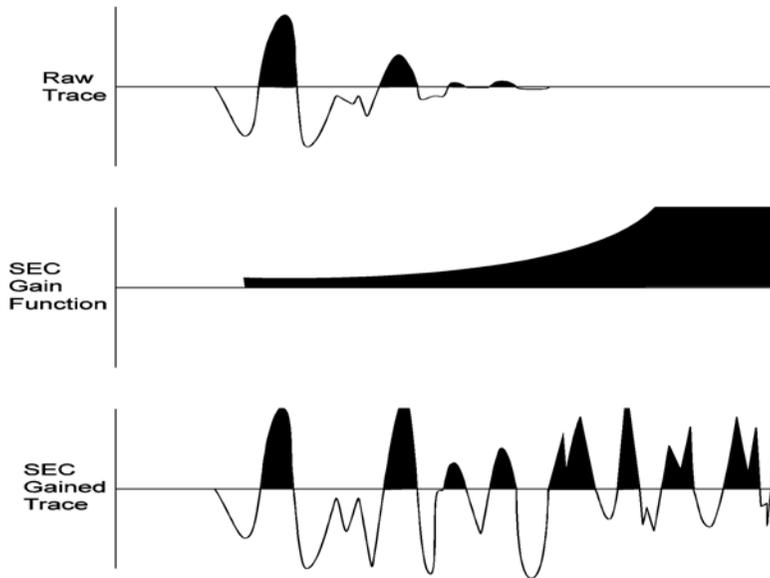


*Figure 13-21: Shows the exponential nature of the SEC function (middle). The SEC gained trace (bottom) is a result of multiplying each point in the raw trace (top) with the equivalent point in the SEC function.*
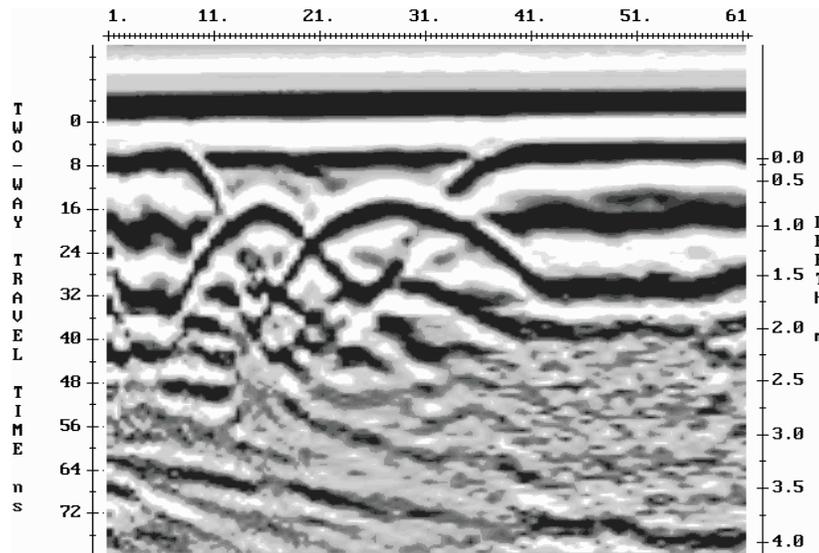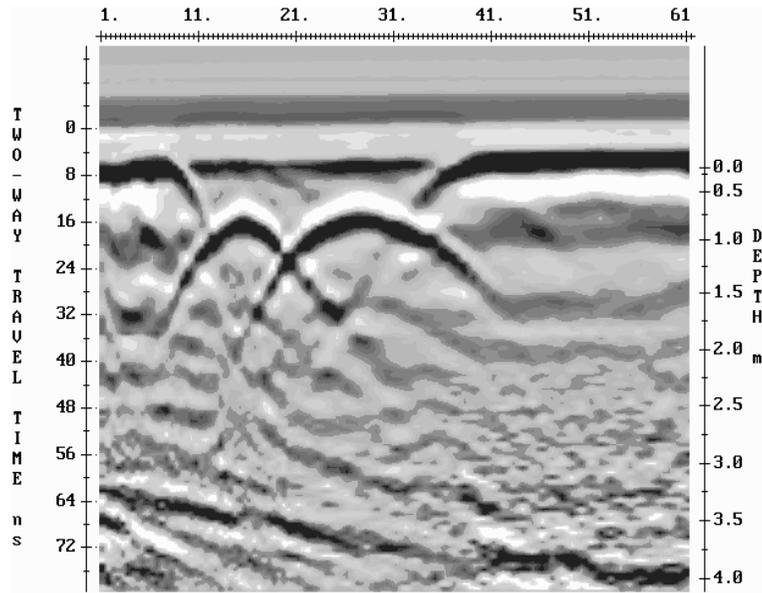
*Figure 13-22:  Display of a data section over buried tanks.  An SEC gain was applied before plotting.*

The only user variable for the SEC gain is the **Alpha Gain Applied** value. This quantity represents the radar wave attenuation given in decibels/metre. A typical value is 0.5 to 5.

### 13.5.2.3 Constant Gain

This routine will apply a constant gain factor to the input data set. The only parameter required is the constant factor to multiply all data points by. Thus if the user enters the number 10, all data points will be multiplied by a factor of 10. This will gain strong signals and weak signals equally and result in the clipping of strong signals.

The advantage of a constant gain is that it is easy to understand how the amplification works. The disadvantage of a constant gain is that it tends to over-gain the strong signals at the beginning of the trace Figure 13-23.

The parameter needed for the Constant gain function is the **Constant Multiplier**. Typical values for the Constant gain are in the range from 5 to 1000.
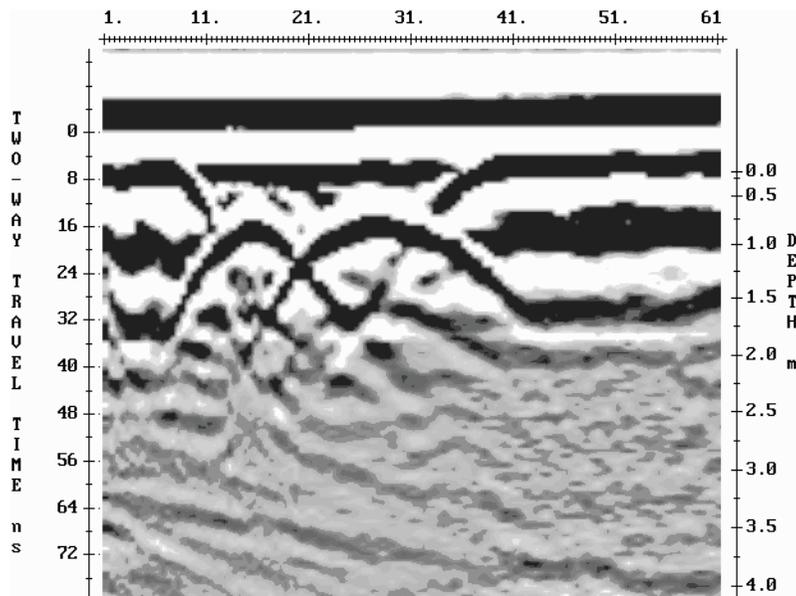


*Figure 13-23: Display of a data section over buried tanks. A Constant gain was applied before plotting.*

## 13.6  DVL Setup Menu

### 13.6.1 Set DVL Time and Date

The date and time are saved with the data files.  The DVL date and time setting can be changed by moving to one or more of the appropriate fields and editing the current setting.  The LEFT and RIGHT arrows are used to move between fields.  To change any of the numbers or months, use the UP and DOWN arrows to increase or decrease the value.  When the desired date and time are set, press ENTER to save the changes.
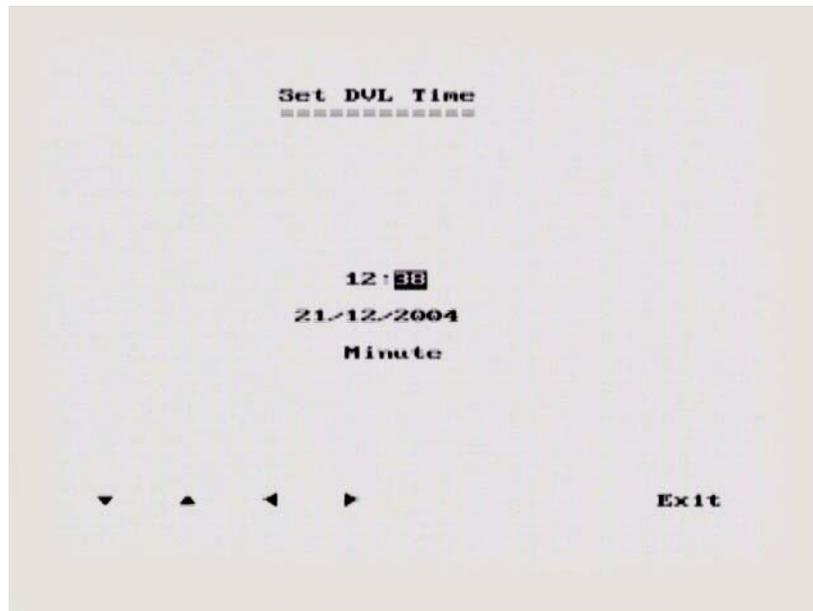


*Figure 13-24:  DVL set time and date screen.*

### 13.6.2 Set DVL Transfer Mode

Transfer Mode requires the use of the optional PXFER cable so this menu is **not** required for users transferring pulseEKKO PRO data using the removable compact flash drive.

This menu allows the user to set the transfer mode to Normal or Turbo depending on what type of PXFER cable they have (see Appendix H: Using the PXFER Cable and WinPXFER Software).

### 13.6.3 Set DVL into Upgrade Mode

Upgrade requires the use of the optional PXFER cable so this menu is **not** required for users who upgrade their DVL firmware using a removable compact flash drive.

The menu allows the user to enter Upgrade mode to update the firmware on the DVL. Selecting Upgrade puts the DVL into listen mode to allow a software upgrade to be transferred from an external PC to the DVL using the PXFER and WinPXFER cable. Avoid pressing this button until the instructions in a software upgrade tell you to. Once pressed, the DVL must have the power disconnected to exit from this menu item.

### 13.6.4 Select Display Info Mode

The Display Info Mode refers to the messages written to the screen at the start of data collection. When the user presses the Start button to acquire a line of data, the system must set up communications between the various system components and initialize them. During this process, messages are written to the screen. The Display Info mode determines the level of message detail.

There are two options available under Display Info Mode: Normal and Display Info.

In normal mode, a minimal number of messages are written. In Display Info mode, detailed messages about every system interaction are written to the screen.

In general, it is best to use Normal mode unless you are trying to troubleshoot a system problem (Section 17: P137).

## 13.7  View Complete Setup

The View Complete Setup option displays a listing of the current setup parameters for the pulseEKKO PRO (See Figure 13-2 on page 65).

## 13.8  Return

Selecting Return will exit the System Setup menus and return the user to the pulseEKKO PRO main menu screen (see Section  on page B-61). Exit also serves an important function. Before exiting, the program saves all the current data collection parameters. This process enables the user to continue with the same settings when the system is restarted.

# 14   Running in Scope Mode

Once the System Setup parameters have been set, data collection can begin by selecting **1 - Run pulseEKKO GPR** from the main menu. The screen shown in Figure 14-1 will be visible.

Turn on the transmitter and receiver and ensure that they are fully powered and initialized by checking that the Power LED on the top of the unit has stopped flashing.

**Scope Mode** (described in this section) is used to check that the system is running correctly before starting to collect and save survey data in **Collect Line Data** or **Collect Grid Data** mode (Section 15: P105).
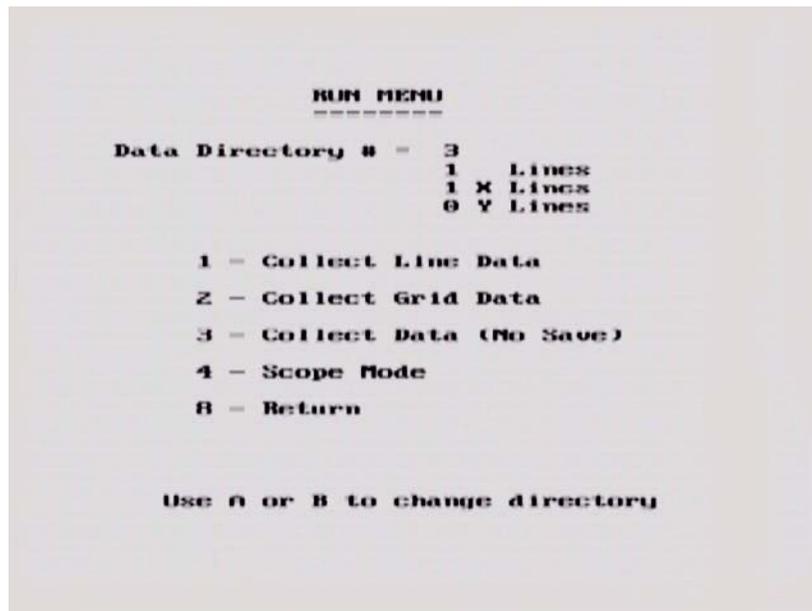


*Figure 14-1:  The Run menu allows the operator to find the pulse and set up timezero in Scope mode, collect Line data, grid data or collect data without saving. If data are to be saved, the data directory number is selected using the A and B buttons.*

**Scope** mode is used to make sure that connections are correct, all parameters are properly set and valid data are being collected. Scope mode displays the radar trace in the traditional oscilloscope scan format (see Figure 14-2). Scope mode should normally be run first, prior to data collection and storage. Data cannot be saved in Scope mode. Once the user is satisfied that everything is working, they can switch to Collect mode to begin data collection.

Scope mode serves two main functions:

   a)   to ensure that valid data are being collected properly, and

   b)   to set the location of the transmit pulse (which is the reference timezero or the first break).

Selecting **Scope Mode** from the main menu displays a screen with **EXIT**, **SCALE** and **START**.

**START** begins data collection. **EXIT** returns the user to the Run menu shown in Figure 14-1. **SCALE** allows the user to modify the maximum amplitude displayed on the graph scale. This parameter may take on any value between 1 and 50 millivolts. The default value of 50 is rarely changed.

## 14.1  Scope Screen

A sample of a screen data plot while in Scope mode is shown in Figure 14-2. The radar amplitude (in millivolts) is plotted in the vertical axis while the time axis is plotted in the horizontal axis. The length of the time axis depends on the Time Window value. Each division in the time axis is 10% of the length of the Time Window. In the case shown in Figure 14-2, the Time Window is 100 ns so each division is 10 ns wide.

Below the plot, the vertical amplitude scale, trace number, time window, sampling interval (DeltaT), timezero offset, number of points, stacks and frequency are listed. It also indicates that the data trace is being filtered with a 25 point DEWOW filter (see Appendix B: on page B-1).

Pressing the **START** button begins data collection. Traces are plotted to the screen continuously, with the trace number incrementing for each new trace.

The data collection speed in Scope mode does not necessarily correspond to the data collection speed in Collect mode (Section 15: P105). While the system is capable of collecting data at speeds up to hundreds of traces per second, in Scope mode traces are plotted to the screen every 0.5 seconds. The user can slow down the trace display speed in Scope mode by changing the Free Run Delay time to a value greater than 0.5 seconds (Section 13.3.3: P79).

The STOP pauses acquisition and displays a menu with further options.
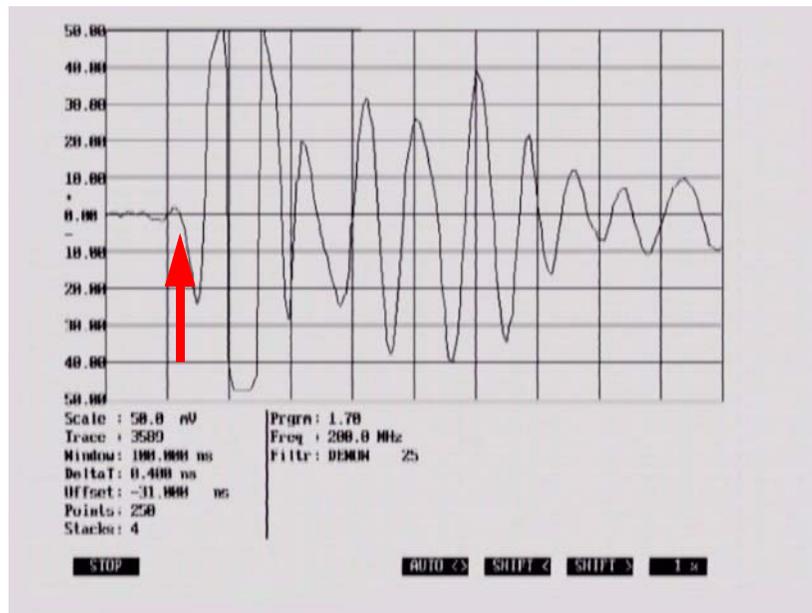


*Figure 14-2: A sample of a screen data plot while using Scope mode. The parameters below the graph, the trace number, time window, sampling interval (DeltaT), points, stacks and frequency are listed (Section 13: P65). The Offset parameter listed is explained below.*

The **Offset** is the value used to adjust the first break to the ideal region.  The value has no importance to the radar data; it is only used for the adjustment of the initial radar pulse to the desired position within the time window. It compensates for changes in cables and differences in electronic components.

## 14.1.1 Adjusting Timezero (Offset)

Assuming that data are coming in, the first step is to ensure 'timezero' is in the correct location. Timezero, for our purposes, is defined as the first arrival of the radar wave; it is used as a convenient reference starting point for the trace, hence the name: timezero.

Timezero should be located near the beginning of the second vertical division on the screen (Figure 14-2). Locating timezero to the right (further in time) of the second division has no ill effect on the data, it just means possible reflectors may be lost off the bottom of your recording window. Locating timezero to the left of the second division should be avoided.
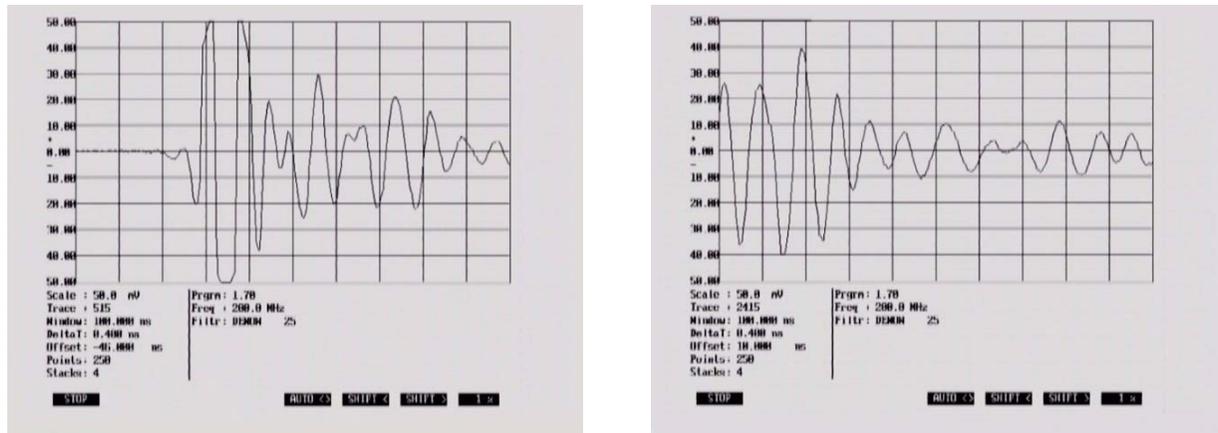


*Figure 14-3: Timezero or the first break is the first large deflection in the trace. Ideally, timezero needs to be shifted to the start of the second vertical division as shown in Figure 14-2. Use the **Auto <>** button to try and automatically locate timezero and set it to the correct position. The **Shift >** and **Shift <** buttons can be used to move timezero to the right and left respectively. When a Shift button has been pressed, it changes to reverse video and timezero will keep moving in that direction until Shift is turned off by pressing it again. The percentage button indicates the percentage of the shift in each step, a larger percentage indicating a larger shift. Locating timezero further to the right reduces the amount of data collected from the subsurface (left). Locating timezero further left affects the data collected and should be avoided.*

The location of timezero is affected by a number of factors. These include: various system hardware components, length of fibre optic cables, separation of transmitter and receiver antennas, and the total time window.

To set 'timezero', the transmit and receive antennas should be set to the antenna separation being used for the survey (Section 13.2.4: P71). This assures a large first arrival with minimal propagation delay. The start of the second division represents the 'ideal' location for timezero (see Figure 14-2). The purpose is to adjust the 'timezero' location so that it falls near the start of the second division. There are 4 menu options along the bottom of the screen to assist with adjusting timezero: Auto <>, Shift <, Shift > and a percentage.

Pressing **Auto <>** initiates an automatic search and adjust to bring the timezero location within the ideal region. The automatic search and adjust, while not perfect, should work get timezero close to the ideal region most of the time. It is based on the assumption that the first break (first signal to arrive) is strong compared to the surrounding background noise. If antennas are at a large separation, or there is a large amount of external noise then this automatic adjustment may not function correctly.
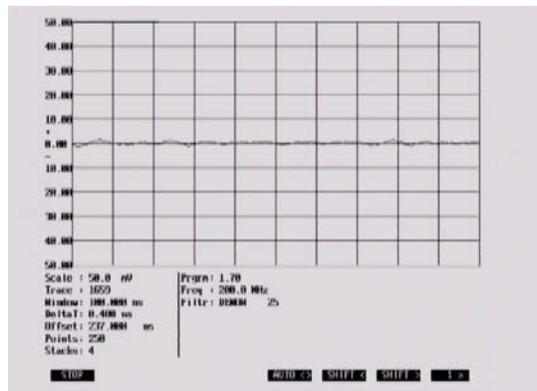
*Figure 14-4: If the transmit pulse is not visible on the Scope screen, use Auto <> to shift the pulse closer to the ideal region shown in Figure 14-2.*

**Shift >** and **Shift <** are used if the transmit pulse is visible on the screen but needs to be moved into the ideal region (Figure 14-3). The Shift button will change to reverse video when selected and the pulse will step across the screen in the direction indicated. Pressing the Shift button again will deactivate the shift and stop the pulse. The percentage value (1%, 5%, 10% and 25%) determine the amount that the pulse is shifted in each step. Generally, 1% or 5% work well. The higher values tend to shift the pulse in large steps and it is easy for the pulse to shift a long way very quickly.

*In general, timezero should be found near an Offset value (listed on the scope screen) of around zero ns.*

If no transmit pulse is found then there is a problem with the transmitter (Section 17.5: P144).

Once the user is happy that everything is working properly and all parameters are correctly set, pressing the **STOP** and **EXIT** button exits Scope mode and returns the user to the main Run menu. At this point, the user can select Collect to begin data collection.

# 15   Data Collection Mode

After timezero has been properly set up (Section 14: P101), data collection can begin.

Ensure that the transmitter and receiver are fully powered and initialized by checking that the Power LED on the top of the unit has stopped flashing.

Select **Run pulseEKKO** to initiate data collection. **Collect** mode will collect data or replay previously collected data.
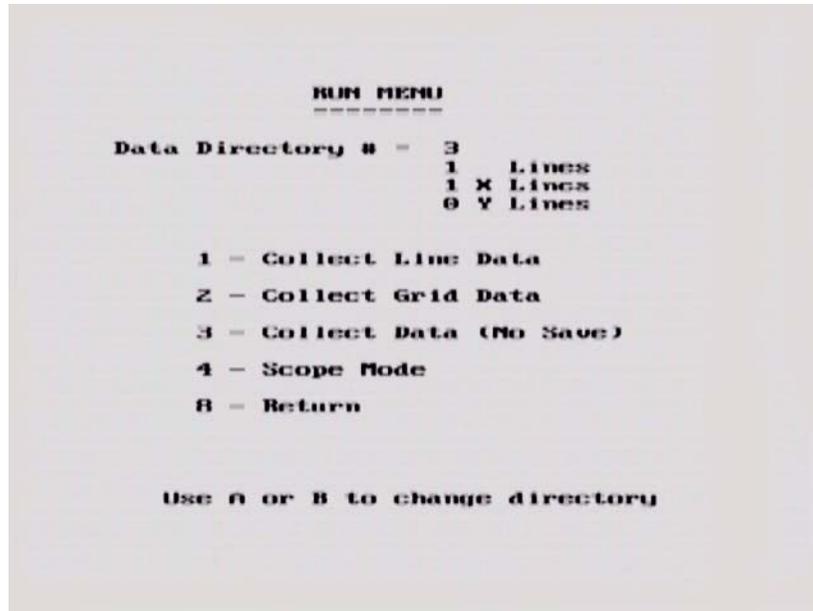


*Figure 15-1:  The Run menu allows the operator to find the pulse and set up timezero in Scope mode, collect Line data, Grid data or collect data without saving. If data are to be saved, the data directory number is selected using the A and B buttons.*

## 15.1  Data Directory

The current directory number is listed on the Run Menu screen. There are 20 directories available and the current directory number can be changed using the A and B buttons. In general, related data files should be saved in the same directory number.

The directory number can also be changed in the Survey Parameters menu (Section 13.4.4: P87).

As the name implies, Collect Line Data is selected when the user is ready to collect data.

## 15.2  Select Line Number

The first screen displayed after selecting Collect Line Data is shown in Figure 15-2. This screen is used to determine the number of the line to be collected.
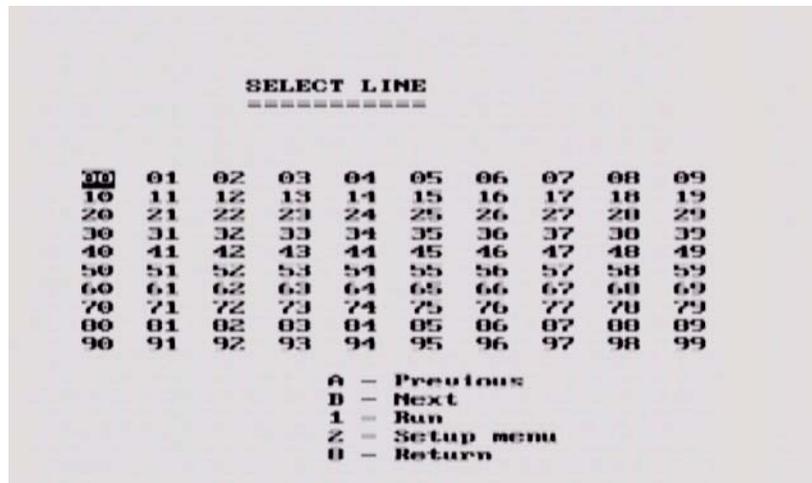


*Figure 15-2:  Selecting Collect Line Data will display this screen. The user can select the line number to be collected. The default line number is the lowest line number available. As lines are collected, their associated number will appear in black on this screen. Use the A and B buttons to move to any number on the list. When ready to collect data press **1 - Run**. If you select the number of an existing line, you will have the option to Overwrite or View the data file.*

## 15.3  Data Collection

Once the line number or Collect Data (No Save) is selected, the program begins data collection.

**Antennas:** Before starting data collection, the user must make sure that the antennas are in their correct starting positions and are ready to be moved to the next position when required.

**System Initialization Messages:** Before data collection begins, the system conducts an initialization process where it attempts to communicate with all the components and ready them for data acquisition. During this process, comments are written to the screen indicating what component is being initialized (Figure 15-3). The level of detail in these messages is control by the Display Info Mode (Section 13.6.4: P100).

If an error occurs during this process, a message is written to the screen indicating where the problem occurred and how it might be solved (Section 17: P137).
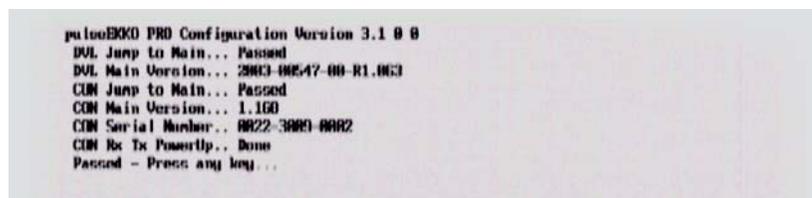


*Figure 15-3:  After a line name is selected, the system initialization process attempts to communicate with all the components and ready them for data acquisition. During this process, comments are written to the screen. If an error occurs during this process, a message will appear indicating where the problem occurred and how it might be solved.*

**Error Messages:** Messages will be displayed if any system connection is incorrect or if there is a problem with the system (Section 17: P137).

**Collect Screen:** A sample of a screen data plot while in COLLECT mode is shown in Figure 15-4.
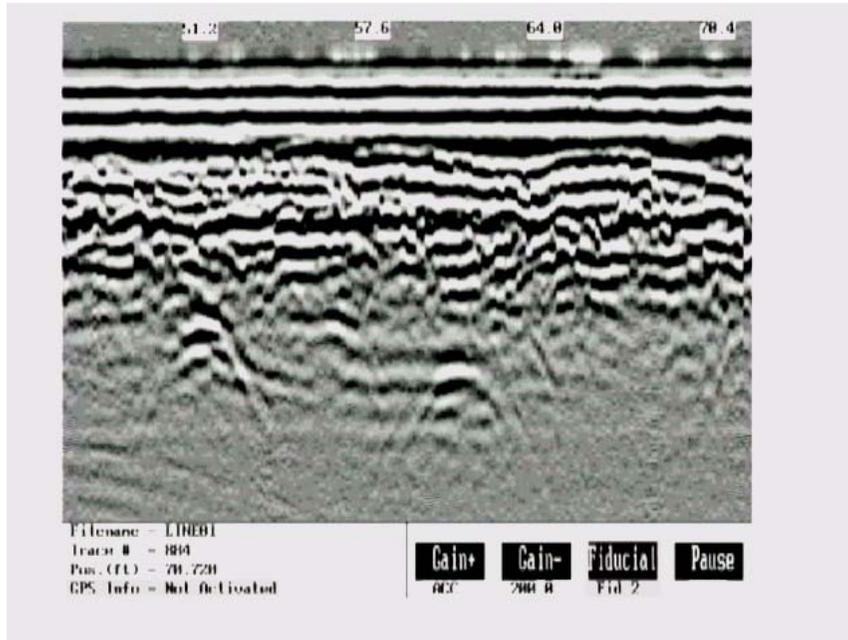


*Figure 15-4: Data collection screen with traces plotted in grey scale. The horizontal distance of data plotted on the screen depends on the pixel width of the traces (Section 13.5.1: P92)*
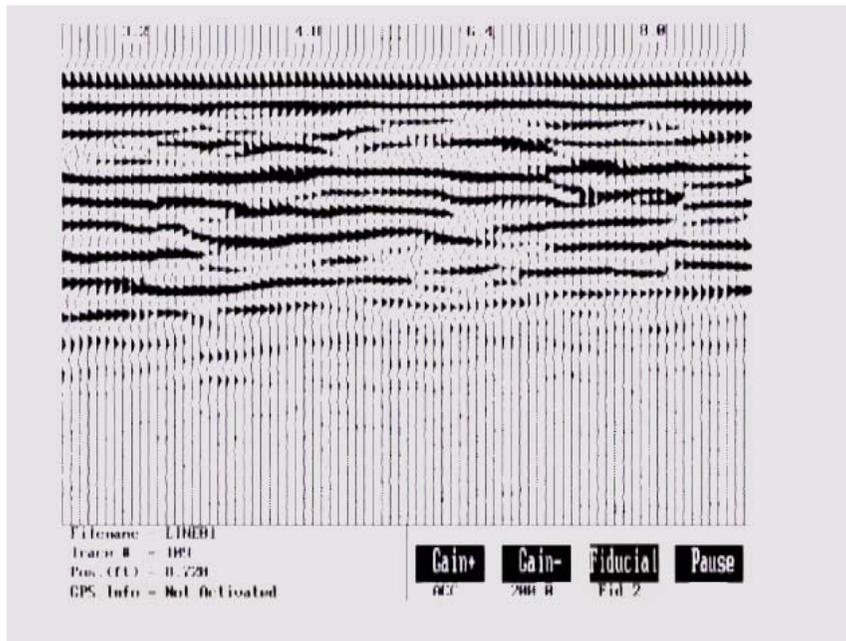


*Figure 15-5: Data collection screen with traces plotted in wiggle trace mode with shading on the right (Section 13.5.1: P92)*

**Trace Type:** Depending on the user's choice for Trace Plotting Type (Section 13.5.1: P92) the data will be plotted as either grey scale (Figure 15-4) or wiggle traces (Figure 15-5).

In general, wiggle traces are commonly used for deep geological sounding where horizontal and vertical distances are similar. Grey scale plots work better when exploration is shallow and traces must be squeezed together because the vertical depth is much smaller than the horizontal distance on the display.

**Axes:** Time is plotted vertically from top to bottom and position is plotted horizontally from left to right on the data image. Periodically, position values are displayed on the top of the data image. That position corresponds to the left of the white box displaying the position.

On the bottom line of the screen the file name, trace number and position of the current trace are listed. It also displays the GPS status.

If a GPS receiver is attached to the DVL (Section 11.4: P57) a message will appear in the bottom of the screen indicating whether the GPS data is successfully being logged. The possible messages are:

> **GPS fix** means standard GPS data are currently being logged.

> **DGPS fix** means differential GPS data are currently being logged.

> **GPS Fix Type X** means the fix type output by the GPS is X, a value greater than 2.

> **Fix not valid** means GPS data are NOT currently being logged. This is usually because GPS satellites are not available.

> **Not Activated** means the GPS receiver is not operating properly. Check the settings and test the system (Section 13.3.4.7: P83).

> **No GGA** means the GPS receiver is not outputting a GGA NMEA string that the DVL requires (Section 13.3.4: P79).

**Gain:** The data are displayed with the current gain applied to the data. The gain value can be modified by the user by pressing the **Gain+** button to increase the gain or pressing the **Gain-** button to decrease the gain. If the gain is changed in this way, the gain value is not saved and the next line collected will be displayed with the current gain applied (Section 13.5.2: P94).

*No matter which gain function has been selected, the data are ALWAYS stored in raw format WITHOUT any gain applied. Gain is only applied for real-time display purposes.*

More details about the actual data stored can be found in the section on formatting in Appendix A: Data File Formats.

Pressing the **Pause** key suspends data collection and displays a menu with further options (Section 15.5: P110).

## 15.4  Fiducial Markers

A fiducial marker flags a specific position on the data section during data acquisition. Adding these markers during data collection is useful for recording significant landmarks or objects with known positions, e.g. a survey stake, encountered during the survey.
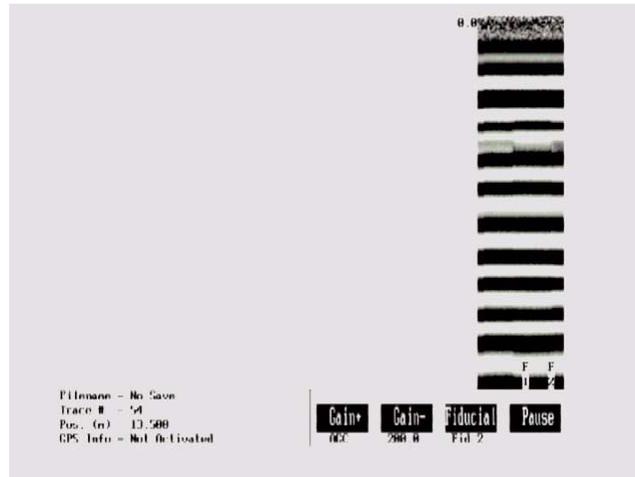


*Figure 15-6:  Fiducial markers can be added to the data by pressing the Fiducial button during data acquisition. Fiducial markers are written to the trace header of the next trace collected and displayed on the bottom of the data trace. Fiducial markers are always an "F" followed by an incrementing number, i.e. F1, F2, F3, etc.*

A fiducial marker is activated by:

    1)  pressing the **Fiducial** button on the DVL keypad,

    2)  pressing the **A** button on the DVL keypad,

    3)  pressing the button on the electrical beeper/trigger (Section 11.1: P51), or

    4)  pressing the button on the TR1000 electrical beeper/trigger (Section 9.1: P41)

during data acquisition (see Figure 15-4).

The position and name of the object encountered at each marker can be recorded in a field notebook.

The fiducial marker is written to the trace header of the next trace to be collected.  Fiducial markers are numbered sequentially (F1, F2 etc.).  When the data are transferred to a PC and reviewed, these markers can assist with data interpretation.

### 15.4.1 Fiducial Markers for Rubberbanding

Fiducial markers are useful when the data line is to be "rubberbanded". If fiducial markers corresponding to known positions are added to the data during data acquisition, these known positions can be used to stretch or squeeze the data line to a constant step size. This makes it possible to estimate the required step size and collect data without a tape measure or other measuring device, as long as there are a few locations along the survey line where the position is known.

The rubberbanding routine is a post-processing step available in the EKKO_View Enhanced and EKKO_View Deluxe software packages.

### 15.4.2 Fiducial Markers for GPS

If a GPS receiver is attached to the DVL, a file containing GPS information can be saved (Section 13.3.4: P79). In "On a Tag" mode, a line of GPS information will be added to the GPS file (Section 13.3.4.1: P81) whenever a fiducial marker is added to the data.

## 15.5  Data Collection Pause Menu

Pressing the **Pause** button suspends the data collection cycle and displays a menu that is displayed at the bottom of the screen.  The menu items are:

### 15.5.1 Exit

Exit from the data acquisition of the current line and go back to the Line Number screen (See Figure 15-2 on page 106) to prepare for the collection of the next line.

### 15.5.2 Continue

Go back to Collect mode and continue with the data collection of the current line.

### 15.5.3 Scale

During data acquisition, the time axis is not plotted on the image. To view the time axis, pause the data collection and select **Scale**. When Scale is pressed once a time axis will appear on the left of the data image (Figure 15-7, left). If **Scale** is pressed a second time, a depth axis will appear on the left of the data image (Figure 15-7, right).
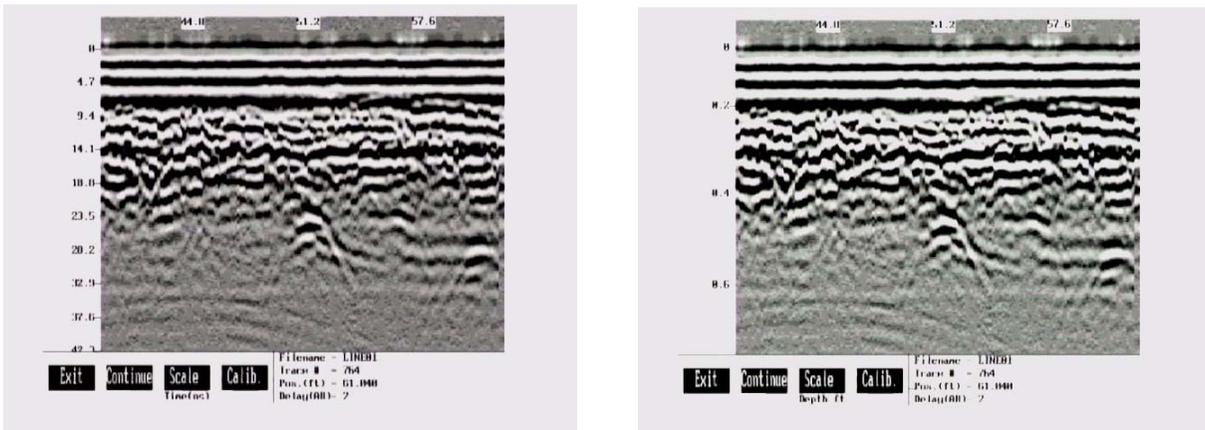


*Figure 15-7:  A time axis (left) and depth axis (right) can be plotted on the left of the data image by pausing the data collection and pressing Scale once for a time axis and twice for a depth axis.*

If, after displaying the Time scale or Depth scale, the user presses the **Continue** button to continue with data collection, the new data traces will have horizontal scale lines superimposed on them.

The user should be aware that if an accurate depth axis is desired, the proper radar wave propagation velocity (see Section 13.2.6 Radar Velocity on page 73) must be used to generate the correct depth.

## 15.5.4 Calib - Velocity Calibration

GPR systems can be used to scan into many different materials including soil, rock, concrete, snow, ice and wood. The radio wave emitted by a GPR system will travel at different velocities depending on the material being scanned. As discussed earlier (Section 13.2.2.1: P69), depth estimates are only accurate if the system has been properly calibrated to determine the velocity of the material being scanned.

The Calibration function is a tool for determining the velocity of the material being scanned.  A velocity value can be input directly or determined in one of two different ways depending on the situation: Hyperbola matching and Target of known depth.

### 15.5.4.1   Hyperbola Matching

The most accurate way of determining the velocity of the material being scanned is to use the hyperbola fitting method because it extracts the speed from data collected in the area.  This method may not work in all situations because it depends on having a good quality hyperbola (or inverted U) in the data.

A hyperbola is the characteristic GPR response from a small point target like a pipe, rock or even a tree root. This phenomenon occurs because radar energy does not radiate as a pencil-thin beam but more like a 3D cone. Reflections can appear on the record even though they are not directly below the radar system. Thus, the radar system "sees" the pipe before and after going over top of it and forms a hyperbolic reflection.
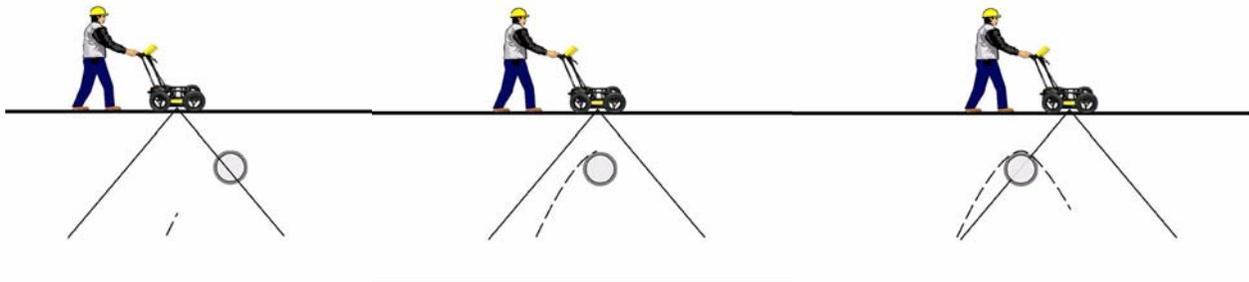


*Figure 15-8:  Hyperbolas in the data result from the conical shape of the GPR energy as it goes into the ground. Targets, like pipes, are detected as the GPR approaches them (left), passes over them (middle) and after it has passed by them (right) because the GPR energy propagates both in front and behind the instrument.*

If the hyperbola has long tails on it, we can match the shape of the hyperbola and determine the velocity of the material in the area.

With the hyperbola visible on the DVL screen, select the **Calib** button. This will superimpose a hyperbola on the data. This hyperbola can be moved up, down, left and right using the appropriate buttons. The goal is move the hyperbola until it lies on top of the hyperbola in the data (see Figure 15-9). Then, the user can adjust the width of the hyperbola to make it wider (Vel+) or narrower (Vel-) until the shape of the hyperbola matches the shape of the hyperbola in the data. After matching the hyperbola, the velocity value is extracted and used for all subsequent data acquisition.

Pressing the **Up**, **Down**, **Left**, and **Right** buttons once makes a very small change in the position of the hyperbola.  These buttons must sometimes be pressed many times to move the hyperbola to the correct position.  The **Repeat** button speeds up the movement of the hyperbola. Select the direction (Left, Right, Up or Down) and press **Repeat**. The hyperbola will then start moving in that direction.  When the hyperbola gets close to the desired location, press the **Repeat** button again to stop it. Then use the up, down, left and right buttons to fine-tune the position.  The **Repeat** button can also be used after pressing the wider (**Vel+**) or narrower (**Vel-**) buttons.
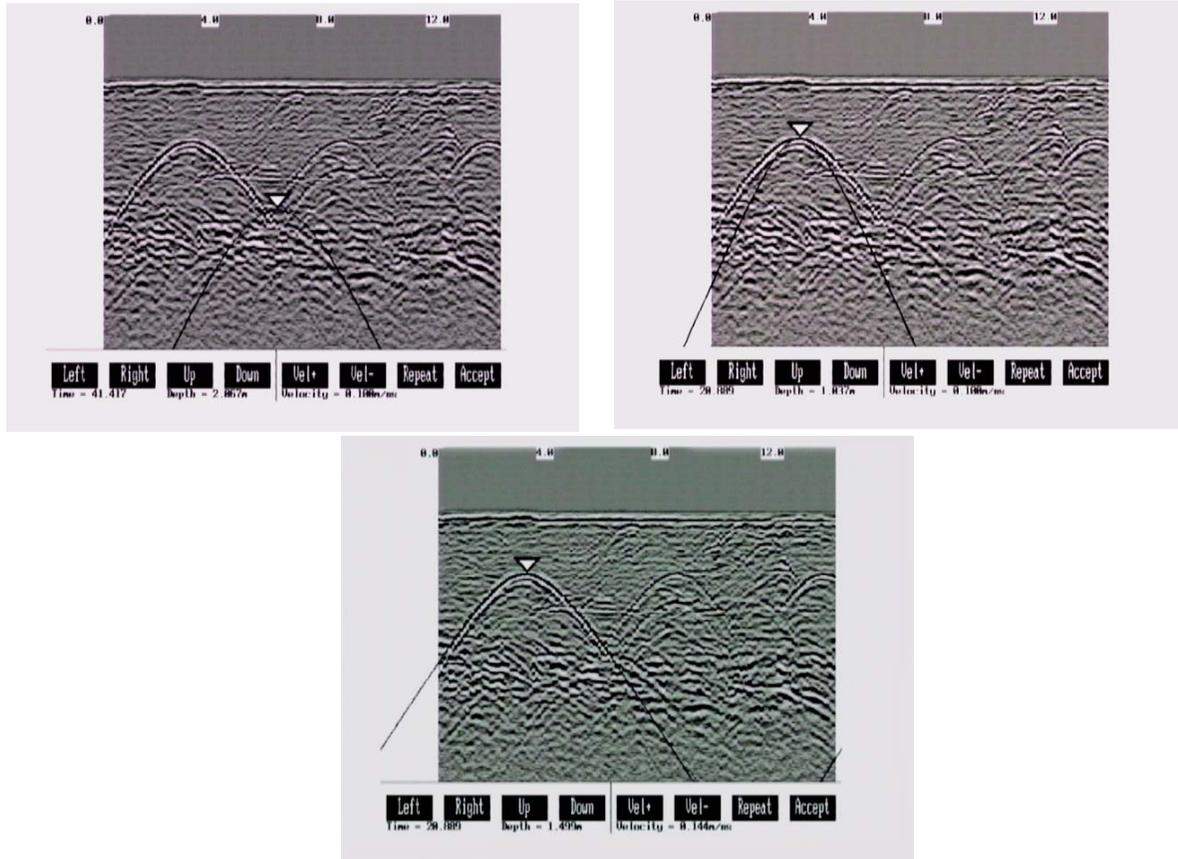


*Figure 15-9:  Hyperbola matching to extract velocity.  After pressing the Calib button a hyperbola appears on the screen (top left). This hyperbola should be moved overtop of a hyperbola in the data using the Left, Right, Up and Down keys (top right).  It can then be widened or narrowed to match the shape of the hyperbola in the data (bottom).  When the hyperbola shapes match, the velocity listed on the bottom of the screen can be used to make depth estimates more accurate in subsequent data. As well, the depth of the target that created the hyperbola is listed on the bottom of the screen.*

Depths will appear in metres or feet depending on which units are selected.  Velocities appear in metres per nanosecond (m/ns) or feet per nanosecond (ft/ns) depending on the Positional Units.

### 15.5.4.2   Identifying Air Reflections

Some hyperbolic reflections can also be caused by objects not in the subsurface such as fences, overhead wires and, in some conditions, even large trees.

An important part of data interpretation is learning to recognize these unwanted "air" events and differentiate them from the desired subsurface events. Good field notes are indispensable for helping identify unwanted events on the data.

One way of identifying air reflections is to use the hyperbola fitting method. If the object is in air, the radar velocity will be 0.3 m/ns or 0.984 ft/ns and will be much faster than if it is in the ground (v ~ 0.1 m/ns or 0.328 ft/ns).
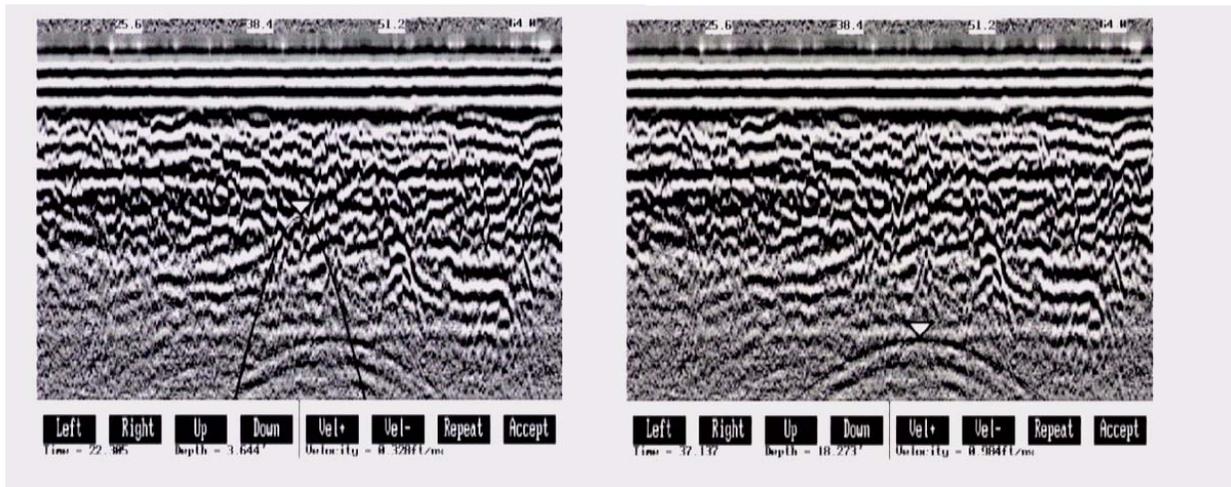


*Figure 15-10:  Hyperbola matching can be used to identify reflections from objects that are not in the subsurface but are from objects above ground. If the hyperbola matching velocity is near the speed of light (0.3 m/ns or 0.984 ft/ns) then the hyperbola was caused by surface object like a overhead wire, tree, etc. After matching the hyperbola (right), the "depth" value displayed on the bottom of the screen is really a measure of how far from the survey line the object is, in the case above, 18.2 feet.*

## 15.5.4.3  Target of Known Depth

If there are no suitable hyperbolas visible in the data to perform the Hyperbola Matching described above, it may be the situation that there is a target of known depth in the area being scanned. If this is the case, use the bottom tip of the hyperbola matching triangle and move it until it lies on top of the GPR response to the known target.  Then, use the **Vel+** and **Vel-** buttons to adjust the velocity value up or down until the known target depth is correct.  Once the depth is matched, the current velocity value is the one used for all subsequent data acquisition.
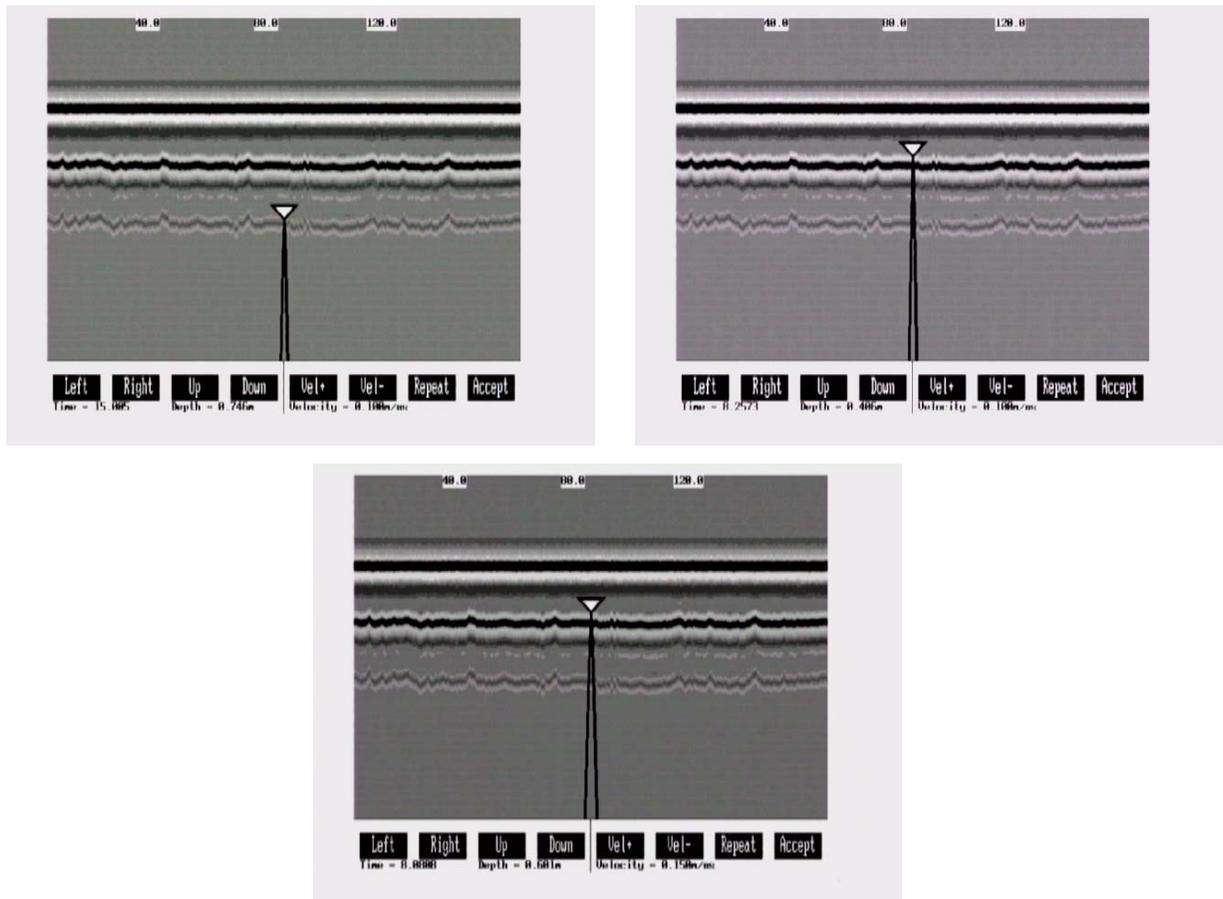


*Figure 15-11:  If a target of known depth is visible in the GPR data image, it is possible to use this target to determine the velocity of the material above the target. Ignoring the tails of the hyperbola superimposed on the data image (top left) and using the bottom tip of the triangle, use the Left, Right, Up and Down buttons to move it until it lies on top of the GPR response to the known target (top right).  Then, use the Vel+ and Vel- buttons to adjust the velocity value up or down until the known target depth listed on the bottom of the screen is correct (bottom), in this case 0.6 m.  Once the depth is matched, the current velocity value listed on the bottom of the screen can be used for all subsequent data acquisition in the area, in this case 0.15 m/ns. This velocity can also be used for an accurate depth axis when plotting the data to the screen or after it has been transferred to a PC.*

If units are metres then depths will appear in metres and velocities in metres per nanosecond (m/ns).  If units are feet then depths will appear in feet and velocities in feet per nanosecond (ft/ns).

## 15.6  Collect Grid Data

As the name implies, Collect Grid Data is selected when the user is ready to collect data in an organized grid.

### 15.6.1 Select Line Direction

The first screen will ask which line direction is being collected, X Lines or Y Lines. Refer to Section 13.4.6 GPR Grid Type on page 87 for definitions of X lines and Y lines.
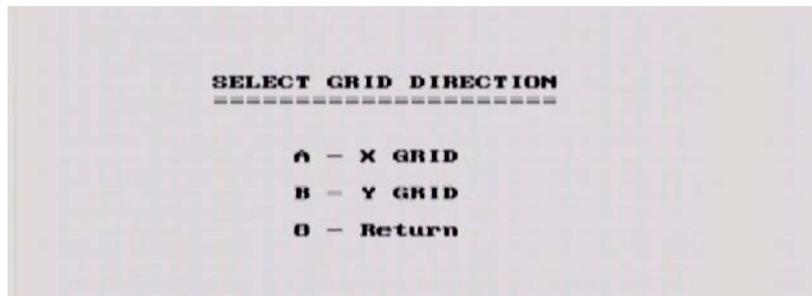


*Figure 15-12:  When collecting grid data, the direction of the lines (X or Y) needs to be determined.*

### 15.6.2 Select Grid Line Number

The next screen displayed after selecting the line direction is shown in Figure 15-13. This screen is used to determine the number of the line to be collected.
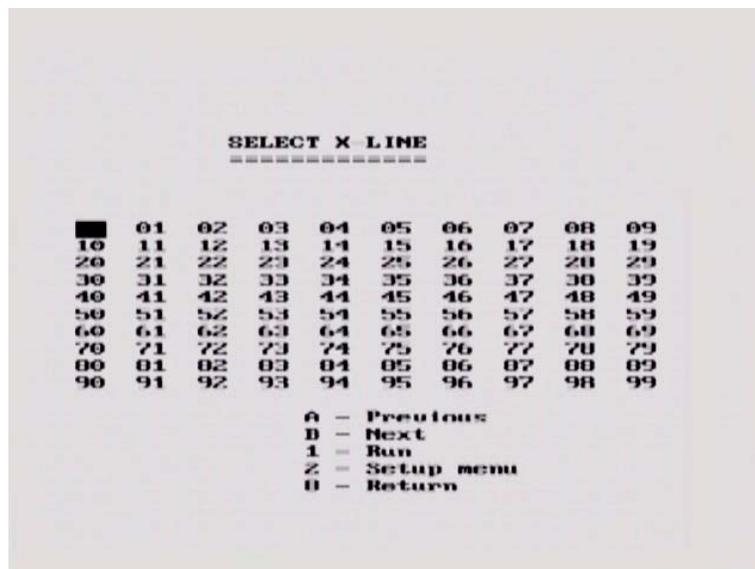


*Figure 15-13:  Selecting Collect Grid Data from the menu shown in Figure 14-1 will display this screen used to select the number of the line to be collected. The default line number is the lowest line number available. As lines are collected, their associated number will appear in black on this screen. Use the A and B buttons to move to any number on the list. When ready to collect data press **1 - Run**. If you select the number of an existing line, you will have the option to Overwrite or View the data file.*

To continue with grid data collection, follow the directions under Section 15.3 Data Collection on page 106.

## 15.7  View Previously Collected Lines

After GPR data files have been collected, it is possible to view them on the DVL screen by using the Collect Line Data or Collect Grid Data option and selecting an existing file. When asked to Overwrite or View the file, select the View option.
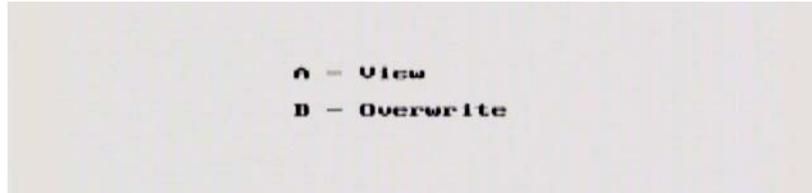


*Figure 15-14:  To view a previously collected data line on the DVL screen, select Collect Data and select an existing line number. When asked if you want to view the file or overwrite it, select View.*

When viewing an existing file, the header (.HD) file containing the survey parameter information is displayed first.
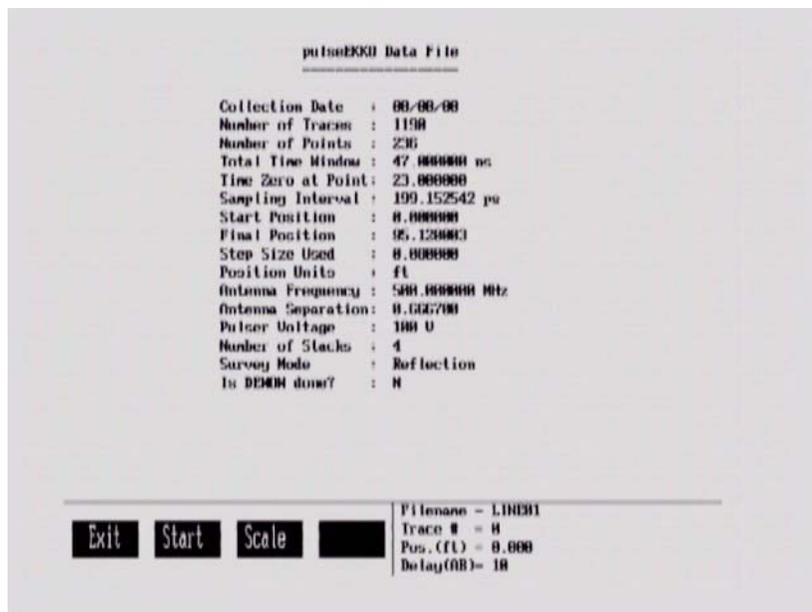


*Figure 15-15:  When viewing an existing file, the header (.HD) file containing all the survey parameters is displayed first.*

To see the data image press **Start**. The data image will scroll on the screen just like it does when data are being collected. Note that the scroll speed can be increased by decreasing the Delay Time between traces using the A and B buttons.
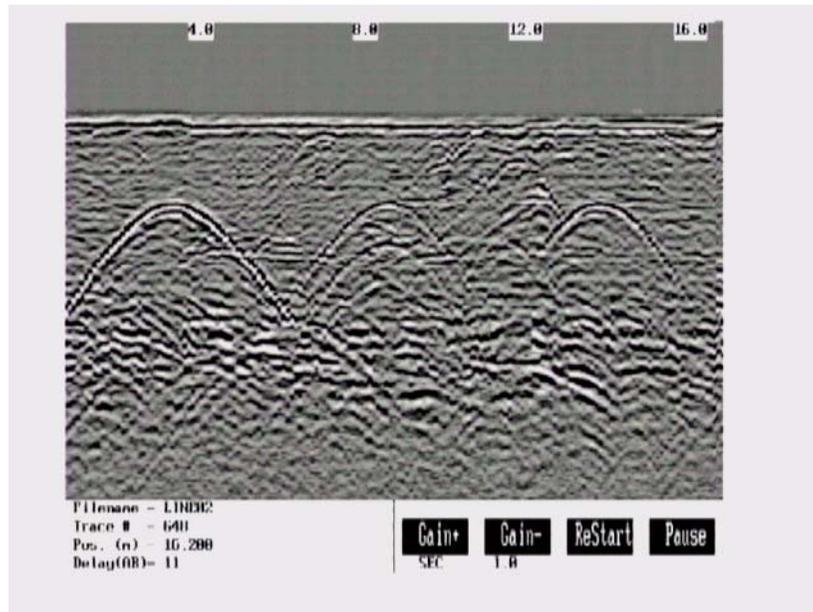
*Figure 15-16:  Viewing an existing data line. The data image scrolls onto the screen just like during real data collection. The scroll speed can be increased and decreased using the A and B buttons. The line can be plotted with a different gain or use the Gain+ and Gain- buttons to increase and decrease the current gain value. ReStart will plot the line again.*

Replaying data can be very useful because it allows the user to quickly modify the plot with different gains (Section 13.5.2: P94), and Trace Plotting Type (Section 13.5.1: P92) to try and enhance the feature of interest.

Pressing the **Pause** allows access to the Calib button so that a Velocity Calibration can be used to determine the velocity in the material being scanned or check for airwave reflectors (Section 15.5.4: P111).

Each time the **ReStart** button is pressed the data is replotted so if settings are changed, the modified image replaces the old one.

## 15.8  Collect Data (No Save)

This selection allows data to be acquired and plotted to the screen but not saved to a file. Once the data scrolls off the screen or when the line is exited, it can no longer be viewed.

This option is useful when the operator just wants to collect a test line to see what conditions are like, perhaps to decide on the best antenna frequency to use in the area or the length of the time window.

During data acquisition, the bottom of the screen will indicate that data are not being saved.

# 16   Surveying Techniques

## 16.1   Antenna Reflection (Profiling) Mode

### 16.1.1 Two Person Operation

The most common method of data acquisition in rough terrain will be with two people in a configuration shown below (Figure 16-1). The person carrying the DVL and Control module has a belt battery fastened around their waist to power these units. The optional DVL carrier shown is not a necessity for the DVL operator. They may be just as comfortable carrying the DVL in their hands.

Data collection can be controlled by the DVL operator using the electrical beeper/trigger or the DVL button. If the optional fibre optic beeper/trigger is available, data collection can be controlled by the antenna operator (Section 13.3.1.1: P78). A third option is to run the system in free Run mode (Section 13.3.1.3: P78) with a time delay between traces (Section 13.3.3: P79).



*Figure 16-1:  Two person data collection with the pulseEKKO PRO system. The antenna operator moves the antennas to each data location point. The data trace is collected by the DVL operator using the electrical beeper/trigger or the DVL button. The data trace can also be collected by the antenna operator using the fibre optic beeper/trigger. The data are visible in real time on the DVL screen.*

The antennas can be held at a constant separation by using a rope tied between them (Figure 16-4).

## 16.1.2 One Person Operation

One person operation is performed in the configuration shown below (Figure 16-2) with the optional DVL carrier (Section 11.2: P55) and the fibre optic beeper/trigger (Section 11.1.1: P52).



*Figure 16-2:  One person operation setup. The operator moves the antennas to each data location point and collects the trace using the fibre optic beeper trigger. The data are visible in real time on the DVL screen.*

## 16.1.3 Strain Relief for Fibre Optic Cables
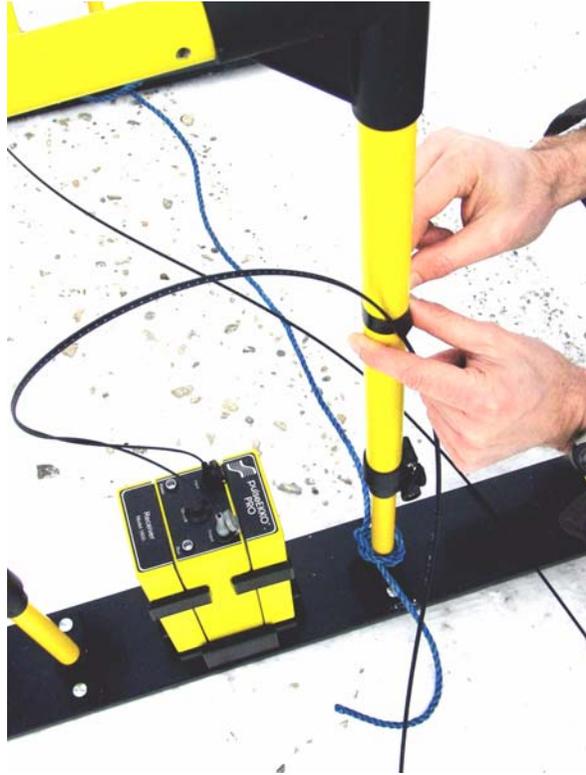


*Figure 16-3:  Fibre optic cables can be broken or damaged if care is not taken. The most common breakage point is right at the connectors when the cables are snagged or pulled hard. Protect the fibre optic cables by making a strain relief. Take an extra loop of cable and tape it to the handle. That way, if the cable gets pulled, the strain is taken up by the tape and not the cable.*

## 16.1.4 Maintaining Proper Antenna Separation



*Figure 16-4:  When using the adjustable handles, the antenna separation can be maintained by using a length of rope tied between the antennas.*

## 16.1.5 One Man Handles

The one-man handles allow for one or two person operation. A two person operation with the one-man handle would be run similar to Figure 16-1. One person operation can be conducted as shown below (Figure 16-5).



*Figure 16-5: One man handle setup. The operator moves the antennas to each data location point and collects the trace using the DVL B button. The data are visible in real time on the DVL screen.*

## 16.1.6 Antenna Movement

If practical, antennas should not move while data are being collected, as indicated by the duration of the beeping tone. Keeping the antennas static assures the highest quality stacked data. When the beep stops, the antennas can be moved to their next position in preparation for the next trace. Obviously, holding antennas stationary is impractical if a continuously moving platform is used for data acquisition (Figure 16-8).

## 16.1.7 Antenna SmartCart

The antenna SmartCart is shown in Figure 16-6. The 0.5 meter separation bars are designed for the 200 MHz antennas while the 1 meter separation bars are used with the 100 and 50 MHz antennas.



*Figure 16-6:  The SmartCart has 0.5m and 1.0m separation bars to accommodate the 50, 100 and 200 MHz antennas.*

When the 1 meter separation bars are used, the front end of the SmartCart gets quite heavy and can be damaged if the front is tilted up. To maneuver the cart, lift the back end and rotate (Figure 16-7).
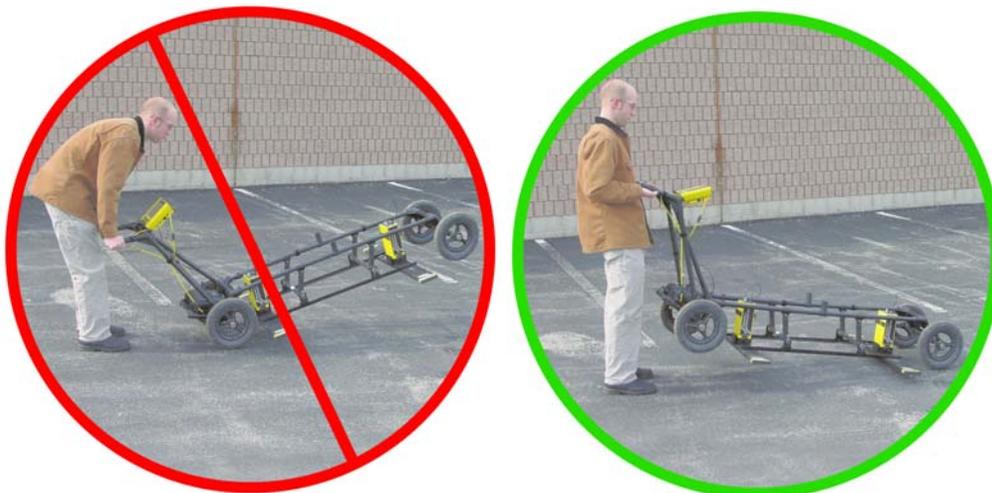


*Figure 16-7:  When using the 1.0 m separation bars, avoid tilting the front of the cart up to maneuver it (left). This can cause damage to the cart. The back end can be lifted (right) to change the cart direction.*

# 16.2 Transducer Reflection (Profiling) Mode

### 16.2.1 Tow Mode Operation

One method of data acquisition in smooth terrain is the tow mode configuration shown below (Figure 16-1). The operator carries the DVL and Control Module (or uses a DVL Carrier) and has a belt battery fastened around their waist to power the system.

Data collection is usually controlled by: 1) the Big Wheel odometer, shown in Figure 16-8 or, 2) the Small Wheel Odometer, shown in Figure 16-9.

It is also possible to remove the odometer and control data acquisition using the electrical beeper/trigger or the DVL button (Section 13.3.1.1: P78).

A third option is to run the system in free Run mode (Section 13.3.1.3: P78) with a time delay between traces (Section 13.3.3: P79).



*Figure 16-8: Hand Tow operation. As the operator drags the transducers across the surface, the odometer triggers data collection at equally-spaced intervals (called the Step Size). The data being collected are visible in real time on the DVL screen.*

*Figure 16-9:  Hand Tow mode using Small Wheel Odometer.*



*Figure 16-10:  The Small Wheel Odometer can be put on either end of the transducer skid plate.*

## 16.2.2 Transducer SmartCart



*Figure 16-11:  The SmartCart has separation bars to accommodate the 250, 500 and 1000 MHz transducers.*

## 16.3  Antenna Orientation

Both the high and low frequency, bistatic antennas of the pulseEKKO PRO system have the flexibility to allow different orientations with respect to one another.
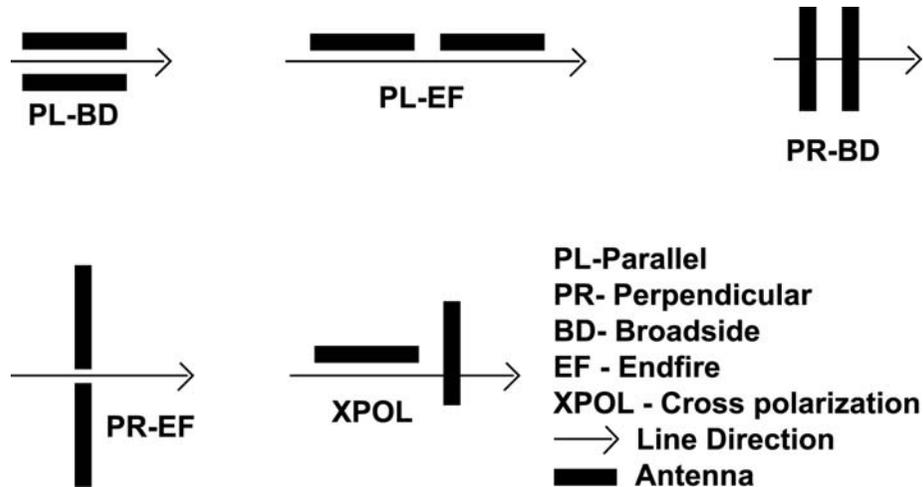


*Figure 16-12:  Definitions of antenna orientations available with bistatic antennas. Perpendicular-Broadside (PR-BD) is most commonly used for reflection surveys.*

The most common antenna orientation is the parallel-broadside configuration. This orientation provides the best coupling between antennas and the most energy in the direction of the survey line which reduces reflections from targets off to the side of the line.



*Figure 16-13:  Most common reflection surveying technique. Antennas are held at the proper antenna separation for the selected frequency and perpendicular to the survey line direction. This antenna orientation ensures the maximum in-line GPR energy and reduces reflections from off-line targets.*

## 16.4  Triggers

If the Trigger Method is set to Electrical, Fibre-Optic or DVL Key (B), the following data collection sequence is followed:

a)  Set the antennas at the correct separation and centred on the starting position for the survey line. The antennas should be oriented perpendicularly to the survey line direction as shown in Figure 16-13.

b)  The data collection screen on the DVL should display "Press Trigger".

c)  The operator presses the DVL B button, electrical or Fibre Optic trigger.

d)  The system starts to beep, indicating that data are being collected. The antennas should be kept in contact with the ground surface while the system is beeping.

e)  When the beeping stops, one trace has been collected.

f)  Move the antennas together along the survey line a distance equal to the Step Size distance.

g)  Repeat from step b)

h)  During data collection, fiducial markers (Section 15.4.1: P109) can be added at known positions so the data can be "rubberbanded" during post-survey editing.

## 16.5  Free Run

If the Trigger Method is set to Free Run, the radar will go through the following cycle:

a)  Set the antennas at the correct separation and centred on the starting position for the survey line. The antennas should be oriented perpendicularly to the survey line direction as shown in Figure 16-13.

b)  Press the Start button on the DVL screen.

c)  The system starts to beep, indicating that data are being collected. The antennas should be kept in contact with the ground surface while the system is beeping.

d)  When the beeping stops, one trace has been collected.

e)  The system will pause for the number of seconds specified under Free Run Trace Delay. In that time, move the antennas together along the survey line a distance equal to the Step Size distance.

f)  then back to c) to repeat the cycle.

g)  During data collection fiducial markers (Section 15.4.1: P109) can be added at known positions so the data can be "rubberbanded" during post-survey editing.

## 16.6  Odometer Data Acquisition

Data acquisition can be controlled by an odometer triggering the radar system to collect data at specified step sizes (Section 13.3.1.2: P78). There are several odometers available for the pulseEKKO PRO system including the Big Wheel Odometer (See Figure 7-5 on page 34), the Small Wheel Odometer (See Figure 7-6 on page 35), SmartCart odometer (Figure 16-11), the TR1000 Odometer (See Figure 9-2 on page 42) and the vehicle odometer (contact Sensors & Software for more details).

### 16.6.1 Skipping Traces

In odometer mode, it is possible to move too fast and trigger too quickly for the system to keep up.

If the odometer is being triggered too quickly, the DVL will write the total number of skipped traces on the bottom of the screen.  When this occurs, positional accuracy is retained but "skipped" traces will be filled in the data file as a repeat of the last successfully collected trace. When traces are repeated, the data display may appear "blocky" because two or more identical traces are being displayed. If more than 10 to 15% of the data traces in a survey line have been skipped, the operator should consider surveying the line again at a slower speed to reduce the number of skipped traces.
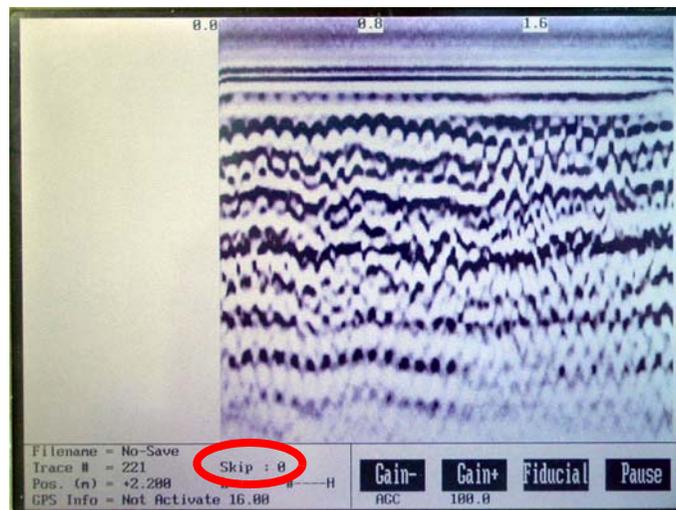


*Figure 16-14:  Skipped traces are indicated on the bottom of the data acquisition screen.*

If the electrical beeper/trigger is activated (Section 11.1: P51), it will beep every time a trace is skipped. This provides an audio indicator to the operator to slow down.

If maintaining speed is important, the other option is to reduce the time window (Section 13.2.2: P69) or number of stacks (Section 13.2.7: P74) to allow the traces to be collected faster. Data trace acquisition speed can also be increased by increasing the temporal sampling interval but it is important to make sure that the temporal sampling interval does not exceed twice the recommended value or the data will be aliased and may become uninterpretable (Section 13.2.3: P70).

### 16.6.2 Backing up to Pinpoint Target Positions

The Big Wheel and SmartCart odometers allow the user to stop the GPR system in the middle of a survey line and back up. When this is done, an arrow and vertical line appear on the data image and move back along the image as the system moves backwards. This makes it possible to correlate a target in the data image to an exact location on the ground. Once the arrow lines up with the target, mark the ground at the mid point of the antennas.

When the system is moved forward again to continue with the survey, the GPR system does not start collecting data again until you reach the position where you stopped at. This feature is useful for producing a continuous data image even if the system is backed up during the survey line.

Note that it is not possible to back up and have the arrow indicator move more than one screen.

### 16.6.3 Increasing Data Quality with DynaQ

When collecting data with an odometer, data quality can be increased using the DynaQ stacking option (Section 13.2.7.1: P75).

## 16.7  Signal Polarity

In the course of collecting data along a profile line or lines, it is important to keep the relative antenna orientation the same (note: it is the electronic unit orientation which controls the polarity, antenna direction alone does not affect polarity), especially after any interruption in data collection to change batteries, etc. One way to control polarity is to always have the pulseEKKO name pointed in the direction of antenna movement. If this precaution is not followed, the signals may have reverse polarity (this can be corrected in EKKO_View Deluxe program if necessary).

## 16.8  Spatially Aliasing the Data

Increasing production by increasing the step size is not always a good idea. Undersampling the data with a step size that is too large can make interpretation difficult. Use the guidelines to set step size properly (Section 13.2.5: P72).

If you are surveying for a large target, it is possible to increase the step size to maximize productivity and minimize the data volume but keep in mind that the step size should still be small enough that one or more traces are collected over top of the target. For example, if your target is 0.3m (1 foot) in diameter the maximum step size should be about 0.1m (0.33 feet).

If the objective of the survey is to follow a flat-lying layer like a soil layer or asphalt that varies little laterally, the step size could be increased to 1.0m or more. As a rule of thumb its better to collect more data than not enough.

## 16.9  Creating a Test Line for Data Quality

One of the best ways of detecting problems with the GPR system is, shortly after receiving the system and getting comfortable with its operation, to collect a line of data at a convenient, easily accessible location. The line does not have to be too long but 100 - 200 traces 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.

## 16.10 Adding GPS for Positioning



*Figure 16-15: Various system configurations with GPS added. Ideally, the GPS should be positioned near the mid-point of the GPR antennas.*

## 16.11 Common Mid-Point (CMP) Survey

A Common Mid Point (CMP) survey is performed to measure GPR velocity in the survey area. A CMP survey is best done in an area with flat lying reflectors and relies on changing the antenna separation to increase the signal path length from the mid point reflector (Figure 16-16). The resulting data can then be processed using a semblance analysis routine to extract average velocities to the reflectors (Figure 16-18). The extracted velocities can then be used when adding a depth axis for other GPR survey lines collected in the area of the CMP.
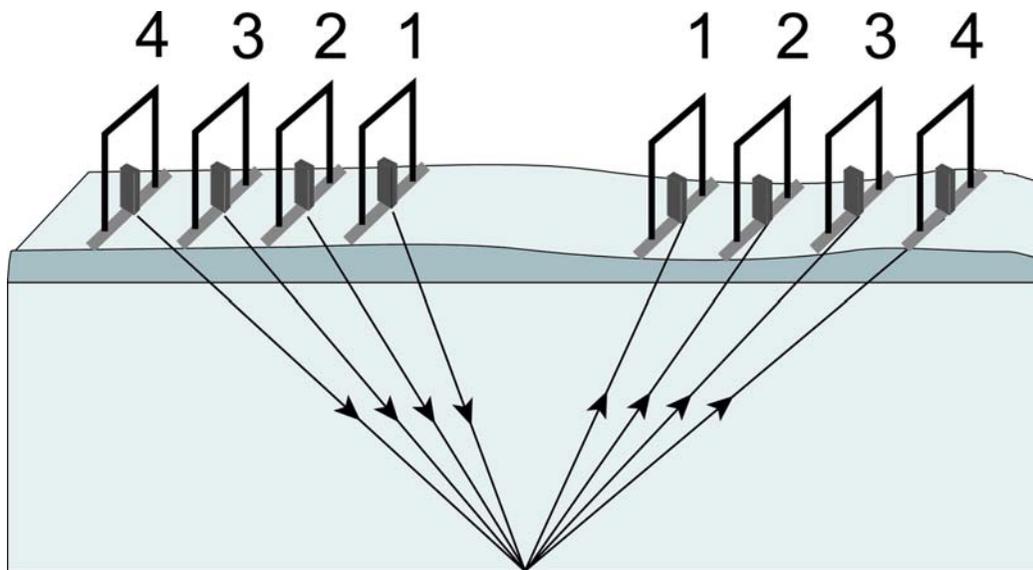


*Figure 16-16: CMP setup. CMP surveys are used to measure the GPR velocity to a reflector or series of reflectors. Each trace is collected with the antennas at a larger separation resulting in an increased travel path length and therefore increased travel time. The data can be analyzed with a semblance analysis routine to extract the average velocity to the reflector.*

Conducting a CMP survey efficiently normally requires two people and may require the use of the optional 20m fibre optic cables (available from Sensors & Software) rather than the standard 5m fibre optic cables.



*Figure 16-17: CMP field operation.*

Follow this procedure when collecting CMP data:

1) Conduct a CMP survey after the reflection survey lines have been collected in the area because it is best to identify a location with at least one strong, flat-lying reflector.

2) Place a tape measure (Section 20.2: P161) on the ground in the direction that the antennas will be expanded about the central point. Try to make the central point correspond to a round number on the tape measure, i.e. 5m, 10m, 20 feet, so that moving the antennas to the new location for each trace is easy for the operators.

3) Set the antennas on the ground at the usual antenna separation distance for the selected frequency (Section 13.2.4: P71). The antennas should be centred on the central point.

4) Place the DVL and control module between the antennas but off to the side.

5) On the DVL, under **Survey Parameters**, set the **Survey Type** to CMP/WARR (Section 13.4.5: P87).

6) Under **Survey Parameters**, set the **Start Position** value to the starting antenna separation (Section 13.4.1: P86).

7) Set the **Step Size** (Section 13.2.5: P72) to double the amount that each antenna will move. Typically, the step size will be similar to the step size recommended for the frequency of the antenna being used but, if necessary, round the number down to a number that is easily divisible by two. For example, the normal step size for 100 MHz antennas is 0.25m but moving each antenna 0.125m for a CMP is difficult, so in this case, it is better to set the step size to 0.2m and move each antenna 0.1m for the collection of each trace. The point is that CMP collection is fast, so make small steps.

8) There are several options to trigger the collection of each trace (Section 13.3.1.1: P78). If a third person is available for data acquisition, set the system in Electrical trigger mode and have one person on each antenna and the third person at the DVL pressing the electrical trigger at each collection point. With two people and a fibre optic trigger, put the system in Fibre Optic trigger mode and have the person with the transmitting antenna control the data acquisition. The third option with two people (or even one person) is to set the system in Free Run mode (Section 13.3.1.3: P78) so data collection occurs based on time and put a 2-5 second (or longer) delay between traces (Section 13.3.3: P79) to allow the operators to move the antennas to the new locations.

9) CMP data collection should continue until the amplitude of the reflections is very weak or down to the noise level in the data, Figure 16-18 is a good example.
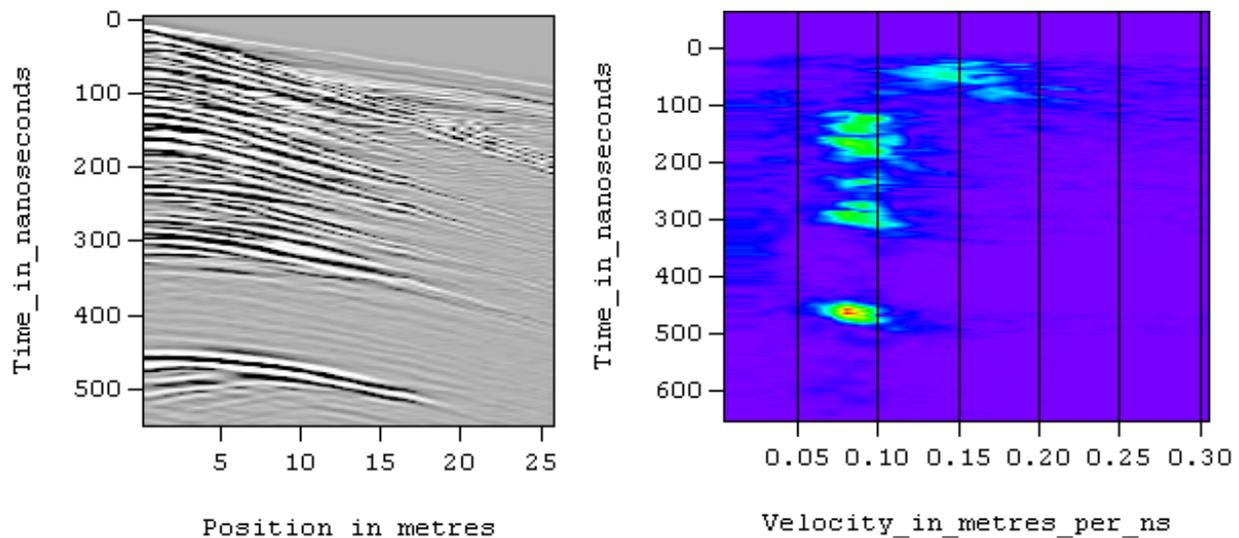
*Figure 16-18: CMP survey data (left) can be processed to produce an average velocity section (right) that shows high amplitudes (bulls-eyes) indicating the average velocity to each reflector.*

# 16.12 Transillumination Surveys

For a transillumination survey the transmitter and receiving antennas are placed at opposite sides of a structure to study the transmission properties of the dividing material. Depending on the structure shape, it is desirable to obtain as many different raypaths through the structure as possible. This is achieved by varying the transmitter and receiver geometry around the structure.

Users must keep systematic notes on antenna positions for each trace collected. Operation is best done in Line mode (Section 15: P105) with a trigger used to initiate trace acquisition once the transmitter and receiver are properly positioned.

## 16.12.1 Borehole GPR

The most common type of transillumination survey is cross hole GPR conducted between boreholes (Figure 16-19) or from a borehole to the surface. This type of survey requires the use of borehole antennas (Figure 16-20). See Appendix I: pulseEKKO PRO Borehole Data Acquisition for details of borehole GPR surveys.

# Transillumination
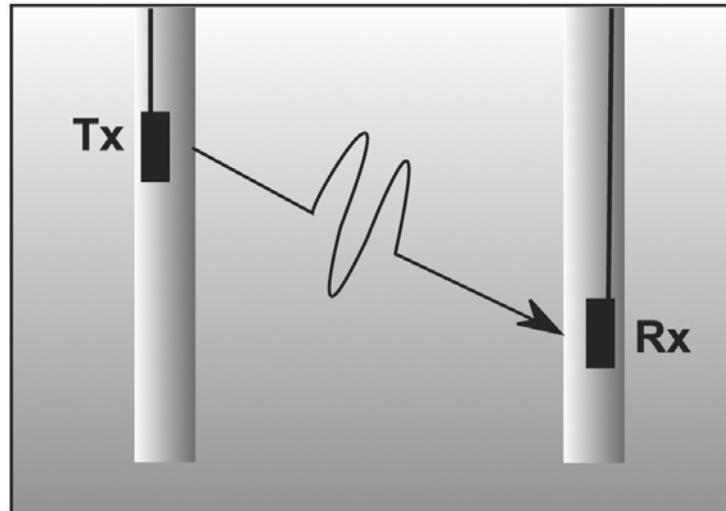


*Figure 16-19:  Cross hole transillumination surveys send signal from the transmitting antenna in one borehole to the receiving antenna in another borehole. If this is done with the antennas at many different positions to collect data at many different raypaths between the boreholes, travel times, amplitude variations and signal period changes can be analyzed to produce images of veloc-ity, attenuation and dispersion.*



*Figure 16-20:  Cross hole transillumination surveys with the pulseEKKO PRO system require the use of 50, 100 or 200 MHz bore-hole antennas available from Sensors & Software. See Appendix I: pulseEKKO PRO Borehole Data Acquisition for more details.*

## 16.12.2    Walls, Pillars and Monument Surveys

Another type of transillumination survey uses the surface antennas to send signals through a structure like a wall, pillar or monument.



*Figure 16-21:  Transillumination survey setup with antennas (top) and transducers (bottom). With a transillumination survey, the GPR signal is sent from the transmitter directly to the receiver after it has passed through a structure. The DVL is centrally located and data acquisition is controlled by either triggering the system with the electrical or fibre optic beeper/trigger or using Free Run mode with a time delay between traces.*

# 17   Troubleshooting

The pulseEKKO PRO system is designed to minimize user problems; however, all electronic devices are subject to possible failure.  The following are troubleshooting hints if your system fails to operate.

If the radar is not running properly, an error message will be displayed indicating the possible cause of the problem (Figure 17-1).



*Figure 17-1:  During system initialization or at any time, error messages on the screen indicate where the problem may have occurred.*

To narrow down where the problem is, it may be necessary to change the Display Info Mode to the more detailed level (Section 13.6.4: P100).

**Check Connections:** If a problem occurs during system initialization, the first step is to check the connections. Make sure that cable connections are tight and fibre optic cables are connected correctly with the strain relief colour matching the receptacle door colour (Figure 17-2) and that they have "clicked" into place. A common error when the fibre optic beeper/trigger is used with the system is to connect the short fibre optic cable incorrectly (See Figure 11-3 on page 53).

Also, ensure that the software settings for the transmitter are correct for the transmitter that you are using with the system (Section 13.2.8: P76).

*Figure 17-2: Make sure fibre optic strain relief colour matches the receptacle door colour (grey to grey and black to black).*

**Reset the System by Powering Down:** If the connections are OK but the error persists, try powering down the system completely. This power down will include turning off the DVL and Control module as well as the transmitter and receiver and fibre optic beeper/trigger (if present). Then power everything back on and see if the system runs.

# 17.1  Power Supply

Another common problem that can occur while trying to run a system is insufficient power.  The battery may be dead or have a low voltage.  If the system is being run from AC, there may be a problem with the AC power supply or adapter.

## 17.1.1 DVL and Control Module Power Requirements

The DVL and pulseEKKO PRO control module are designed to operate from a 12 volt DC, 3 to 4 amp source such as batteries or power supply (See Figure 12-1 on page 59). The input voltage tolerance is 10.2 volts to 15 volts. The standard belt battery supplied with the system (See Figure 12-1 on page 59) is a 7 Amp-hr. battery that should power the DVL and the control module for approximately 8 hours.

The control module is only powered when data collection begins so there needs to be sufficient power in the battery for the control module.

If there is enough power to run the DVL, the upper red LED on the front of the DVL below the keypad will light up when the battery is plugged into the system.  If this light is on and the DVL boots up, runs and displays the main menu then there is sufficient power for the DVL.

f the DVL turns on, the voltage of the battery can be monitored from the main menu (See Figure 12-4 on page 62).

### 17.1.1.1   Low Battery Indicator

If the battery voltage is less than about 10.2 volts, the DVL may not turn on and the upper red LED will flash or not illuminate.

If the DVL is already on as the battery voltage drops below 10.2 volts, the upper red LED will start to flash to indicate the battery is getting low and should be recharged or replaced soon.

### 17.1.1.2  Battery Maintenance

Check the battery voltage with a voltmeter. Try to do this while the battery is still attached to the DVL and control module to get a true measure of the voltage while under load (it may be necessary to open the battery case or belt 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 (Figure 17-3) and try running the system again.

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



*Figure 17-3:  Belt battery (right) used to power the DVL and Control Module. The battery charger is shown on the left.*

Batteries are fused to protect the system. For the belt battery, remove the battery from padded casing and check the 5 Amp fuse.  Replace the fuse if necessary. For the larger SmartCart battery, 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.

## 17.1.2 Transducer Power Requirements

The pulseEKKO PRO transducers (See Figure 2-15 on page 13) do not require separate batteries for their operation. They are powered by the same 12 V battery that powers the DVL and Control Module (see above). Power is sent to the transducers through the transducer cables.

## 17.1.3 Transmitter and Receiver Power Requirements

The pulseEKKO PRO receiver and transmitter both use two 12-volt sealed lead acid batteries. The transmitter will, under normal conditions, run for about 4 hours or more on a pair of 2.3 AH batteries. The receiver should run about twice that long on a pair of batteries.

### 17.1.3.1   Low Battery Indicators

There are 2 ways that a low battery voltage is communicated to the operator:

1) When the transmitter and receiver battery voltages drop below 11.4 volts, the DVL will display a warning message as the system initializes at the start of the GPR survey line. The operator can continue to collect data but should consider changing or the batteries as soon as possible.

2) The receiver and transmitter also contain a voltage monitoring circuit that will cause the Power LED on top of the units to slowly flash when the battery voltage is very low, usually around 10.2 volts and below. When this occurs, batteries should definitely be replaced soon or data quality will be reduced.

If the batteries are not replaced and the voltage continues to drop, the unit will eventually turn off.

**pulseEKKO 100 Transmitter:** When a pulseEKKO 100 transmitter is being used with a pulseEKKO PRO system (Section 13.2.8: P76), the pulseEKKO 100 transmitter is unable to communicate the proper battery voltage to the DVL so the DVL low battery warning message from number 1 above is displayed before every survey line is collected. In this case, it is OK to ignore the message and continue with data acquisition. The low battery indicator in number 2 above can be used.

### 17.1.3.2   Battery Maintenance

If they are maintained in a charged condition they will give long life and reliable service. Improper use and 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 (Figure 17-4).

Charge batteries at room temperature whenever possible.

If the voltage of the discharged batteries is measured some time after they have been changed it will be higher than 10.2 volts (this is normal).  Do not mix charged and discharged batteries and DO NOT attempt to use discharged batteries a second time.

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 LED will not light).  If the fast charge light does not come on within 6 hours the battery should be considered damaged and 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 hours from start of fast charge. When charging a depleted battery it is normal for the charge light to go out after 6-8 hours. The charger has gone into trickle mode only and the battery must remain in the charger for the minimum 12 hours required.**

---

*Figure 17-4: Battery charger for the transmitter and receiver batteries.*

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

### 17.1.4 Testing Transmitter and Receiver Batteries

If you are experiencing reduced operation time with either your pulseEKKO PRO Receiver or Transmitter the problem will be the result of a damaged 12 V battery or a poor battery connection in one of the battery compartments.

All battery compartments should be checked periodically for proper operation. Take a known good pair of batteries and install into the battery compartments. Ensure the power light activates with no intermittent operation. If the power light will not activate look in the battery compartment and check the battery contact for signs of excessive stress. Also check the condition of the 2A fuse wiring. If the problem persists, remove the six screws holding the battery plate in place and lift upwards. On the bottom of the battery plate you will see a small circuit board that extends the battery input to the power switch. Check the connections to and from this board. Please contact Sensors & Software Inc. should all the above fail to resolve the problem.

## 17.2  Testing Fibre Optic Cables

When troubleshooting problems with the system, error messages may indicate a problem with the transmitter or receiver. Since the transmitter and receiver communicate with the control module using fibre optic cables, it is possible that the problem may be because of damage to the fibre optic cables. Use the fibre optic testing routine under System Setup - Acquisition Control - Fibre Optic Testing to test cables.

Setup the fibre optic cable as shown in Figure 17-5. The feedthrough connector located in the spare parts kit (See Figure 19-1 on page 154). During the test, gently move the cable around, especially near the connectors, to see if a failure occurs. If the cable fails at any time, even once, it should be repaired or replaced. If the cable is going to be repaired, it is necessary to find the point of damage and cut the cable off at this point. Then look at the section on repairing fibre optic cables (Section 19.7: P156).
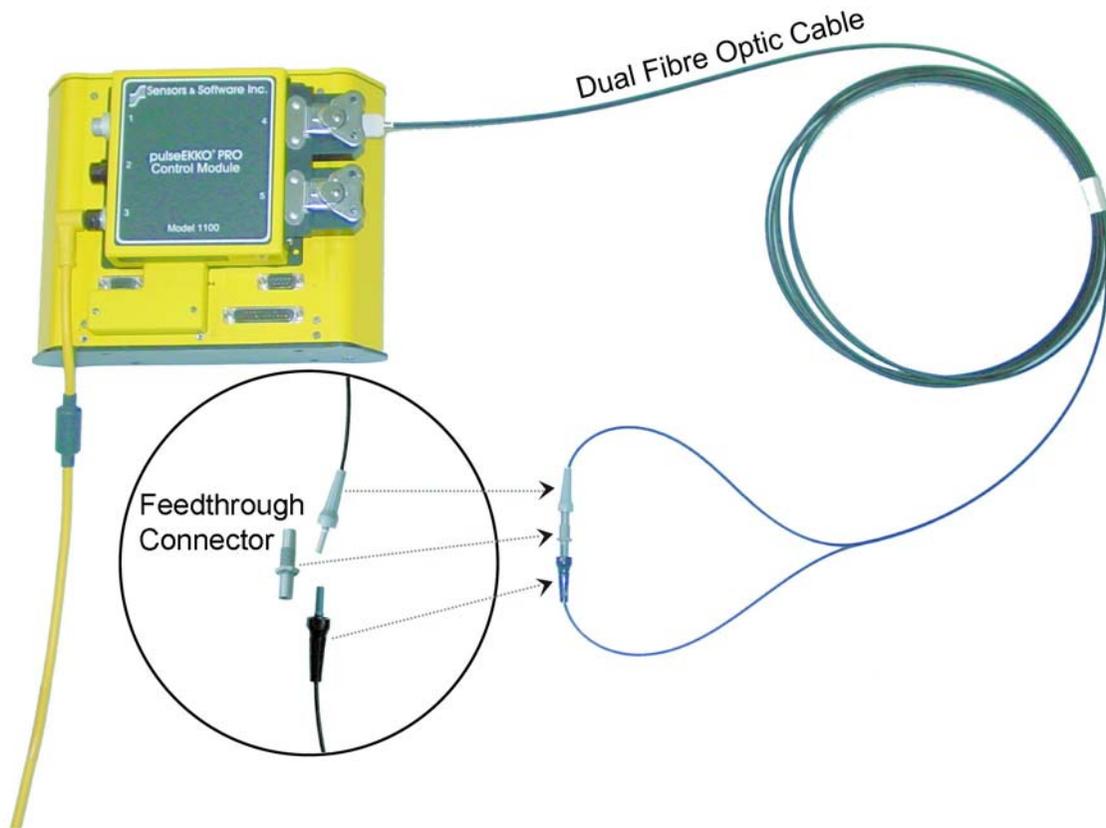
*Figure 17-5:  Setup for fibre optic cable testing. Make sure that the cable is plugged into the control module receptacle number 4 and the loose ends of the cable are connected together using the feedthrough connector.*
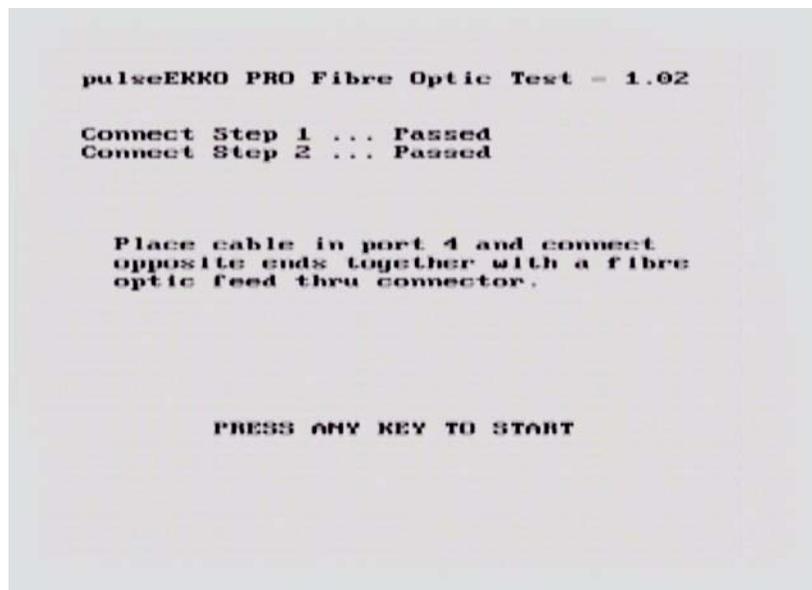


*Figure 17-6:  After connecting the fibre optic cable as shown in Figure 17-5, select System Setup - Acquisition Control - Fibre Optic Testing.*
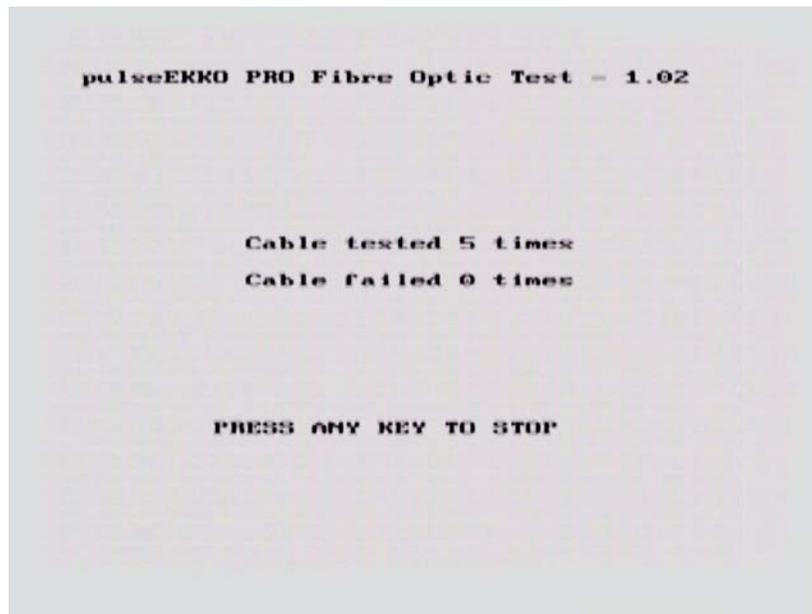
*Figure 17-7:  The fibre optic test routine will continuously test the cable. During the tests, gently move the cable around, espe-
cially near the connectors, to see if a failure occurs. If so, repair or replace the fibre optic cable.*

## 17.3  Control Module Related Errors

Control Module related errors are generated whenever the DVL fails to communicate with the control module for any reason.

The most common causes of these errors are the following:

   a)   Control Module-to-DVL connection is loose or faulty.

   b)   The Control Module is damaged.

The following checks should be carried out.

   a)   With the system completely hooked up turn the DVL and control module OFF then back ON again and retry the system.

   b)   If you are still having problems running the radar system, the problem is either with the control module itself or the DVL.  The control module or DVL may need factory service.

## 17.4  Receiver Related Errors

If a receiver error is encountered, check that the receiver is turned on, that the batteries for the receiver are properly charged and that the receiver to control module fibre optic cable is not damaged and is properly connected.

Perform the following checks:

   1)   Check that the red POWER light on the top of the receiver is ON.  If not, then press the ON/OFF switch once to see if the light comes ON.  If it does, retry the system to see if it will run.  If the red POWER light still does not light up or flashes, check to make sure the batteries are fully charged.

   2)   Check the condition of the fibre optic cables.  Look for any sign of stress or damage.  Replace, if possible.

If neither of the above solutions solve the problem, contact Sensors & Software Inc.

## 17.5  Transmitter Problem: No Signal on Screen

In Scope mode try the Auto timezero search.  Keep the antennas about one antenna length apart.

If the pulse still cannot be found do the following checks:

   1)   Make sure the transmitter batteries are properly charged and connected.

   2)   Check the condition of the single fibre optic cable to the transmitter, looking for any signs of stress or damage.  Replace or repair if needed.

   3)   Check that the brass antenna sockets in the bottom of the transmitter and receiver and that the brass antenna pins in the top of the antennas are properly tightened. Also check that there is a good contact between them.

4)  With the system running, find the fibre optic cable from the transmitter and disconnect it at the control module and look for a red light coming from the top hole in the control module. Plug this cable back in and unplug the Input (black) cable at the transmitter.  Check for a red light coming from the cable.

If the signal is still not found, contact Sensors & Software Inc. (Section 17.10: P146).

## 17.6  System Overheating

The pulseEKKO PRO 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.  While the temperature displayed on the DVL in the lower left corner of the main menu indicates the internal temperature of the DVL and not the GPR system, this temperature should give an idea of whether the pulseEKKO PRO transmitter and receiver are overheating.

If you suspect that the system is overheating, shut it off and give it a chance to cool down in a shady location before trying to run it again.

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 system.

Contact Sensors & Software Inc. if the problem persists as there may be defective electronic components that need to be replaced (Section 17.10: P146).

## 17.7  DVL Problem

While the DVL has been ruggedized as much as possible, it should be handled in much the same way a notebook computer is. If the DVL does not power up and boot up, there may be a problem with the CPU or the storage media. If this occurs, contact Sensors & Software Inc. (Section 17.10: P146).

If, when trying to run the radar system, you are getting a consistent control module error and none of the suggestions under Control Module Errors have worked, the problem may be DVL related.

## 17.8  Timezero Jitter

If the first break is shifting up and down as shown below:
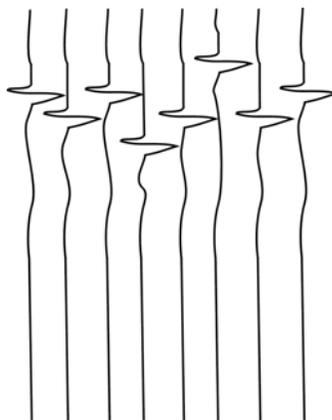


*Figure 17-8:  Time zero jitter is caused by damaged fibre optic cables.*

This is an indication that the fibre optic cables are damaged. Check all cables (Section 17.2: P141) and replace or repair. There are also short fibre optic cables located inside the transmitter and receiver that may be causing the problem (see item K in Figure 19-1). Before attempting to clean or replace these cables, contact Sensors & Software (see below).

## 17.9  System Runs But Data Does Not Look Right

There may be cases when the system does not actually fail and cause error messages but the data being collected does not seem "right", because of perhaps excess noise, banding or very weak signals. The best way to determine whether the strange data is a result of local conditions in the survey area or real problem with the system is to, shortly after receiving the system and periodically afterwards, collect a test line of data at a designated location (Section 16.9: P130). Then, suspected system problems can be confirmed or dismissed by collecting data on the test line and comparing it to earlier data collected along the same line.

## 17.10  Contacting Sensors & Software Inc.

If you develop problems with your GPR system, contact your agent or Sensors & Software Inc.

Sensors & Software Inc.'s hours of operation are 9:00 AM to 5:00 PM Eastern Standard Time, Monday to Friday. You can contact Sensors & Software Inc. at:

> Sensors & Software Inc.
> 1040 Stacey Court
> Mississauga, Ontario
> Canada L4W 2X8
> Tel: (905) 624-8909
> Fax: (905) 624-9365
> E-mail: sales@sensoft.ca

When contacting Sensors & Software Inc., please have the following information available:

DVL, Control Module, Transmitter and Receiver Serial Numbers.

Version number of the data acquisition software.

The error number or message appearing.

A brief description of when the error is happening and the operating conditions (temperature, humidity, sunshine, system and survey setup, etc.).

# 18   File Management

From the main menu (See Figure 12-4 on page 62), pressing the 4 button selects **File Management**.

The File Management menu allows the user to delete data from the DVL, view the amount of disk space remaining on the DVL and copy data from the internal compact flash drive to the removable compact flash drive.

The Transfer options in this (Transfer Directory and Transfer File) in this menu require the use of the optional PXFER cable and WinPXFER software so this menu is not required for users transferring pulseEKKO PRO data using the removable compact flash drive. These options allow the user to export pulseEKKO PRO data to a PC using the optional PXFER cable. This is described in Appendix H: Using the PXFER Cable and WinPXFER Software.
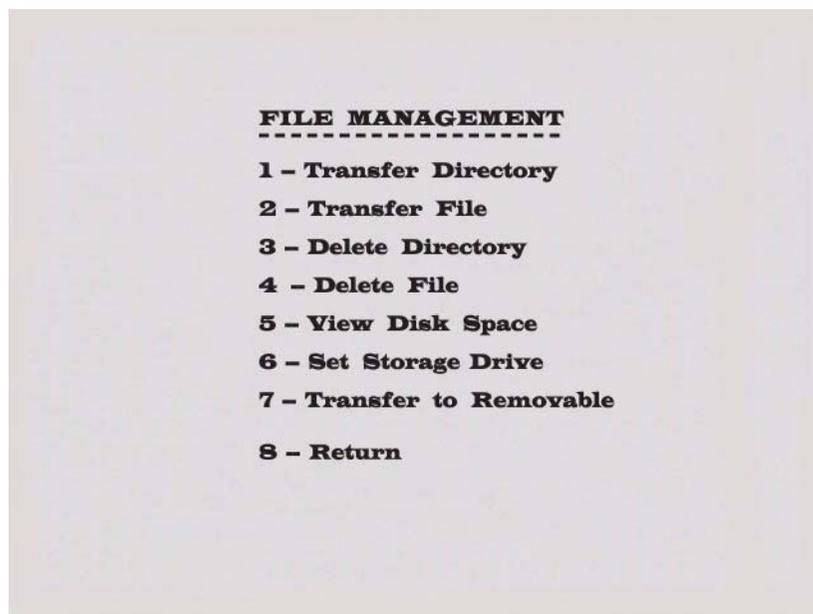


*Figure 18-1:  The File Management menu. The Transfer options require the use of the optional PXFER cable and WinPXFER software. Data are normally transferred using the removable flash drive. Note that menu option 7, Transfer to Removable is only visible if the current storage drive, selected under option 6, Set Storage Drive is set to Removable.*

## 18.1  Transferring Data to a PC using the Removable Drive

Files collected with the pulseEKKO PRO system are saved either to the Internal or the Removable drive on the DVL. To transfer data collected on the removable drive to a PC, eject the compact flash drive from the DVL and insert it into a user-supplied card reader connected to a PC. Use the Windows Explorer program to make a new folder on the PC, read the removable drive and copy the pulseEKKO PRO data files to the new folder.

If data were collected to the internal drive of the DVL (see Section 18.6: P151), the data can be copied to the removable drive so it can be transferred to a PC (see Section 18.7: P151).

*Figure 18-2: pulseEKKO data files saved to the removable drive are easily transferred to a PC. First, power down the DVL, then (i) loosen both of the finger-screws on the top of the DVL so the drive door can swing open freely. (ii) Press the button to partially eject the compact flash drive. (iii) Remove the drive and insert it into a PC card reader (user supplied). Copy the pulseEKKO PRO data files from the drive into a folder on the PC using the Windows Explorer program. The EKKO_View program can then be used to view the pulseEKKO PRO data.*

## 18.2  Transferring Data to a PC using the PXFER Cable

Files collected with the pulseEKKO PRO system are saved to the Internal or the Removable drive on the DVL (see Section 18.6: P151). While the method described above, of transferring data by ejecting the removable drive, is the usual method of data transfer, data can also be transferred to a PC using the optional PXFER cable and the WinPXFER program. This process is described in Appendix H: Using the PXFER Cable and WinPXFER Software.

## 18.3 Delete Directory

After data has been successfully transferred to a PC or if the data is longer required, the whole Directory can be deleted from the DVL. To delete the data in a directory on the DVL, from the File Management menu, press **Delete Directory**.

The next screen shows the number of bytes in all 20 available directories (Figure 18-3). Data directories are selected by using the A and B (Up and Down) buttons to move the arrows (>>>) to the desired directory. To delete the directory to the PC, press the 2 (Delete) button. It is also possible to use the 1 button to Tag several directories so they can all be deleted at once. Use the up and down arrows to highlight the Directory, the TAG button to tag each project and then press the DEL button to delete the data from the DVL.

Before the directory is deleted, the user is asked to confirm the deletion by pressing Yes or No. If the answer to the question is No, the directory is not deleted.



*Figure 18-3: Data Directory Deleting screen. The triple arrows (>>>) on the left indicates which directory is currently selected. Use the A and B buttons to move the arrows up or down to different directories. To delete the directory of data from the DVL, press the 2 (Delete) button. It is also possible to use the 1 button to Tag several directories so they can all be deleted at once.*

## 18.4  Delete File

To delete an individual data file from the DVL to a PC, select **Delete File** from the main File Management menu. On the next screen (Figure 18-4), use the A and B button to select one of the 20 available directories, then use the 1 button (Next Line) to move through the data lines in the directory. When the name of the data line to transfer appears, press 2 (Transfer Line) to send it to the PC.
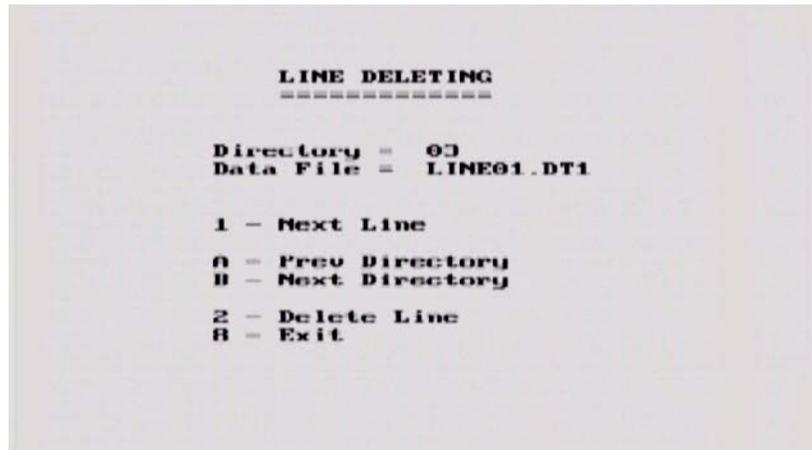


*Figure 18-4:  Line Delete screen. Use the A and B button to select one of the 20 available directories, then use the 1 button (Next Line) to move through the data lines in the directory. When the name of the data line to transfer appears, press 2 (Delete Line) to delete the line from the directory.*

## 18.5  View Disk Space

The View Disk Space option allows the user to see how much disk space has been used and how much remains. The remaining amount is expressed in kilobytes, as a percentage of the total disk space as well as how many traces and how much distance this amount of space represents, based on the current settings for time window, sampling interval and step size.



*Figure 18-5: View Disk Space screen. The total amount of disk space remaining is expressed in kilobytes, a percentage of the total disk space, number of traces and total distance. The last two values are calculated using the current setup parameters.*

## 18.6  Set Storage Drive

This setting controls how data are saved on the DVL. The available options are:

**Internal**: If this setting is selected, the data are saved to the internal compact flash drive in the DVL.

**Removable**: If this setting is selected, the data are saved to the removable compact flash drive accessible by opening the door at the top of the DVL (see Section 12.3: P60).

## 18.7  Copying Data from the Internal Drive to the Removable Drive

If data were collected to the internal drive of the DVL, the data can be copied to the removable drive so the data transfer method described above can be used. To copy data from the internal drive to the removable drive, first, change the current storage drive to Removable (see Section 18.6: P151). Then from the File Management select 7 - Transfer to Removable. **The Transfer to Removable option is NOT available in the File Management menu unless the current storage drive is set to Removable.**

## 18.8  Viewing Data Files on the External PC

After transferring data files to a PC, the pulseEKKO PRO data files can be viewed, processed and plotted using the EKKO_View, EKKO_3D and EKKO_Mapper software.

Appendix A: Data File Formats contains details about the file format of pulseEKKO PRO data.

# 19   Care and Maintenance

## 19.1  General

To operate the pulseEKKO PRO equipment in a geophysical field environment, the user should exercise the normal care afforded other field instrumentation.  Items that require specific maintenance procedures are listed below together with detailed descriptions of the procedures.

All the equipment is 'shower proof' but will not tolerate total immersion.  If the equipment is immersed in water, open up the affected box, and dry it out before operating.  If the equipment is operated in very humid conditions, open up the boxes occasionally and allow the components to dry out.

The interior of the transmitter and receiver can become very hot very quickly if exposed to strong, direct sunlight. High temperatures can affect system electronics and may lead to failures. If a suspected heat failure does occur, stop the system and allow it to cool down before retrying.

The equipment is housed in heavy duty boxes and can withstand a reasonable amount of physical abuse.

## 19.2  Cable Care

1) The cable connectors as well as the connectors on the control module, transmitter, receiver, transducers and DVL 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 done up 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.

## 19.3  Electronic Spares

The low frequency pulseEKKO PRO system comes with spare parts for repairing latches, keepers, hinges sockets and fuses on the transmitter and receiver, replacing pins on the antennas and quarter-turn studs on the adjustable handles. The positions of most of the items pictured in Figure 19-1, are shown in Figure 19-2.



*Figure 19-1:  Electronic spares kit.*
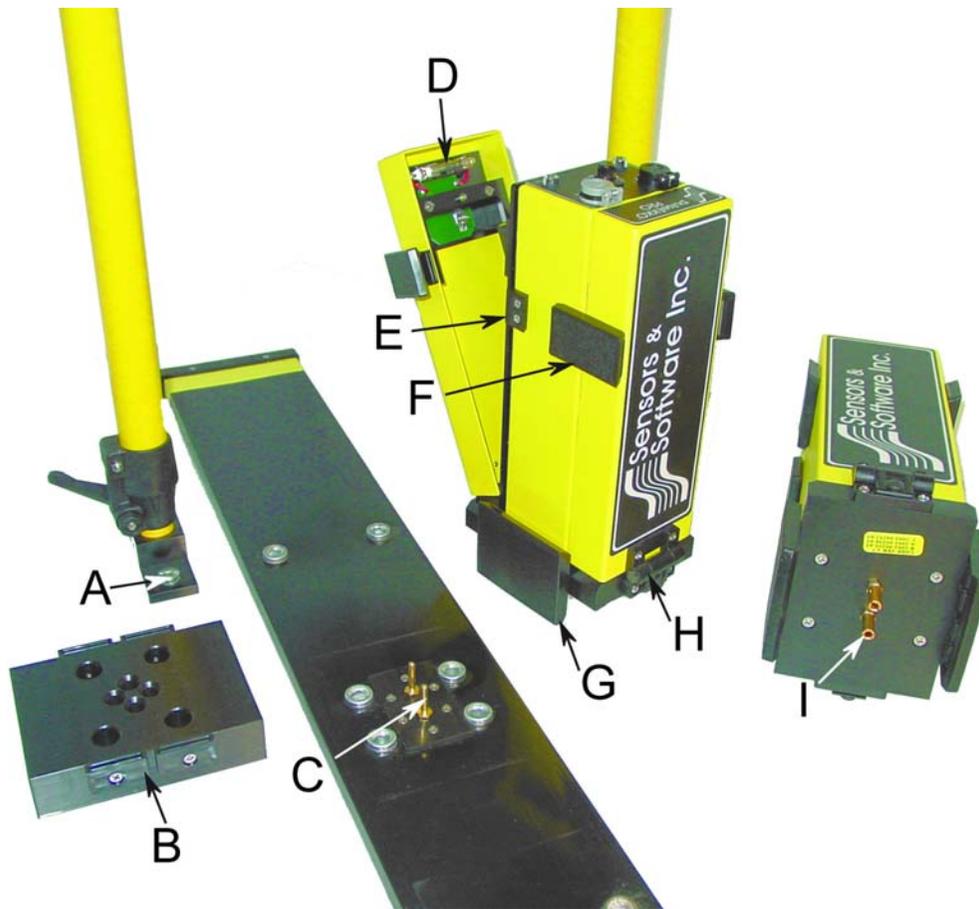
*Figure 19-2: Location of spare parts shown in Figure 19-1.*

## 19.4  Radar Unit

If operated in dusty conditions the control module, transmitter and receiver fibre optic sockets may become dusty inside.  In such conditions open the unit up on a regular basis and blow out or vacuum all the dust.

## 19.5  Antenna Electronics Connection Pins

Ensure that they are protected by leaving the antenna mounting block installed or by covering them with a block of Styrofoam or, better still, removing them when transporting them.

## 19.6  Fibre Optics Cables

The fibre optic cables are the most fragile component in the system. They can be easily damaged by misuse.

When handling the fibre optic cables always roll and unroll them as if they were on a spool.  DO NOT roll them around your arm like a rope or extension cord. Also, these cables do not twist, therefore laying the roll on the ground and pulling the cable off will cause the cables to tangle.

Always push in and remove the cable by holding the strain relief jacket or the plastic end connector. Pulling on the cable will loosen the crimp and damage the cable. After connecting the fibre optic cables to the antenna electronic boxes, loosely loop the cable and tape off some slack onto the handles (Figure 16-3). Most breaks occur right at the cable ends when they are accidentally pulled.

These cables can stand a great deal of abrasive wear but the user should avoid sharp bends in the cable, pulling the cable at right angles close to the fibre optics connectors, or allowing the unprotected ends to get dirty or scratched. Erratic timezero jumps usually indicate a cracked cable (Section 17.8: P145). If problems are encountered with the fibre optics cables, repair is very straightforward and is outlined in detail below. The best policy is to carry spares. Short fibre optic cables are located inside each of the units (see item K in Figure 19-1). These short cables may need cleaning and polishing from time to time.

## 19.7  Fibre Optics Cable Repair

The pulseEKKO PRO antenna system comes with a fibre optic repair kit (Figure 19-3).
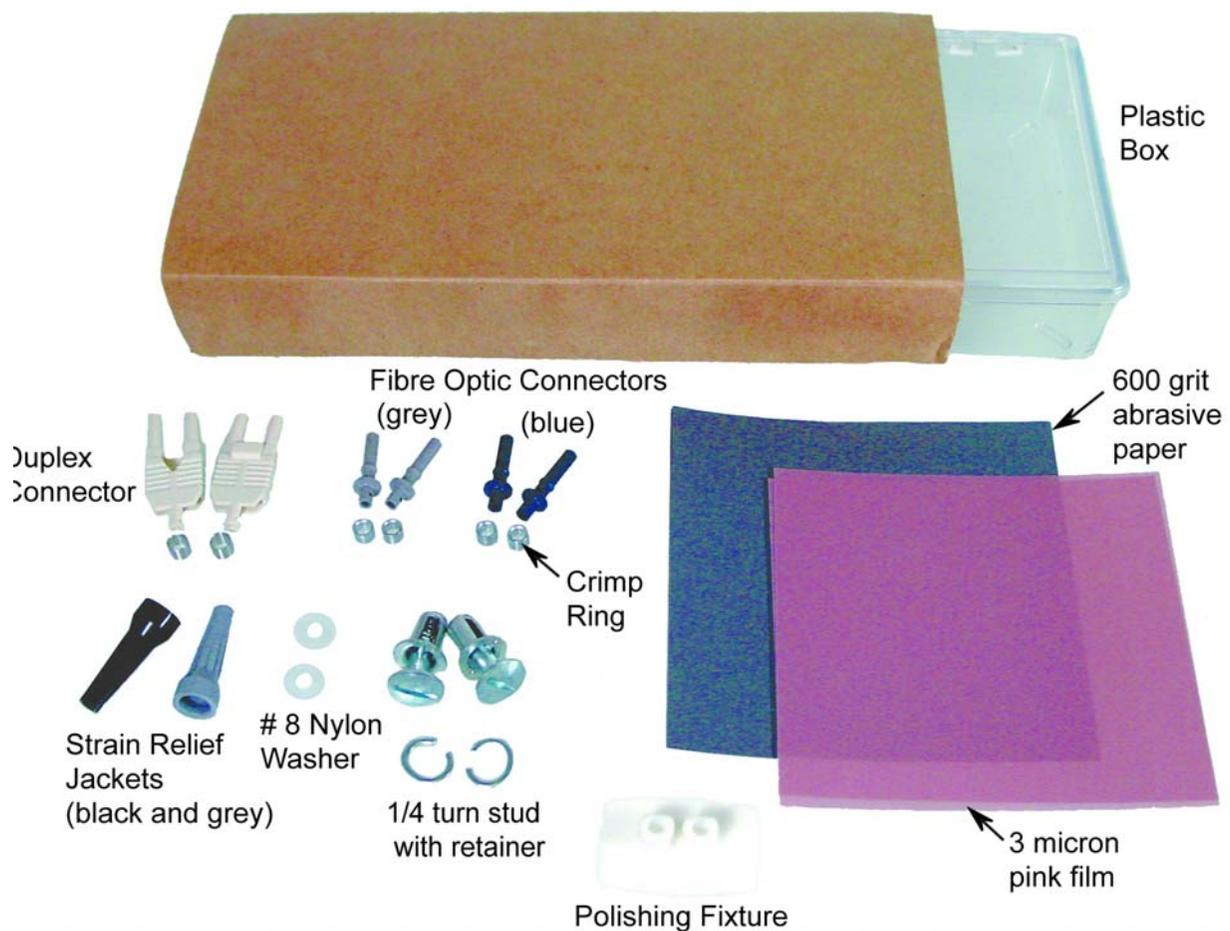


*Figure 19-3:  Fibre optic cable repair kit.*

The following procedure describes how to repair the fibre optics cables that link the pulseEKKO PRO unit to the transmitter and receiver units. The procedure and materials used are described in the Hewlett-Packard Opto-Electronic Data Book excerpts of which are provided in Appendix C: Excerpts from the HP Fiber Optic Handbook.

Connecting the cable is accomplished using the polishing kit consisting of polishing fixture, 600 grit abrasive paper and 3 micron pink lapping film.  No adhesive material is needed to secure the cable and the connector can be used immediately after polishing.

Connectors may be easily installed on the cable end with readily available tools.  Materials needed for the procedure are:

   1)  Fibre optic cable

   2)  Polishing Kit

   3)  Grey/Blue connector and crimp ring

   4)  Grey and black strain relief jackets

   5)  #8 nylon washers

   6)  Industrial razor blade or wire cutters (not supplied)

   7)  16 gauge latching wire strippers (not supplied)

   8)  Crimp tool (not supplied but available from Sensors & Software)
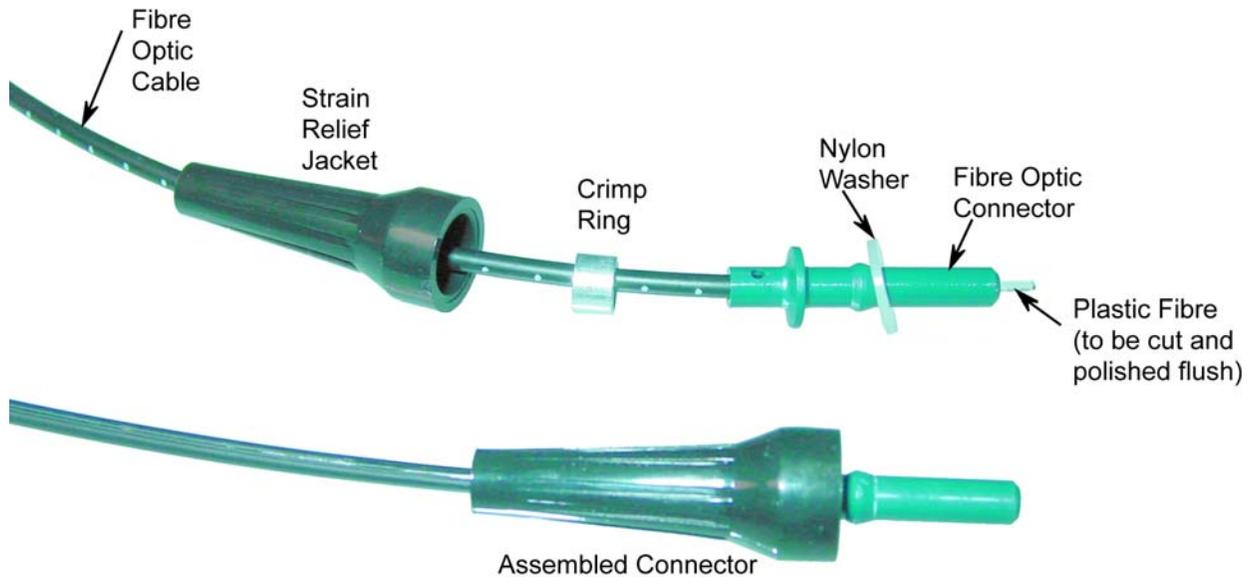


*Figure 19-4:  Assembling fibre optic connectors.*

## Step 1

If the duplex cable is being connected, split the two fibres 2 to 3 inches back from the ends.

Trim off any excess webbing and strip off about 0.3 inch (8 mm) of the outer jacket with the 16 gauge wire strippers.

## Step 2

Slide the two strain relief jackets over the fibres remembering that the blue fibre optic connector will correspond with the black strain relief jacket and the grey fibre optic connector with the grey strain relief jacket.

## Step 3

Place the crimp ring and the connector over the end of the cable; the fibre should protrude about 0.12 inch (3 mm) through the end of the connector.  Carefully position the ring so that it is entirely on the connector and then crimp the ring in place with the crimping tool.

> **NOTE: Place the grey connector on the cable end to be connected to the fibre optic output (grey strain relief jacket) and the blue connector on the cable end to be connected to the fibre optic input (black strain relief jacket) to maintain the color coding (both connectors are the same mechanically).**

## Step 4

Slide one of the plastic washers provided in your pulseEKKO PRO spares kit over the fibre optic connector. This washer will now be inserted into the strain relief jacket.

> **NOTE: You may also use #8 stainless steel flat washers should you run out of the nylon ones. Being very careful not to damage or bend the cable, force the washer into the strain relief jacket.  You may find it useful to use a 3/16 inch nut driver to push the washer into its strain relief jacket as the fibre optic connector will slide inside the driver and even force can be applied to the washer.**

## Step 5

Any excess fibre protruding from the connector may be cut off;  however the trimmed fibre should protrude at least 0.04 inch (1 mm) from the connector end.

Insert the connector fully into the polishing fixture and the connector end protruding from the bottom of the fixture.

> **NOTE: The four dots on the bottom of the fixture are wear indicators.  Replace the fixture when the dots are no longer visible.**

Place the 600 grit abrasive paper on a flat smooth surface.  Pressing down on the connector, polish the fibre and the connector until the connector is flush with the end of the polishing fixture.  Wipe the connector and the fixture with a clean cloth or tissue.

## Step 6

Place the flush connector and the polishing fixture on the dull side of the 3 micron pink lapping film and continue polishing the fibre and the connector for approximately 25 strokes.  The fibre end should be flat, smooth and clean.

The cable is now ready for use.

# 20   Helpful Hints

## 20.1  Batteries

Replace batteries before they go dead.   Nothing is more annoying than losing data in the middle of a traverse. Carry plenty of spares.

## 20.2  Measuring Position

When performing a profile where the accuracy need only be accurate to the nearest metre, set the step size equal to some fraction of your antenna spacing.  On the rope used to hold the antennas at a fixed spacing, mark the step size.  Each time the antennas are moved mark the ground (take note of a mark or feature) where the next antenna placement will be based on the mark on the string.   For accurate positioning a tape measure laid out on the survey line is most effective.

If a tape measure is being used make sure it is NOT metal or does NOT have a metal center.  Some cloth tape measures do have metal centers. Odd effects can appear in data when such measuring tapes are used.

## 20.3  Data Files

Backup data often or at least at the end of each survey day.

## 20.4  Spares

When going out on a trip, make sure you have plenty of spares.  It is much easier to carry a spare fibre optic cable than try and repair one in the field. Remember fuses and a Philips screw driver. A volt/ohm meter is also useful.

# Appendix A:    Data File Formats

## pulseEKKO Data File Format

### HEADER (.HD) FILE:

The header file, identified by the file extension  .HD, is an ASCII file. An example is shown below.

```
1234
Data Collected with pulseEKKO PRO
2005-01-12
NUMBER OF TRACES      = 136
NUMBER OF PTS/TRC     = 409
TIMEZERO AT POINT     = 96
TOTAL TIME WINDOW     = 327
STARTING POSITION     = 9.500000
FINAL POSITION        = 77.000000
STEP SIZE USED        = 0.500000
POSITION UNITS        = metres
NOMINAL FREQUENCY     = 100.000000
ANTENNA SEPARATION    = 1.000000
PULSER VOLTAGE (V)    = 400
NUMBER OF STACKS      = 128
SURVEY MODE           = Reflection
DVL Serial#           = 0000-0000-3333
Console Serial#       = 0022-3009-0024
Transmitter Serial#   = 0026-3171-0005
Receiver Serial#      = 0025-3172-0004
```

It can be read and/or printed using any Word Processor.

### DATA (.DT1) FILE:

The data file contains as many records as there are traces. Each record in turn consists of a header section and a data section. The header section consists of an array of 25 real*4 numbers and a string of 28 characters which is used for annotation. The 25 element real array contains the following information:

| Item # | Description |
|---|---|
| 1 | Trace number |
| 2 | Position |
| 3 | Number of points per trace |
| 4 | Topographic data, if available |
| 5 | (not used) |
| 6 | # bytes/point (always 2 for Rev 3 firmware) |
| 7 | Time Window |
| 8 | # of stacks |
| 9 | Time window |
| 9-10 | reserved for GPS X position (double*8 number) |
| 11-12 | reserved for GPS Y position (double*8 number) |
| 13-14 | reserved for GPS Z position (double*8 number) |
| 15 | reserved for receiver x position |
| 16 | reserved for receiver y position |
| 17 | reserved for receiver z position |
| 18 | reserved for transmitter x position |
| 19 | reserved for transmitter y position |
| 20 | reserved for transmitter z position |
| 21 | timezero adjustment |
| | where:point(x)= point(x+adjustment) |

| | |
|---|---|
| 22 | Zero flag: 0 = data okay, 1=zero data |
| 23 | Used for multi-channel channel numbers |
| 24 | Time of day data collected in seconds past midnight. |
| 25 | Comment flag: 1 = comment attached. |
| 26 - 32 | Comment |

The data section consists of an array of two-byte integers, one value for every data point.

# Appendix B:    GPR Signal Processing Artifacts

## Wow

All GPR data has a low frequency component to it.  The magnitude of the low frequency component and how it manifests itself in the data depends on the ground conditions around the antennas and the distance between the antennas.  In general, the low frequency component of the radar signal does not propagate but diffuses into the ground.  In other words the lower end of the spectrum sees an inductive (eddy current) type response as opposed to a propagating (displacement current) type response.

The result is that the large transmit pulse emitted by the radar can be followed by a slowly decaying transient. This shown as a sketch in Figure B-1 (a) and in real data in Figure B-2. Various terms have been applied to this decaying transient. In some instances it is referred to as **wow**; sometimes it is referred to as **system saturation recovery**. These terms are historical in nature because the response was often caused by system response characteristics rather than being a ground induced response.



a) Raw data trace

Reflection event

b) After removal of inductive WOW
using high pass (DEWOW) filter

Zero phase
filter precursor

Precursor
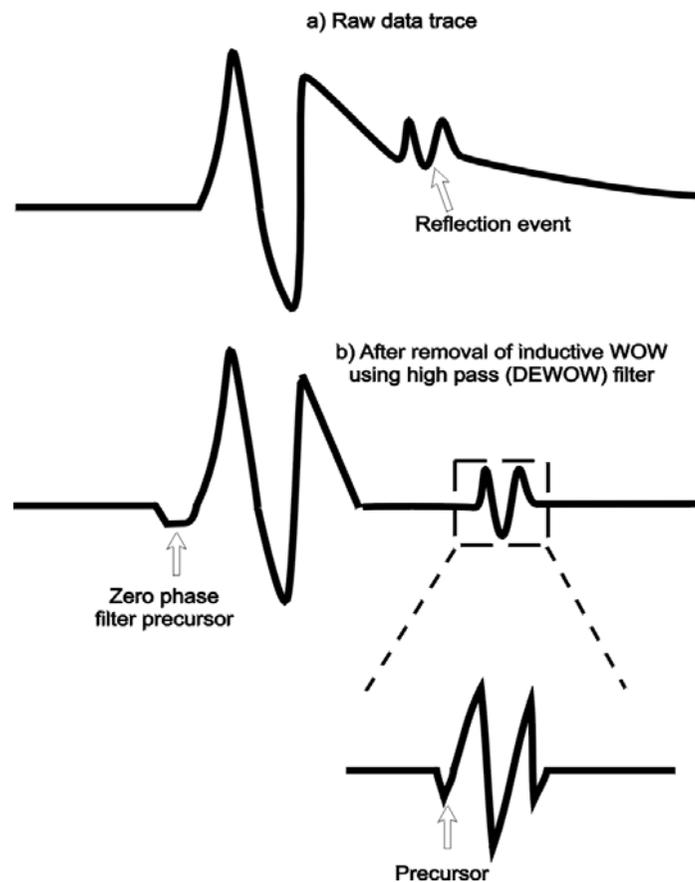
*Figure B-1:   Effect of inductive WOW on GPR data.*
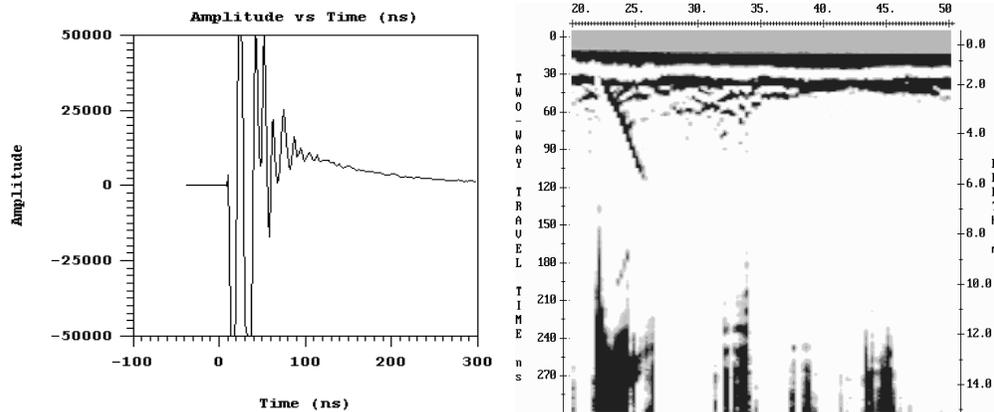
*Figure B-2:   Display of a single data trace (left) and data section (right) with the low frequency WOW component present.  Compare these plots to the figure below where the WOW has been removed with the DEWOW high pass filter.*

Turn the DEWOW filter off to see this low frequency component of the data when plotting the data with Windows-based software.

## Dewow Filter

With this wow usually being present, it is common practice that GPR data is high pass (DEWOW) filtered.

DEWOW is a high pass filter optimized to pass the transmitted signal spectral peak for the specific antenna center frequency with fidelity and suppress the low frequency wow in the data. The wow is removed from the data by applying a running average filter on each trace.  A window with a width the same as that of one pulse width at the nominal frequency is set on the trace.  The average value of all the points in this window is calculated and subtracted from the central point.  The window is then moved along the trace by one point and the process is repeated.

In the initial software releases, this high pass filtering was integral to all of the plotting and display programs.   As a result the user was, in many situations, unaware of this wow or low frequency component in the data.  The raw recorded data, however, always retained this information.
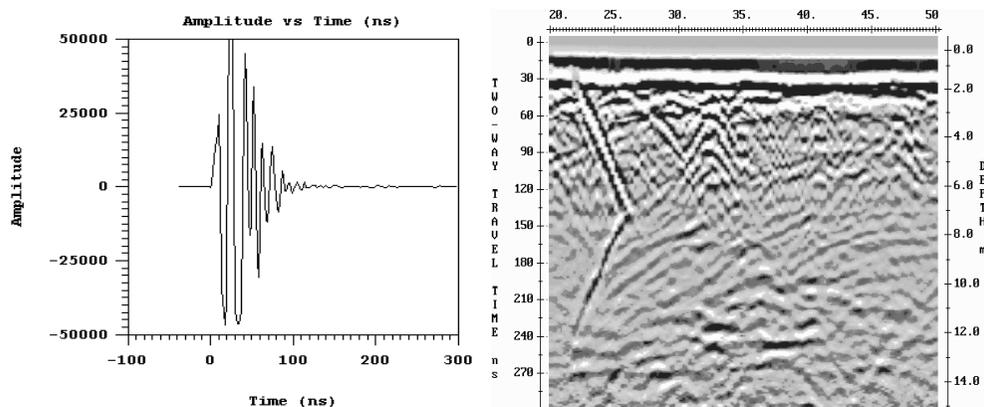


*Figure B-3:   Display of a single data trace (left) and data section (right) where the Wow seen in the figure above has been removed with the Dewow high pass filter.*

# Dewow Artifacts

### 1) Pulse Precursor

The result of high pass filtering can induce two types of artifacts into the plotted data sections. The first is a pre-cursor to the onset of a pulse (Figure B-1 (b) and Figure B-3, left). When the original data are high pass filtered the wavelet is stretched in time with additional oscillations occurring before and after the original pulse. This is what gives rise to a pre-cursor in the data before time-zero when looking at the plotted sections.

### 2) Clipping

The second artifact is caused by electronic clipping. The basic concept is depicted in Figure B-4a, b and c. The original signal which is acquired by the antenna and presented to the receiver electronics looks like that sketched in Figure B-4a. The radar electronics clip any signals above the 50 millivolt level. Figure B-4b shows the type of result that will be measured if clipping occurs in the signal pre-conditioning circuitry. When these data are finally high pass filtered, a blank zone in the area where the original signal had a large wow above the clipping level of the electronics can appear. This results in a blank section on the record with no reflections visible.

a) Original signal

b) Signal after electronic clipping

c) Signal after high pass (DEWOW) filter

Note: No reflections in clipped area
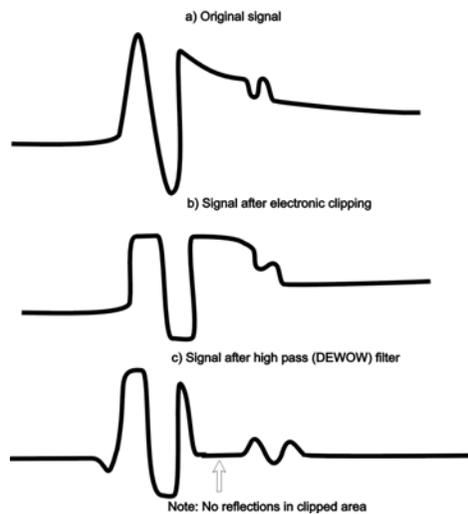
*Figure B-4:   Inductive WOW clipping.*

In the second case where signal saturation clipping occurs, there is no software correction for this.  The user must be aware that this can occur in some geologic settings and the antenna spacing should be increased to reduce the wow signal amplitude below the clipping level of the receiver electronics.  As a general rule, we recommend using an antenna separation at least equal to the length of the antenna being employed.  For example, 100 MHz antennas should have an antenna spacing of at least 1 metre, a 50 MHz antenna system should use an antenna spacing of 2 metres.  Obviously this rule depends on the level of wow or inductive response present at the particular site. Again note that the processing affects only displayed data, not recorded data.

## Other Types of Filters

For dealing with the inductive wow response, high pass filtering is necessary. If an alternative high pass filter is available or the user wishes to try a different type of high pass filtering, the raw data contains all of the information and experimentation can be carried out using the raw data.

A DC removal can also be used to remove a DC level from all the traces in the input data set. This is done by taking all the points in each trace and calculating the average signal level for that trace. This value is then subtracted from each point in the trace. This process is repeated for each trace in the data set. Typically, traces will have approximately the same DC shift in a given data set.

DC removal, in some cases, can be used instead of DEWOW. For example, a DC shift correction applied to high frequency radar data rather than a DEWOW correction may be more effective in reducing artifacts.

If you are unsure about which correction to apply use DEWOW.

# Appendix C: Excerpts from the HP Fiber Optic Handbook

IN-LINE SPLICE FOR HFBR-35XX/36XX FIBER OPTIC CABLE WITH HFBR-4501/4511 SIMPLEX CONNECTORS
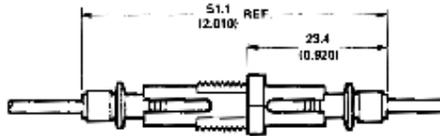


DIMENSIONS IN MILLIMETRES (INCHES)

## Connector Mechanical/Optical Characteristics 25°C Unless Otherwise Specified.

| Parameter | Part Number | | Sym. | Min. | Typ. | Max. | Units | Ref. |
|---|---|---|---|---|---|---|---|---|
| Retention Force Connector to HFBR-152X 153X/ 252X/253X Modules | Simplex | HFBR-4501/4511 | $F_{R-C}$ | 7 | 8 | | N | Note 4 |
| | Simplex Latching | HFBR-4503/4513 | | 47 | 80 | | | |
| | Duplex | HFBR-4506 | | 7 | 12 | | | |
| | Duplex Latching | HFBR-4516 | | 50 | 80 | | | |
| Tensile Force Connector to Cable | Simplex | HFBR-4501/4511 | $F_T$ | 8.5 | 22 | | N | Notes 3, 4 |
| | Simplex Latching | HFBR-4503/4513 | | 8.5 | 22 | | | |
| | Duplex | HFBR-4506 | | 14 | 35 | | | |
| | Duplex Latching | HFBR-4516 | | 14 | 35 | | | |
| Adapter Connector to Connector Loss | HFBR-4505/4515 with HFBR-4501/4511 | | $\alpha_{CC}$ | 0.7 | 1.5 | 2.8 | dB | Notes 1, 5 |
| Retention Force Connector to Adapter | HFBR-4505/4515 with HFBR-4501/4511 | | $F_{R-B}$ | 7 | 8 | | N | Note 4 |
| Insertion Force Connector to HFBR-152X/153X/ 252X/253X Modules | Simplex | HFBR-4501/4511 | $F_I$ | | 8 | 12 | N | Notes 2, 4 |
| | Simplex Latching | HFBR-4503/4513 | | | 16 | 35 | | |
| | Duplex | HFBR-4506 | | | 13 | 46 | | |
| | Duplex Latching | HFBR-4516 | | | 22 | 51 | | |

**Notes:**
1. Factory polish or field polish per recommended procedure.
2. No perceivable reduction in insertion force was observed after 2000 insertions. Destructive insertion force was typically at 178N (40 lbs).
3. For applications where frequent temperature cycling over temperature extremes is expected please contact Hewlett-Packard for alternate connectoring techniques.
4. All mechanical forces were measured after units were stored at 70°C for 168 hours and returned to 25°C for one hour.
5. Minimum and maximum limits of $\alpha_{CC}$ are for 0°C to 70°C temperature range. Typical value of $\alpha_{CC}$ is at 25°C.

## Connectoring

The following easy procedure describes how to make cable terminations. It is ideal for both field and factory installation. If a high volume connectoring technique is required please contact your Hewlett-Packard sales engineer for the recommended procedure and equipment.

Connectoring the cable is accomplished with the Hewlett-Packard HFBR-4593 Polishing Kit consisting of a Polishing Fixture, 600 grit abrasive paper and 3-µm pink lapping film (3M Company, OC3-14). No adhesive material is needed to secure the cable in the connector, and the connector can be used immediately after polishing. Improved connector to cable attachment can be achieved with the use of a RTV (GE Company, RTV-128) adhesive for frequent, extreme temperature cycling environments or for elevated temperature operation.

Connectors may be easily installed on the cable ends with readily available tools. Materials needed for the terminating procedure are:

1) Hewlett-Packard Plastic Fiber Optic Cable
2) HFBR-4593 Polishing Kit
3) HFBR-4501/4503 Gray Simplex/Simplex Latching Connector and Silver Color Crimp Ring
4) HFBR-4511/4513 Blue Simplex/Simplex Latching Connector and Silver Color Crimp Ring
5) HFBR-4506 Parchment Duplex Connector and Duplex Crimp Ring
6) Industrial Razor Blade or Wire Cutters
7) 16 Gauge Latching Wire Strippers
8) Crimp Tool, HFBR-4597

### Step 1

The zip cord structure of the duplex cable permits easy separation of the channels. The channels should be separated approximately 50 mm (2.0 in.) back from the ends to permit connectoring and polishing.

After cutting the cable to the desired length, strip off approximately 7 mm (0.3 in.) of the outer jacket with the 16 gauge wire strippers. Excess webbing on duplex cable may have to be trimmed to allow the simplex or simplex latching connector to slide over the cable.

When using the duplex connector and duplex cable, the separated duplex cable must be stripped to equal lengths on each cable. This allows easy and proper seating of the cable into the duplex connector.



### Step 2
Place the crimp ring and connector over the end of the cable; the fiber should protrude about 3 mm (0.12 in.) through the end of the connector. Carefully position the ring so that it is entirely on the connector with the rim of the crimp ring flush with the connector, leaving a small space between the crimp ring and the flange. Then crimp the ring in place with the crimping tool. One crimp tool is used for all connector crimping requirements.

**Note:** *Place the gray connector on the cable end to be connected to the transmitter and the blue connector on the cable end to be connected to the receiver to maintain the color coding (both connectors are the same mechanically). For duplex connector and duplex cable application, align the color coded side of the cable with the appropriate ferrule of the duplex connector in order to match connections to the respective optical ports. The simplex connector crimp ring cannot be used with the duplex connector. The duplex connector crimp ring cannot be used with the simplex or simplex latching connectors. The simplex crimp has a dull lustre; the duplex ring is shiny and has a thinner wall.*
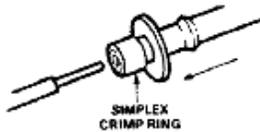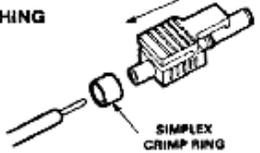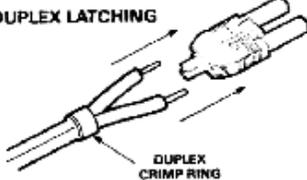


### Step 3
Any excess fiber protuding from the connector end may be cut off; however, the trimmed fiber should extend at least 1.5 mm (0.06 in.) from the connector end.

Insert the connector fully into the polishing fixture with the trimmed fiber protruding from the bottom of the fixture. This plastic polishing fixture can be used to polish two simplex connectors or two simplex latching connectors simultaneously, or one duplex connector.

**Note:** *The four dots on the bottom of the polishing fixture are wear indicators. Replace the polishing fixture when any dot is no longer visible.*

Place the 600 grit abrasive paper on a flat smooth surface. Pressing down on the connector, polish the fiber and the connector using a figure eight pattern of strokes until the connector is flush with the bottom of the polishing fixture. Wipe the connector and fixture with a clean cloth or tissue.
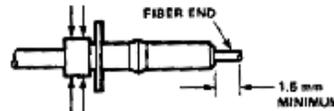


### Step 4
Place the flush connector and polishing fixture on the dull side of the 3 micron pink lapping film and continue to polish the fiber and connector for approximately 25 strokes. The fiber end should be flat, smooth and clean.

The cable is now ready for use.

**Note:** *Use of the pink lapping film fine polishing step results in approximately 2 dB improvement in coupling performance of either a transmitter-receiver link or a bulkhead/splice over 600 grit polish alone. This fine polish is comparable to Hewlett-Packard factory polish. The fine polishing step may be omitted where an extra 2 dB of optical power is not essential, as with short link lengths. Proper polishing of the tip of the fiber/connector face results in a tip diameter between 2.8 mm (0.110 in.) minimum and 3.2 mm (0.125 in.) maximum.*
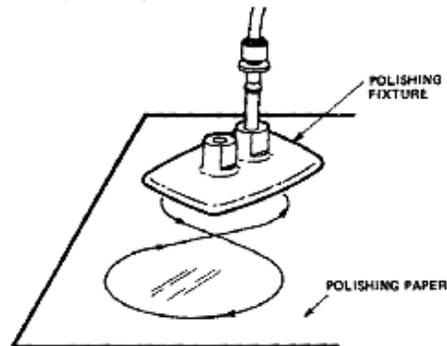


For simultaneous multiple connector polishing techniques please contact Hewlett-Packard.

### HFBR-4593 POLISHING KIT
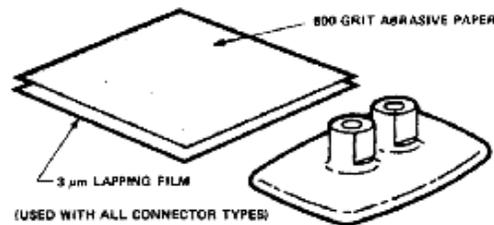
# Appendix D:   Health & Safety Certification

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 D-1.
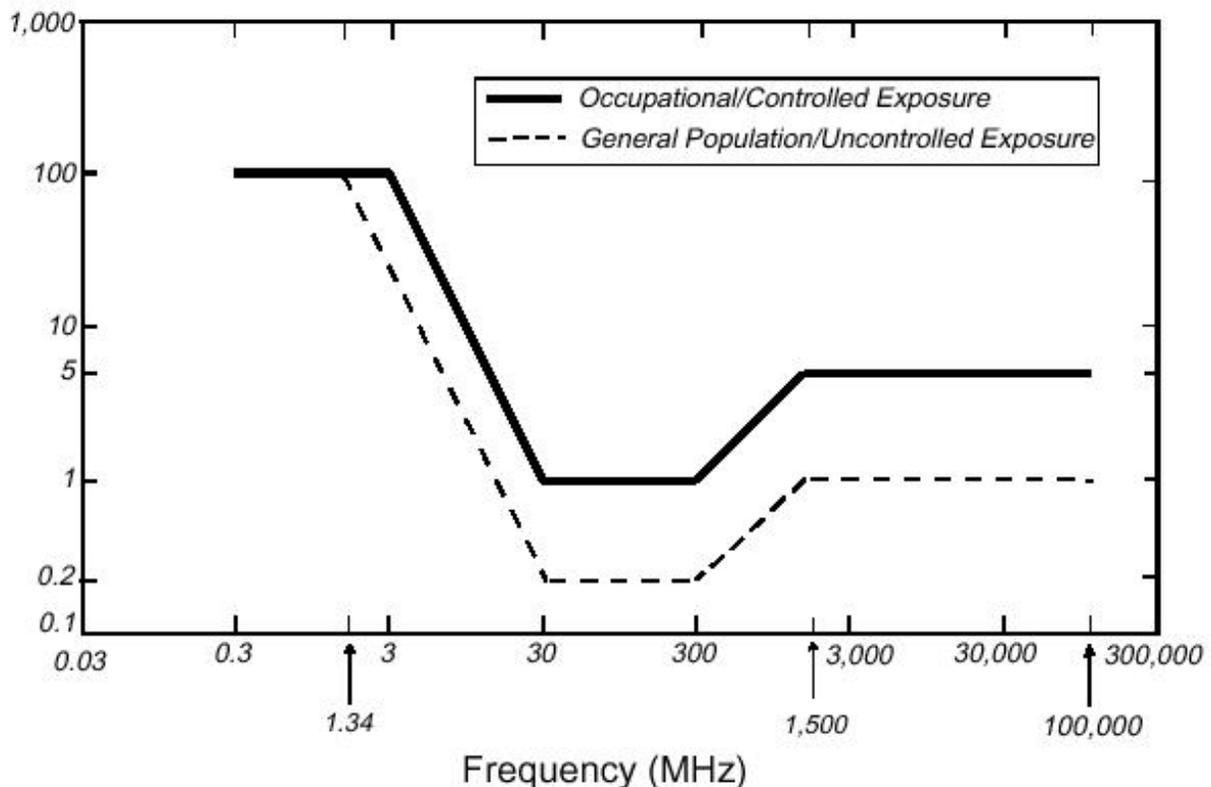


*Figure D-1:  FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm$^2$.*

All Sensors & Software Inc. pulseEKKO, Noggin and Conquest 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

1. 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)

2. 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)

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

## Web Sites

www.fcc.gov/Bureau/EngineeringTechnlogy/Documents/bulletin

www.osha-slc.gov/SLTC (see radio frequency)

# Appendix E:    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.

Sensors & Software Inc. extensively test their pulseEKKO, Noggin and Conquest subsurface imaging 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.

GPR instruments are considered to be UWB (ultra-wideband) devices.  The regulatory regimes worldwide are devising new rules for UWB devices.  Sensors & Software Inc. maintains close contact with the regulators to help guide standard development and assure that all products conform.  You should continually monitor the "News" link on our website (www.sensoft.ca) for updates on standards.

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.

## E-1   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 Sensors & Software Inc. 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, fire fighting, 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. [1]  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

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1.   See 47 C.F.R. §§15.509(b), 15.511(b), and 15.513(b)

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 dif-

ferent 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: [E.G. QJQ-PE-PRO-TLF-A)]


EQUIPMENT NOMENCLATURE: [E.G. PULSEEKKO PRO TLF-A]



Send the information to:

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


INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

## E-2   ETSI Regulations for the EC

In the European Community (EC), GPR instruments must conform to ETSI (European Technical Standards Institute) standard EN302066. 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 EN302066.

# Appendix F:    Instrument Compatibility

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 additive signal 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 G: 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.

# Appendix H: Using the PXFER Cable and WinPXFER Software

## H-1 Transferring Data to a PC using the PXFER Cable

There are two methods available to transfer data files from the DVL to a PC. The usual method is to save the data to the removable compact flash drive that is accessible using the door on the top of the DVL. After powering down the DVL, this drive can be removed and inserted into a card reader attached to a PC.

The other method of transferring data files to a PC, described in detail in this section, requires the use of the optional PXFER cable and WinPXFER software.

### H-1.1 Connecting the DVL to a PC

To transfer data files from the DVL to an external computer, the computer must be connected to the DVL using the special parallel PXFER cable that is supplied with the system (Figure H-1). Note that this is a special cable and standard 25 pin to 25 pin or Laplink cables will not work. As well, the computer must have the utility program called WinPXFER running on it (H-1.3: p.H-2).
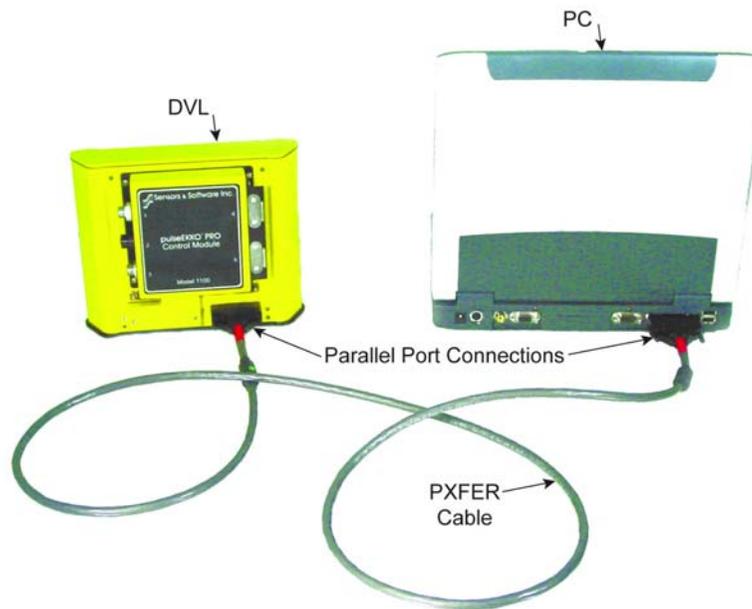


*Figure H-1: Parallel PXFER cable connections*

The 2 connections that must be made before attempting to transfer data are:

1) Attach the 25 socket parallel connector to the 25 socket parallel port on back of the DVL, and

2) Attach the 25 socket parallel connector the parallel port of the external computer.

WARNING: To avoid damaging any of the components, turn off the DVL and computer before making any of these connections.

## H-1.2 PXFER Cable Types

There are two types of PXFER cable, Normal and Turbo. The Turbo PXFER cable can be identified by the pink band visible near the connector at either end. The Normal PXFER cable does not have this pink band.
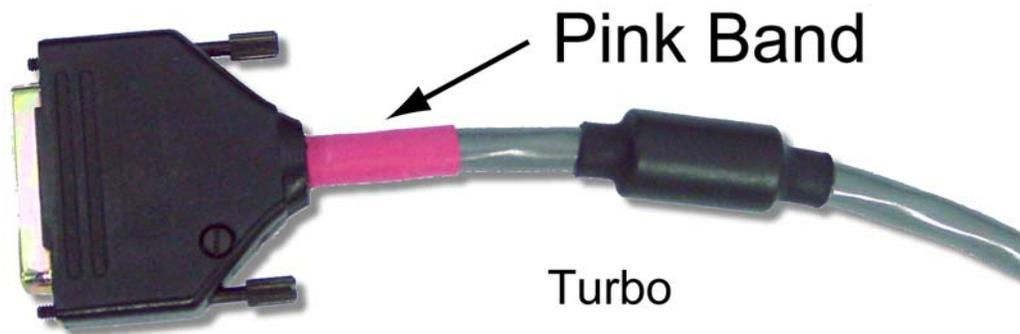


*Figure H-1: Turbo PXFER cable.*



*Figure H-2: Normal PXFER cable.*

Data transfer can only occur if the DVL is set to the correct type of cable (see H-1.4: p.H-4). As well, the WinPXFER software must be set to the correct type of cable (see H-1.2: p.H-2).

## H-1.3 Installing and Running the WinPXFER Software on a PC

The system will come with a CD containing the WinPXFER software installation. This will be the WinPXFER folder on the CD. Run the SETUP.EXE program to install WinPXFER. If necessary, refer to the software installation document that came with the system. This same document in electronic format is in the root folder of the CD.

Once the WinPXFER program has been installed on the computer and the user is ready to transfer data to the computer, the WinPXFER program needs to be run. Double-click the WinPXFER icon on the desktop or go to Start - Program Files - Sensors & Software GPR - WinPXFER.

The first time that WinPXFER is run, it will install a driver.
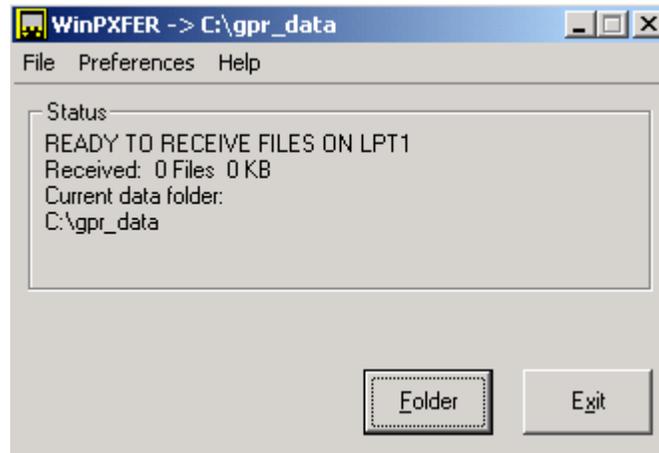
*Figure H-1: The WinPXFER software needs to be installed on the PC that the GPR data files are to be transferred to. The main WinPXFER screen is shown above. The user can use the Folder button to specify or create a folder to copy the GPR data into.*

When the WinPXFER program has been run, it will display a screen as shown in Figure H-1.

This means that it is ready to receive data transferred from the DVL to the LPT port number 1.

This command assumes that the data buffers are being transferred across Parallel Port 1 (LPT1). If using Parallel Port 2 (LPT2) or higher (LPT3, LPT4 etc.), specify the parallel port number under the Port menu item from WinPXFER.

The name of the folder that the GPR data will be transferred into is listed under the "Current data folder". In the example in Figure H-1, the data will be transferred to the C:\gpr_data folder. The data folder can be changed by pressing the Folder button and choosing another folder.

It is vital that WinPXFER be configured properly for the type of PXFER cable (see H-1.2: p.H-2). If the PXFER cable is a Normal cable, the Turbo option under Preferences should NOT be checked when attempting to transfer data. If the PXFER cable is a Turbo cable, the Turbo option under Preferences should be checked when attempting to transfer data.
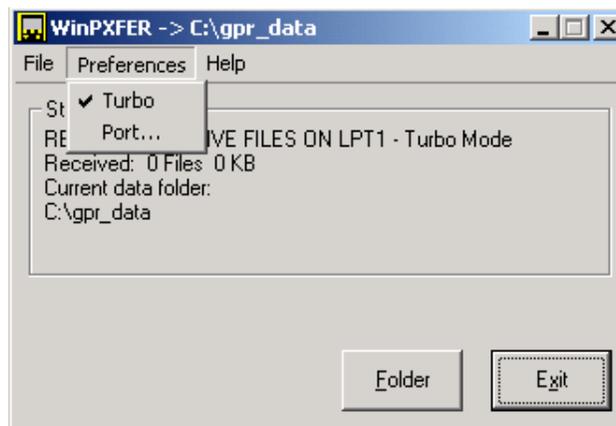


*Figure H-2: Turbo mode under Preferences should only be checked if a Turbo PXFER cable is being used.*

## H-1.4 Setting the DVL to the PXFER Cable Type

The DVL needs to be configured for the type of PXFER cable being used (see H-1.2: p.H-2). Select **System Setup** from the main menu and then **DVL Setup Menu** and **Set DVL Transfer Mode**. The choices are Normal and Turbo.

## H-1.5 Transfer Directory

Once the parallel XFER cable is connected (Section H-1.1: p.H-1) and the WinPXFER software is installed and running (Section H-1.3: p.H-2), it is now possible to transfer data to the external computer.

On the DVL, from the File Management menu, press **Transfer Directory**.

The next screen shows the number of bytes in all 20 available directories (Figure H-1). Data directories are selected by using the A and B (Up and Down) buttons to move the arrows (>>>) to the desired directory. To transfer the directory to the PC, press the 2 (Send) button. It is also possible to use the 1 button to Tag several directories so they can all be sent at once

The data will be transferred from the DVL to the computer and saved in the current folder listed by the WinPXFER software. The progress of the data transfer will be displayed on the DVL screen and the external computer.

When the data transfer is complete, exit from the WinPXFER program. Press any button on the DVL to return to the main menu.

It is best to always copy data to a new folder on the PC. Since the data files are given set names like LINE01, LINEX01, etc., existing data files in the folder on the PC will be overwritten by the new data files being transferred without warning.



*Figure H-1: Data Directory Transfer screen. The triple arrows (>>>) on the left indicates which directory is currently selected. Use the A and B buttons to move the arrows up or down to different directories. To transfer the directory to the PC, press the 2 (Send) button. It is also possible to use the 1 button to Tag several directories so they can all be sent at once.*

## H-1.6 Transfer File

Once the parallel XFER cable is connected (Section H-1.1: p.H-1) and the WinPXFER software is installed and running (Section H-1.3 on page 2), it is now possible to transfer data to the external computer.

To transfer an individual data file from the DVL to a PC, select **Transfer File** from the main File Management menu. On the next screen (Figure H-1), use the A and B button to select one of the 20 available directories, then use the 1 button (Next Line) to move through the data lines in the directory. When the name of the data line to transfer appears, press 2 (Transfer Line) to send it to the PC.

```
        LINE  TRANSFER
        =============

Directory =   03
Data File =   LINE01.DT1

1 - Next Line

A = Prev Directory
B - Next Directory

2 - Transfer Line
A = Exit
```

*Figure H-1: Line Transfer screen. Use the A and B button to select one of the 20 available directories, then use the 1 button (Next Line) to move through the data lines in the directory. When the name of the data line to transfer appears, press 2 (Transfer Line) to send it to the PC.*

The data will be transferred from the DVL to the computer and saved in the current folder listed by the WinPXFER software. The progress of the data transfer will be displayed on the DVL screen and the external computer.

When the data transfer is complete, exit from the WinPXFER program. Press any button on the DVL to return to the main menu.

H-5

# Appendix I:     pulseEKKO PRO Borehole Data Acquisition

## I-1   Overview

This appendix is designed to guide the user through the general assembly and operation of the pulseEKKO PRO GPR Borehole system.

The pulseEKKO PRO borehole manual consists of the following parts:

**System Assembly**: Section I-2: p.3 discusses in detail the step by step procedure for assembling the pulseEKKO PRO borehole radar system. This section should be read carefully before attempting to operate the system.

**Borehole Data Acquisition Parameters:** Section I-3: p.13 covers the procedure for selecting appropriate data collection parameters. Although every effort has been made to make the software as transparent and user friendly as possible, this section explains in greater detail each of the options and menu items in the data collection program.

**Borehole Data Collection**: Section I-4: p.25 describes running the radar system and collecting borehole data.

**Care and Maintenance:** Section I-5: p.26 discusses procedures for the care and maintenance of your pulseEKKO PRO borehole system.



*Figure I9-1: Borehole GPR data collection.*

# I-1.1   First Word - Crosshole GPR Philosophy

Crosshole GPR is quite different than reflection GPR. Reflection GPR surveys are appealing because the subsurface or internal image of the material can be viewed immediately as data are plotted to the computer screen. However, crosshole GPR surveys are transillumination surveys. Transillumination surveys are those where radio energy is transmitted between boreholes or through a structure to study the transmission properties of the material. The data collected requires data processing before images can be viewed.

Going from data collection to a final tomographic images requires forethought and planning. There are several processing steps before a final image is created. We have tried very hard to create a procedure that simplifies the steps for the user to get from data collection to final image with a minimum of headaches. We have experimented extensively and have developed what we think is a methodology to ease the necessary work. We make some assumptions and restrictions that you may not agree with but overall we have found this method to be the best for the majority of users; allowing them to create final images in an expeditious manner. If you do not follow the procedures outlined here, be prepared to spend tedious hours editing data.

A few points about the borehole data acquisition procedure we recommend:

1) Since tomographic processing depends on very precise time measurements, timezero calibration is automatically done before each transillumination survey.

2) For collecting Multiple Offset Gathers (MOG's) and Vertical Radar Profiles (VRP's) (see Part 2 Section 2.0 for a description of MOG's and VRP's), we use a convention of fixed transmitter antenna and moving receiver antenna.

3) VRP's always have the transmitter antenna on the surface and the receiver antenna in borehole. This approach limits the exposure of the receiver antenna to outside noise sources.

4) By convention, borehole depths are positive numbers. For generality and reference to an absolute datum, transmitter and receiver Z data are saved as elevations in the data file.

5) For collecting Multiple Offset Gathers (MOG's) and Vertical Radar Profiles (VRP's), each MOG or VRP is saved to a separate file. It is possible to collect an entire survey into one file but the risks of a computer fail could risk the entire survey. We thought it best to save the files individually so a computer failure does not result in a complete loss of data. At the end of the survey the data can be merged together into a single file for processing into tomographic images.

6) For collecting Multiple Offset Gathers (MOG's) and Vertical Radar Profiles (VRP's), we use automatic naming of files to allow for rapid data acquisition and easier post-survey processing. Automatic position updating is also used. User overrides are possible if an error occurs in the field.

7) While we have tried to automate acquisition of positioning information and other ancillary data with the GPR data, we highly recommend keeping a written log of data recording. It will help immensely during post-survey processing.

# I-2   System Assembly and Startup

The modular design of the pulseEKKO PRO borehole GPR makes the system very flexible and readily field-portable. There are four essential components to the radar system: the Digital Video Logger (DVL), the control module, the transmitter assembly and the receiver assembly. The transmitter and receiver assemblies are connected to the control module via appropriate fibre optics cables (Figure I9-2). This section discusses the detailed steps to follow to assemble the pulseEKKO PRO borehole system.
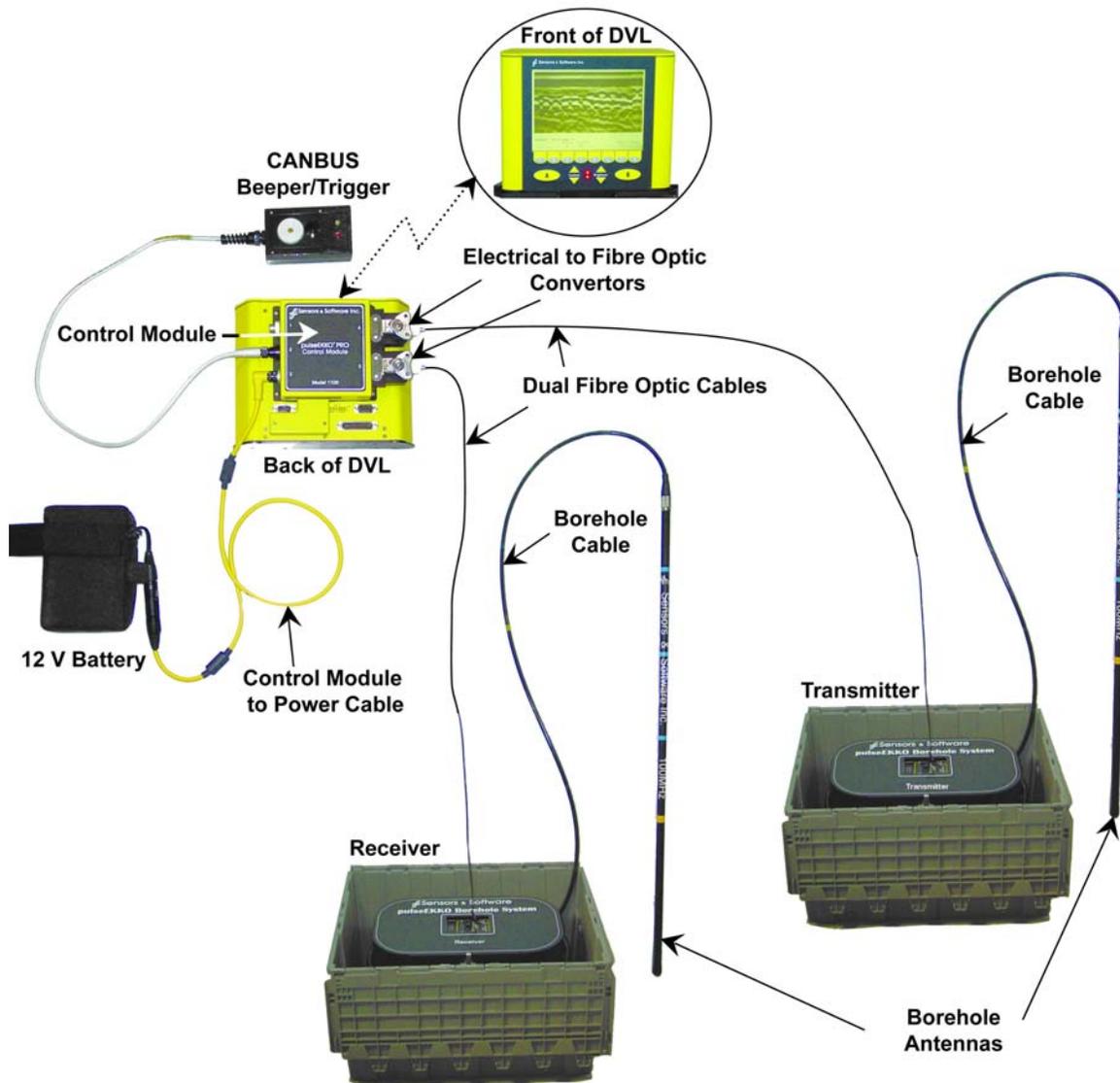


*Figure I9-2: Borehole System Assembly.*

# I-2.1    Antenna Assembly

The procedures for assembling the transmitter and receiver antennas are identical. The assembly steps are as follows:

1) Unlatch and open the lid the electronics housing (Figure I9-3).



*Figure I9-3: The housings for the pulseEKKO PRO receiver and transmitter electronics are mounted inside the grey shipping cases.*

2) Insert the two male brass antenna pins into the two threaded holes in the bottom of the housing. Tighten the pins finger-tight. DO NOT APPLY UNDUE FORCE!



*Figure I9-4: Insert and hand tighten the two male brass antenna pins into the bottom of the housing (bottom).*

3) Attach the antenna mounting blocks to the inside bottom of the transmitter and receiver electronics housings by using the flathead screwdriver to tighten the four (4) quarter-turn fasteners. Ensure that the male brass antenna pins protrude up the center holes of the mounting blocks. Quarter-turn fasteners work by aligning the screw in the socket and then pressing downward and tightening a quarter of a turn. DO NOT APPLY UNDUE FORCE! It is usually best to have all the screws properly aligned in their sockets before starting to tighten each one.
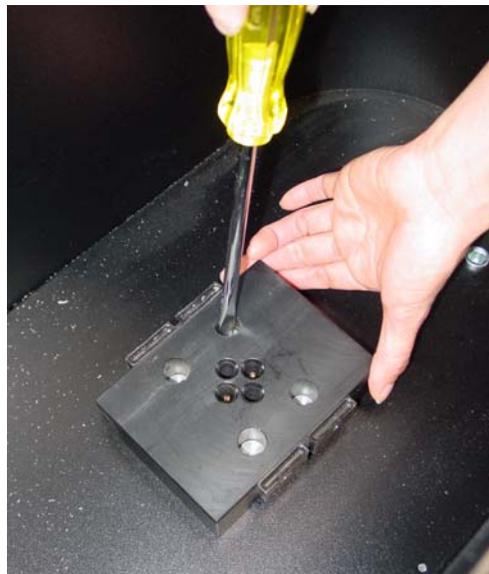


*Figure I9-5: Attach the mounting block to the housing using the quarter-turn fasteners.*

4)  Insert and tighten the two female brass antenna sockets into the bottom of the transmitter and receiver electronic boxes. Tighten the sockets finger-tight. DO NOT APPLY UNDUE FORCE!



*Figure I9-6: Hand tighten the brass sockets into the bottom of the transmitter and receiver.*

5)  Carefully place the transmitter and receiver electronics units into the appropriate housing (they are labelled Transmitter and Receiver) and down onto the mounting block such that both brass pins fully connect. Then use the 2 plastic draw latch connectors to hold the electronics units on the mounting block.



*Figure I9-7: Attach the transmitter and receiver to the mounting blocks in the bottom of the housings and secure into place using the latches. For consistent signal polarity, ensure the transmitter and receiver are oriented the same way with respect to one another.*

6)    With the transmitter and receiver power switched OFF, unlatch the 2 battery covers on the sides of the electronics and open. Place one 12-volt battery on each side on the electronics boxes making sure the positive (+) terminal faces inward toward the electronics (the battery only fits properly in this orientation). Close and latch the battery covers (see Section 2.2.6: p.10 in the main pulseEKKO PRO manual).

7)    Close the lids of the electronics housings (Figure I9-8). The top of the receiver and transmitter should be visible through the rectangular hole in the lid of the electronics housing. This allows the transmitter and receiver to be easily turned on and off.



*Figure I9-8:*

8)    Uncoil the borehole cables from around the outside of the electronics housings and remove the dust cap.



*Figure I9-9: Remove the dust cap from the end of the borehole cable. When storing the borehole housings always use the dust cap to protect the connector.*

9)  Connect the borehole antenna with the desired frequency to the end of the borehole cable. This is done by inserting the threaded end of the antenna into the receptacle at the end of the cable and twisting until a snug fit is achieved.



*Figure I9-10: Connect the borehole antenna to the borehole cable by twisting into place. Ensure a snug connection to prevent water from leaking in.*

# I-2.2   Connecting up the Radar

The next step is to connect the transmitter and receiver to the control module.

The pulseEKKO PRO Borehole system uses 2 dual fibre optic cables like the one shown in Figure I9-11. These cables should be tested periodically and inspected for kinks or signs of damage and repaired if necessary (see Section 17.2: p.141 in the main pulseEKKO PRO manual).

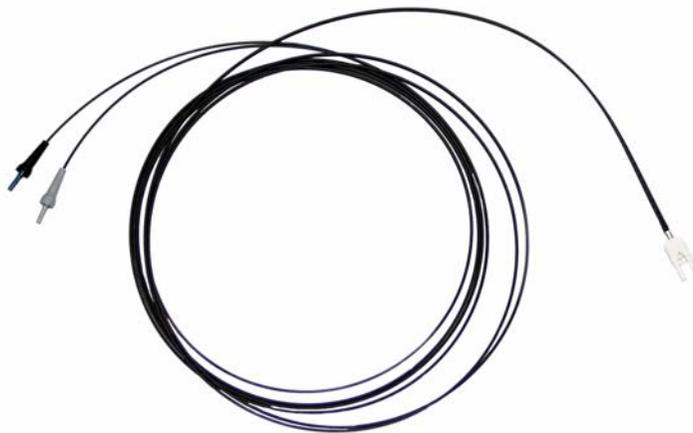

*Figure I9-11: Dual fibre optic cable used with the transmitter and receiver. The black and grey strain reliefs on the end of the cable (left) plug into the same coloured fibre optic receptacles on the top of the transmitter and receiver (see Figure I9-12). The connection on the other end of the cable (right) connects to either fibre optic receptacle on the control module (see Figure I9-13).*

To connect the pulseEKKO PRO in the borehole configuration shown in Figure I9-2, plug the dual fibre optics cable into the transmitter making sure the colour on the strain relief jacket matches the colour of the receptacle door, black to black and grey to grey (Figure I9-12). Confirm that the fibre optic connection is seated properly by pushing down gently until the connection "clicks" into place.



*Figure I9-12: Attaching the fibre optic cables to the transmitter and receiver. Make sure to match the connector colour to the door colour (grey to grey and black to black). Push the fibre optic cable down until you can feel it "click" into place*

The pulseEKKO PRO system can be used with a pulseEKKO 100 transmitter (see Section 13.2.8: p.76 in the pulseEKKO PRO manual). **If the transmitter is a pulseEKKO 100 transmitter, the fibre optic Output connection on the transmitter should NOT be connected.**

Attaching the fibre optic cables to the receiver (Figure I9-12). Make sure to match the connector colour to the door colour (grey to grey and black to black). Push the fibre optic cable down until you can feel it "click" into place.

After attaching the dual fibre optic cables to the transmitter and receiver, the other end of the fibre optic cables are attached to the fibre optic converters on the control module (Figure I9-13). The fibre optic cable from the transmitter connects to the fibre optic converter labelled 4. The fibre optic cable from the receiver connects to the fibre optic converter labelled 5. Note that the fibre optic connection at the control module is keyed and will only attach properly in one orientation.



*Figure I9-13: The dual fibre optic cable from the transmitter and receiver attaches to the electrical to fibre optic converters on the control module. The fibre optic cable from the transmitter connects to the control module receptacle labelled 4 while the fibre optic cable from the receiver connects to the control module receptacle labelled 5. This connection is keyed so it will only attach when the fibre optic cable is in the orientation shown.*

## I-2.3   Practical Suggestions for Collecting Quality Data

While every effort has been made to reduce emissions, the control module, system electronics, borehole cables and the DVL can be sources of external noise. For the best quality data, these components should be kept away from the receiver electronics as much as practical. The following suggestions will ensure the best quality data is collected:

1)  Try to keep the electronics housings as far apart as possible. It is best to place them on opposite sides of the boreholes as shown in Figure I9-14.

2)  Keep the borehole cables as far away from the transmitter and receiver electronics housings as possible. Avoid having the excess borehole cable lying between the two housings or near the console and computer.

3)  Keep the DVL and control module away from the system electronics and the borehole cables.
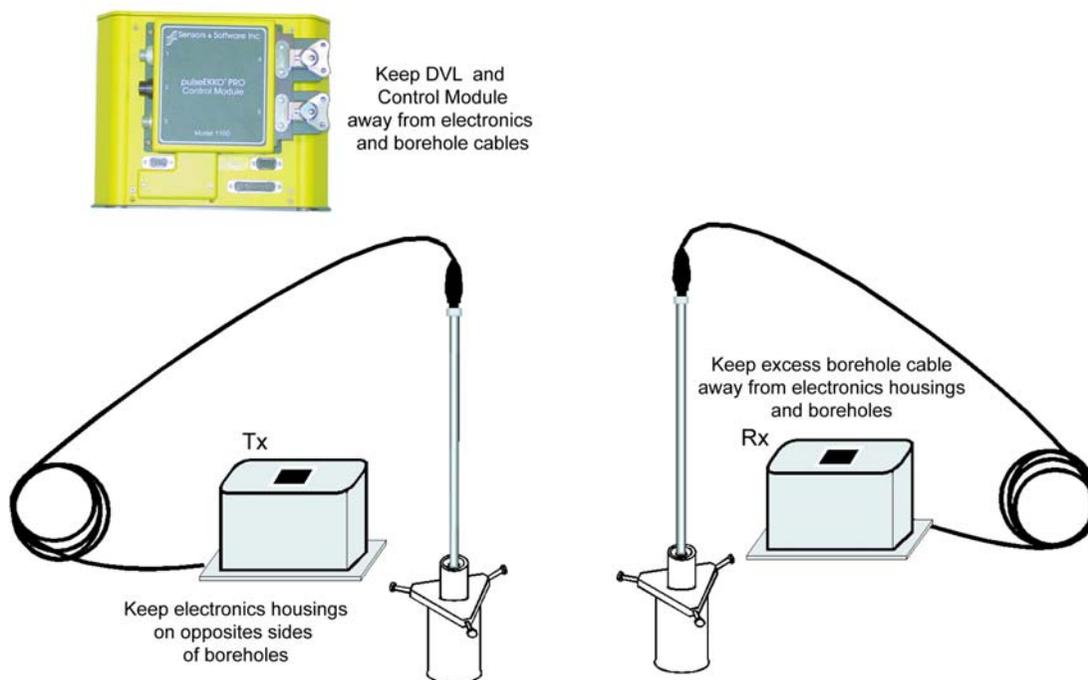


*Figure I9-14: To avoid noise in the data, keep the DVL and control module 5 metres away from the housings. Do not place the housings or extra borehole cable between the boreholes and prevent the borehole cables from crossing each other.*

## I-2.4   Connecting Remote Trigger/Beeper Units

Trigger and beeper units are used to remotely trigger the radar system to collect data and also to hear exactly when the radar system is collecting data.

There are two types of trigger and beeper units available for use with the pulseEKKO PRO borehole system: an electrical unit and a fiber optic unit. These are described in detail in Section 3: p.19 in the main pulseEKKO PRO manual.

## I-2.5    Using the Borehole Cable Guides

The borehole cable guides are designed to attach to the top of cased boreholes 3 centimeters to 20 centimeters in diameter. The rounded edges of the guide allow the borehole cable to smoothly run down the borehole, minimizing wear on the cable. The guide also provides a means of clamping the cable to hold the borehole antenna at a specific depth in the borehole. This is extremely useful when performing multiple-offset gathers (MOG's) where the transmitter antenna needs to be held a fixed depth in the borehole for the whole survey (see Section I-3.1.2: p.16).

For small diameter casing, the guide will clamp to the outside of the casing. To use the borehole cable guide, rotate the 3 clamp adjustment bolts until the adjusting clamps are slightly larger than the outside diameter of the casing. Center the guide into the top of the casing and equally rotate the 3 clamp adjustment bolts until the guide is firmly clamped onto the casing.

For larger diameter casing, the clamp will slide inside the casing and can be expanded until it is clamped tightly to the casing. When clamping to the inside of a casing, choose the one of the three shoulders on the adjusting clamp (see Figure I9-15) whose diameter most closely matches the inside diameter of the casing. Then rotate the 3 clamp adjustment bolts until the diameter of that shoulder is slightly smaller than the inside diameter of the casing. Center the guide into the top of the casing and equally rotate the 3 clamp adjustment bolts until the guide is firmly clamped onto the casing.
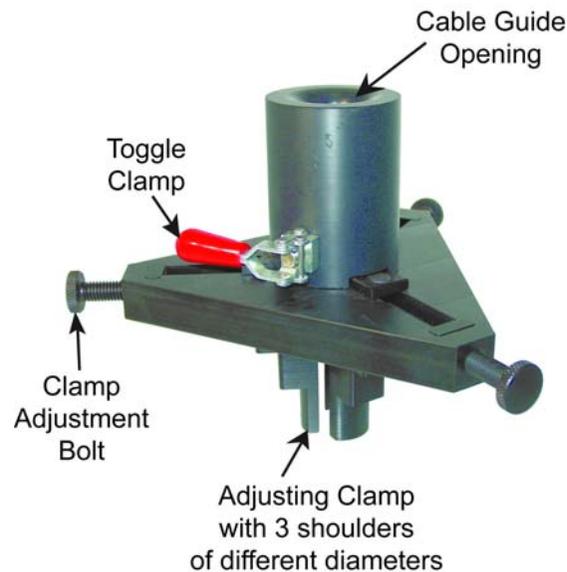


*Figure I9-15: Borehole Cable Guide.*

Once the borehole cable guide is attached to the top of the borehole, feed the antennas and cables through the opening and into the borehole. To fix the antenna at a certain depth, move the toggle clamp to the side until the cable is held firmly at that position.

The guides can also be used to hold the antennas at the top of the boreholes for calibration of timezero (see Section I-3.1.4: p.20). To do this move, the toggle clamp until the cable guide opening is blocked so that the antenna will NOT fit down the borehole. Now, if the antennas are placed in opening and leaned to the side slightly, they should stand up reasonably vertically for the timezero calibration. If both antennas lean in the same direction, the horizontal separation between the antennas will be accurate.

# I-2.6   Starting the System

Once all components are properly connected, the radar is ready to operate under the control of the DVL.

1) Connect the DVL and control module power supply (see Section 12.1: p.59 in the main pulseEKKO PRO manual).

2) Turn the transmitter and receiver ON by pressing the button on the top of each unit. The red Power LED on the top of the unit will flash 5 times and then stay on to indicate the unit is ready for operation. If not, check that the batteries inside the Transmitter and Receiver are fully charged and have been inserted the right way.

3) When not collecting data, the transmitter, receiver and console should be turned OFF to increase the life of the batteries.

# I-3  Borehole Data Acquisition Parameters

General pulseEKKO PRO GPR parameters are described in detail in Section 13: p.65 of the pulseEKKO PRO manual. This section describes the parameters that must be set up for borehole data acquisition.

## I-3.1  Survey Type

A general description of the **Survey Type** parameter is described in Section 13.4.5: p.87 of the main pulseEKKO PRO manual. This section describes setting the Survey Type specifically for borehole data acquisition.

All borehole GPR surveys are transillumination surveys. Transillumination surveys are those where radio energy is transmitted through a structure to study the transmission properties of the material. The transmitter antenna and the receiver antenna are placed on opposite sides of the structure being investigated. Properties that can be measured are: velocity, attenuation and dispersion. Transillumination surveys are less common than reflection surveys because the data requires a fair amount of processing before images can be seen.

The types transillumination surveys described here are designed for surveys in and around boreholes and therefore are all 2 dimensional (single plane). In theory, 3D GPR transillumination surveys could be conducted but the amount of data acquisition time, not to mention the software and computer resources necessary to process such a data set, make this impractical for the typical GPR user.

The 3 types of transillumination surveys are Zero-Offset Profile (ZOP), Multiple-Offset Gather (MOG) and Vertical Radar Profile (VRP). There is also a timezero calibration survey (CAL) that must be run before each transillumination survey.

# I-3.1.1 ZOP (Zero Offset Profile)

This is a quick, reconnaissance-type survey for borehole radar work. The borehole radar antennas are both moved at equal steps down their respective boreholes and radar data collected.

Variations in the travel-time and/or amplitude data can indicate anomalous zones or targets between the boreholes.
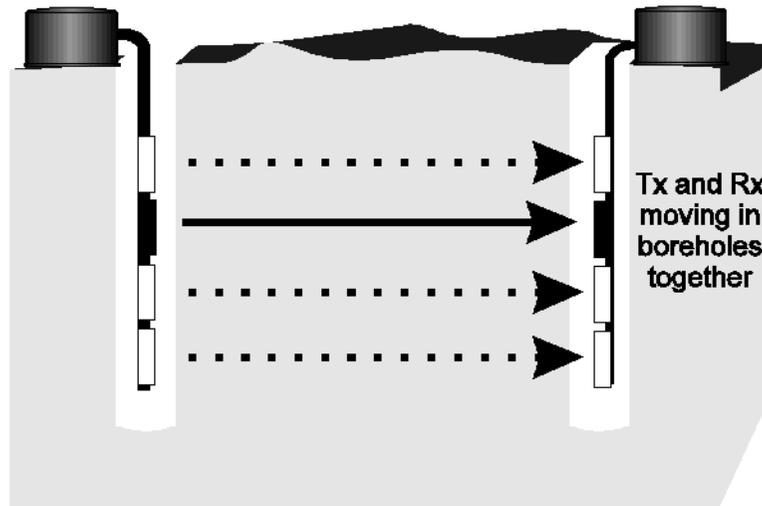


*Figure I9-16: Zero Offset Profile (ZOP).*

## ZOP Parameters

To conduct a ZOP survey, the following parameters must be set:

### I-3.1.1.1 Borehole Separation

This records the distance between the two boreholes in the survey. It is set under the **Antenna Separation** parameter (see Section 13.2.4: p.71 in the main pulseEKKO PRO manual).

The borehole separation should also be used for the Timezero Calibration (CAL) files (see Section I-3.1.4: p.20). The X position of the Transmitter borehole is set to zero and the X position of the Receiver borehole is set to the Borehole Separation (same as the Antenna Separation).

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

### I-3.1.1.2 Transmitter-Receiver Start Position

This is the position in the borehole (Z direction) of the Transmitter antenna and Receiver antenna for the first trace. This is set under the **Start Position** parameter (see Section 13.4.1: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so this value will usually be positive. This position can be based on the top of the hole, the top of the casing (if, applicable), the top of the pulseEKKO Borehole Cable Guide or any other arbitrary position.

The Tx-Rx Start Position is usually set to zero but may be different if the ZOP is designed so that the antennas start at a certain depth down the borehole.

This may occur:

1) if the survey only covers part of the full depth range of the borehole,

2) if there is a metal casing in the upper part of the hole so that the ZOP must start below this casing.

3) if there is casing extending up out of the boreholes above the surface and you want the ground surface to be the zero depth point, you can set the start position to a negative value since, by convention, borehole depths are positive.

The Transmitter and Receiver Z position saved with each trace is calculated by:

TxRx Start Position + (trace number - 1) * TxRx Step Size

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

### I-3.1.1.3   Transmitter-Receiver Step Size

This specifies the distance both Receiver and Transmitter antennas will be moved in the borehole (Z direction) each time to collect a new trace. This is set under the **Step Size** parameter (see Section 13.4.2: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so when surveying from the top to the bottom of the borehole (the recommended procedure) this value will be positive. The borehole cables are marked every quarter-metre (0.25m) so this is often the Step Size used. However, larger (or smaller) step sizes can be used depending on the objectives of the survey.

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

## I-3.1.2  MOG (Multiple Offset Gather)

This is a detailed borehole radar survey that attempts to image the location and size of anomalous features between the boreholes. For best results, it is necessary to have as many raypaths at as many different angles as possible between the boreholes. This is done by collecting numerous MOG's; each one conducted by fixing the Transmitter antenna at a certain depth in the borehole and collecting data as the Receiver antenna is moved from the top to the bottom of the borehole at regular steps. The Transmitter antenna is then moved to another depth and the process is repeated.

By convention, the software assumes each MOG will have a fixed Transmitter antenna position and the Receiver antenna will move in the borehole for each trace collected.

When all the MOG's (and VRP's, if available) are merged together and processed, tomographic images showing variations in velocity, attenuation and dispersion can be produced.
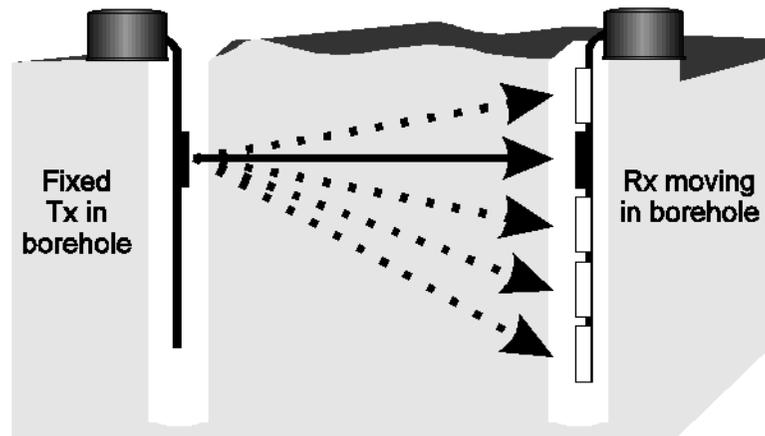


*Figure I9-1: Multiple Offset Gather (MOG).*

### MOG Parameters

To conduct a MOG survey, the following parameters must be set:

### I-3.1.2.1   Borehole Separation

This records the distance between the two boreholes in the survey. It is set under the **Antenna Separation** parameter (see Section 13.2.4: p.71 in the main pulseEKKO PRO manual).

The borehole separation should also be used for the Timezero Calibration (CAL) files (see Section I-3.1.4: p.20). The X position of the Transmitter borehole is set to zero and the X position of the Receiver borehole is set to the Borehole Separation (the same as the Antenna Separation).

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

### I-3.1.2.2   Transmitter- Receiver Start Position

This is the position in the borehole (Z direction) of the Receiver antenna for the first trace. It is also the first fixed transmitter position in the borehole for the first MOG file.

This is set under the **Start Position** parameter (see Section 13.4.1: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so this value will usually be positive. This position can be based on the top of the hole, the top of the casing (if, applicable), the top of the pulseEKKO Borehole Cable Guide or any other arbitrary position. It is usually set to zero but may be different if the MOG is designed so that the Receiver antenna starts at a certain depth down the borehole. This may occur:

1) if the survey only covers part of the full depth range of the borehole,

2) if there is a metal casing in the upper part of the hole so that the Receiver antenna must start below this casing.

3) if there is casing extending up out of the boreholes above the surface and you want the ground surface to be the zero depth point, you can set the start position to a negative value since, by convention, borehole depths are positive.

The Receiver Z position saved with each trace is calculated by:

Start Position + (trace number - 1) * Step Size

The fixed Transmitter Z position saved with each MOG is calculated by:

Start Position + line number * Step Size

where line numbers start counting at zero (0).

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

## I-3.1.2.3   Transmitter-Receiver Step Size

This specifies the distance the Receiver antenna will be moved in the borehole (Z direction) each time to collect a new trace. It also specifies the distance the Transmitting antenna will be moved in the borehole to the next fixed position for the next MOG file.

This is set under the **Step Size** parameter (see Section 13.4.2: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so when surveying from the top to the bottom of the borehole (the recommended procedure) this value will be positive. The borehole cables are marked every quarter-metre (0.25m) so this is often the Step Size used. However, larger (or smaller) step sizes can be used depending on the objectives of the survey.

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

# I-3.1.3  VRP (Vertical Radar Profile)

If only one borehole is available, or, to increase the number of angles used to produce the tomographic image between 2 boreholes, VRP's can be conducted.   This involves fixing the Transmitter antenna at a certain position on the surface and collecting data as the Receiver antenna is moved down the borehole at known steps. The Transmitter antenna can then be moved to another position on the surface and the process repeated.

When all the VRP's (and MOG's, if available) are merged together and processed, tomographic images showing variations in velocity, attenuation and dispersion can be produced.
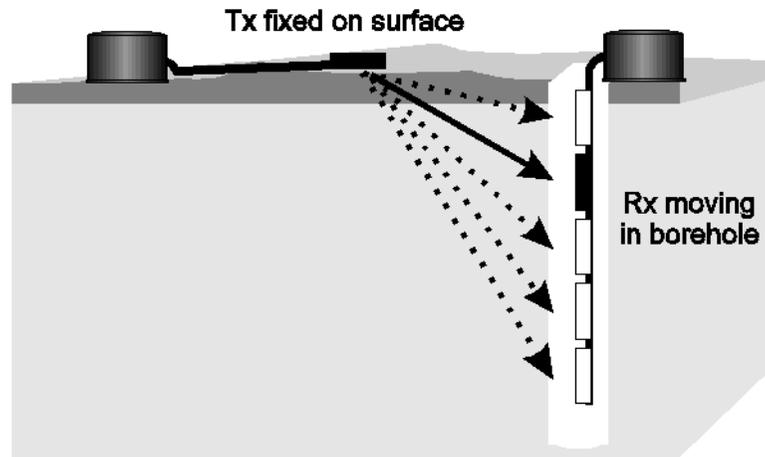


*Figure I9-1: Vertical Radar Profile (VRP).*

## VRP Parameters

To conduct a VRP survey, the following parameters must be set:

## I-3.1.3.1  Transmitter- Receiver Start Position

This is the position in the borehole (Z direction) of the Receiver antenna for the first trace. It is also the first fixed transmitter position on the surface (X direction) for the first VRP file.

This is set under the **Start Position** parameter (see Section 13.4.1: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so this value will usually be positive. This position can be based on the top of the hole, the top of the casing (if, applicable), the top of the pulseEKKO Borehole Cable Guide or any other arbitrary position. It is usually set to zero but may be different if the VRP is designed so that the Receiver antenna starts at a certain depth down the borehole. This may occur:

1) if the survey only covers part of the full depth range of the borehole,

2) if there is a metal casing in the upper part of the hole so that the Receiver antenna must start below this casing.

3) if there is casing extending up out of the boreholes above the surface and you want the ground surface to be the zero depth point, you can set the start position to a negative value since, by convention, borehole depths are positive.

The Receiver Z position saved with each trace is calculated by:

Start Position + (trace number - 1) * Step Size

The fixed Transmitter X position saved with each VRP is calculated by:

Start Position + line number * Step Size

where line numbers start counting at zero (0).

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

## I-3.1.3.2    Transmitter-Receiver Step Size

This specifies the distance the Receiver antenna will be moved in the borehole (Z direction) each time to collect a new trace. It also specifies the distance the Transmitting antenna will be moved on the surface to the next fixed position for the next VRP file.

This is set under the **Step Size** parameter (see Section 13.4.2: p.86 in the main pulseEKKO PRO manual).

By convention, distances down the borehole are positive so when surveying from the top to the bottom of the borehole (the recommended procedure) this value will be positive. The borehole cables are marked every quarter-metre (0.25m) so this is often the Step Size used. However, larger (or smaller) step sizes can be used depending on the objectives of the survey.

It is assumed that the units are the units specified under Units (see Section 13.4.3: p.86 in the main pulseEKKO PRO manual).

## I-3.1.4   CAL (Timezero Calibration)

The accuracy of all transillumination surveys are dependent on very precise measurements of travel time through the material. To do this properly, the time the radio waves are radiated from the transmitter (absolute timezero) must be established. Therefore, before any transillumination survey is conducted, a timezero calibration must be performed. This value will be used for the ZOP survey or all the files in the MOG or VRP survey.

Timezero calibration is done by holding the borehole antennas up in the air at a known distance apart (often the borehole separation distance, see Figure 9-1). Any distance can be used as long as the **Antenna Separation** is properly set (see Section 13.2.4: p.71 in the main pulseEKKO PRO manual).

Five traces are collected and processed to calculate the absolute timezero value that will be used for the rest of the survey.
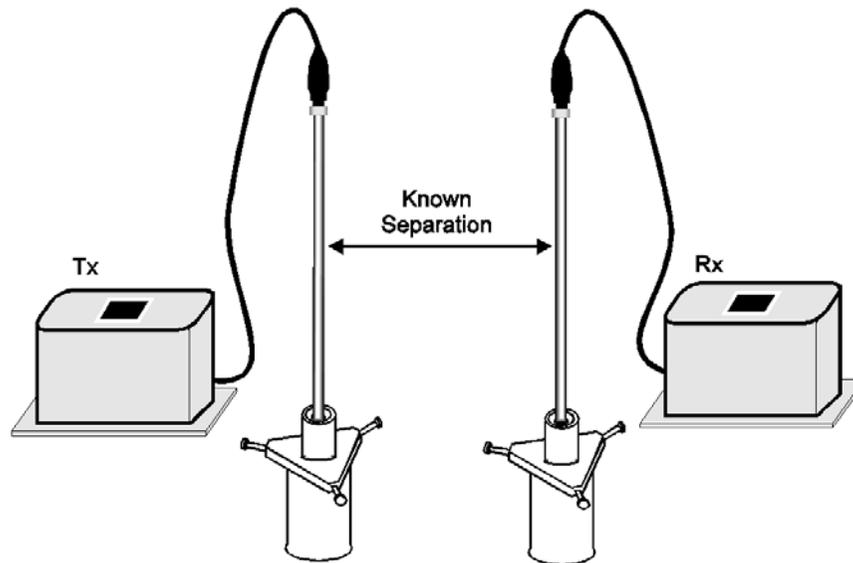


*Figure I9-1:  To collect a Calibration data file, set the borehole antennas at a known separation (often the borehole separation) and collect 5 traces.*

If two people are available for data acquisition, each person can hold one antenna vertically at the separation distance.

However, if only one person is present, the antennas can be held upright by setting them in the top of the borehole cable guide (see Section I-2.5: p.11).

To do this, move the lever on the Borehole Cable Guide to the side until the piston arm moves into the cable guide opening. This should block the opening enough so that the antenna will NOT fit down the borehole. Now, if the antennas are placed in opening, set on top of the piston arm and leaned to the side slightly, they should stand up reasonably vertically for the timezero calibration. If both antennas lean in the same direction, the horizontal separation between the antennas will be accurate.

The calibration file is processed by determining the first break time. This is usually the direct air wave, unless an error occurs and a noise spike is picked as the first break (if so, this can be fixed later in post-processing). If we know the time at which the transmit pulse arrived at the receiver antenna (the first break time) and the separation of the antennas, we can use the velocity of light to determine the time at which the transmit pulse was radiated. This time is called the absolute timezero.

**Absolute timezero = first break time - (antenna separation/ velocity of light)**
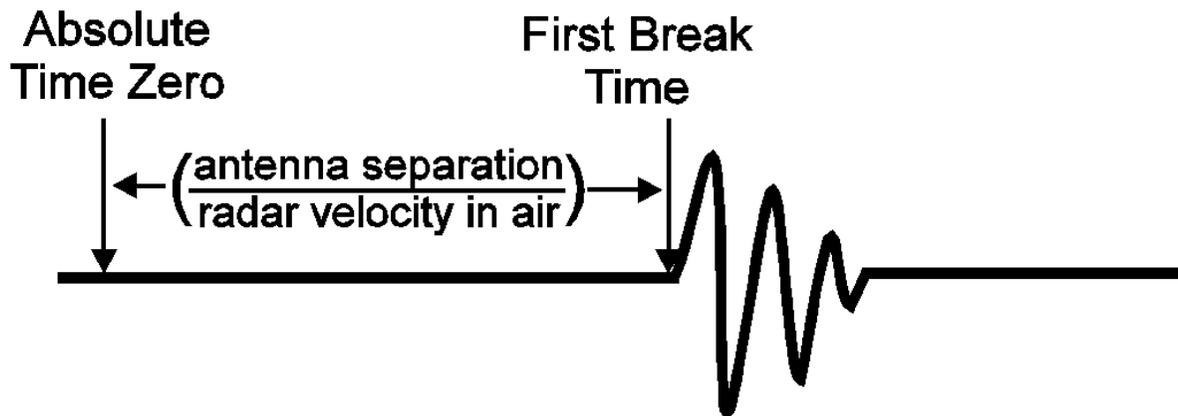


The absolute timezero point value is saved and used for all subsequent files.

**When Calibration files are collected on the DVL, they will have standard names like LINE00, LINE01, LINE02 etc. After the calibration files have been transferred to a PC for processing using the EKKO_Image software, they must have their names changed to CAL1, CAL2, etc. The names of the data files can be changed using the EKKO_View Enhanced, EKKO_View Deluxe or Windows Explorer. If using Windows Explorer to change the name, make sure that BOTH the .DT1 file and the .HD file are changed.**

# I-3.2   Trigger Method

A general description of the **Trigger Method** parameter is described in Section 13.3.1: p.77 of the pulseEKKO PRO manual. This section describes setting the Trigger Method specifically for borehole data acquisition.

The Trigger Method to use is best determined by the user after examination of the site to assess the ease with which the radar can be moved from position to position.

## I-3.2.1  Trigger mode

The user controls when the system collects data by pressing the DVL B button, the electrical trigger or the fibre optic trigger. This is the usual method of data collection because it allows the operators to take all the time necessary to have the antennas in the correct location before the data trace is collected. This mode is good for surveying in boreholes where the borehole radar antennas cannot be moved easily or at regular time intervals. For the position of each measurement point, the system assumes the operator has moved the antennas one Step Size in the borehole.

## I-3.2.2  Free Run mode

With where the system automatically collects data at regular, user-determined time intervals. This mode is good if it is possible to move the borehole radar antennas up and down the borehole easily. For the position of each measurement point, the system assumes the operator has moved the antennas one step size along the survey line.

# I-3.3   Step Size

A general description of the **Step Size** parameter is described in Section 13.4.2: p.86 of the pulseEKKO PRO manual. This section describes setting the Step Size specifically for borehole data acquisition.

The transmitter antenna and the receiver antenna are both moved at regular intervals called step size. The borehole cables are marked every quarter-metre (25 cm) so common step sizes are 0.25, 0.5 and 1 metre. Intuitively, the more raypaths you obtain between the boreholes, the better your ability of resolving targets. Therefore, the assumption would be that you want to use as fine a step size as possible. This is true to some extent, however, there are some limitations, both physical and practical that must be considered.

Physically, spatial sampling (or resolution) is dependent on the antenna frequency. Each frequency of antenna has a Fresnel radius which approximates the spatial resolution of the antenna. This spatial resolution is a physical limitation of the antenna and cannot be improved by finer sampling with a smaller step size (the only way to improve the spatial resolution is to use an antenna with a higher frequency). Therefore, the step size should be on the same order as the Fresnel radius for that frequency.

Practical limitations, like the amount of time available to conduct the survey, will have some bearing on the transmitter and receiver step sizes. This factor depends on the data acquisition speed, which depends on other factors like operator experience, site conditions and weather.

Using these limitations as a guideline, suggested maximum step sizes for the various antenna frequencies are listed below. These numbers could reasonably be halved or quartered to over-sample the data. Data over-sampling helps improve data quality, but remember that it will NOT improve spatial resolution.

**Table 1:**

| Frequency (MHz) | Maximum Step Size (m) |
|---|---|
| 50 | 2.0 |
| 100 | 1.0 |
| 200 | 0.5 |

The more raypaths between the boreholes, the better your chance of resolving targets, however, as Jackson and Tweeton (Report of Investigations 9497) point out, increasing the density of raypaths in MOG's does not increase the resolution of targets significantly. Instead, they note, the number of different angles through the structure seems to be more important for resolving the proper size and extent of an anomaly. This means that, where possible, VRP's are a valuable addition to any borehole survey because they vary the angle of raypaths around the boreholes. This means that it may be better to use a coarser step size during MOG's to make sure there is time available to also conduct VRP's.

# I-3.4   Frequency

A general description of the **Frequency** parameter is described in Section 13.2.1: p.68 of the pulseEKKO PRO manual. This section describes setting the Frequency specifically for borehole data acquisition.

Deciding on the antenna frequency to use for a survey is dependent on the objectives of the survey. As frequency decreases the distance a pulse can be transmitted through a structure generally increases but spatial resolution decreases. Therefore, the ideal survey will be one that uses the highest frequency that can adequately be transmitted through the structure. This is not always easy to determine and often field experimentation with several different frequencies is necessary.

The following table offers a guide to deciding on a frequency. The values are based on practical experience and should be used as a quick guide only.

**Table 2:**

| Frequency (MHz) | Borehole Separation (m) |
|:---:|:---:|
| 50 | 20 |
| 100 | 10 |
| 200 | 5 |

The selected frequency requires that you have the correct antennas connected to the system. The software has no way of checking this!!

# I-3.5   Time Window

A general description of the **Time Window** parameter is described in Section 13.2.2: p.69 of the pulseEKKO PRO manual. This section describes setting the Time Window specifically for borehole data acquisition.

The time window parameter is very important to set adequately. An entire survey could fail if the window is not sufficiently long enough to sample to the transmit pulse. Conversely, too long a time window increases the data volume and decreases productivity. Since the radar system really measures time, an estimate of velocity can be used to get a good time window value.

$$W= \frac{1.5 \times \sqrt{(BoreholeSeparation)^2 + (MaximumBoreholeDepth)^2}}{Velocity}$$

A value of 0.1 m/ns is a good average value for geologic materials but, if required, a table listing velocities of common geologic materials is listed under Section 13.2.6: p.73 in the main pulseEKKO PRO manual.

# I-3.6   Temporal Sampling Interval

A general description of the **Temporal Sampling Interval** parameter is described in Section 13.2.3: p.70 of the pulseEKKO PRO manual. This section describes setting the Temporal Sampling Interval specifically for borehole data acquisition.

The temporal sampling interval is the time interval between points on the trace. This parameter is dependent on the frequency of the antennas being used. Higher frequencies need to be sampled at a finer time sampling interval than lower frequencies.

It is best to use the default value displayed on the DVL after the antenna frequency has been selected. The default values for each borehole antenna frequency are listed below

**Table 3: Temporal Sampling Interval**

| Frequency (MHz) | Temporal Sampling Interval (ns) |
|:---:|:---:|
| 50 | 1.6 |
| 100 | 0.8 |
| 200 | 0.4 |

While these sampling interval should be adequate for sampling the signal, since tomographic imaging relies on very accurate time measurements, there may be some justification in halving the sampling intervals shown above.

# I-3.7    Number of Stacks

A general description of the **Stacks** parameter is described in Section 13.2.7: p.74 of the pulseEKKO PRO manual. This section describes setting the Stacks specifically for borehole data acquisition.

In noisy or lossy environments, one way of increasing data quality is to collect more than one trace at each survey position, average them and save the averaged trace. This is known as "stacking". Data quality improves because the noise, which is usually a random addition to the trace, tends to zero when averaged. Consequently, the usable signal is easier to see. This is known as increasing the "signal-to-noise ratio".

While stacking improves data quality, it also slows down survey production. The more stacks, the longer it takes to collect data at each survey position. Therefore, it is important to find the lowest number of stacks that still reveal the target adequately.

While stacks can be set from 1 to 2048, for most surveys, stacking 16, 32 or 64 times is suitable. In special situations stacking can be reduced; for example when production speed is vital.

# I-4  Borehole Data Collection

## I-4.1  Scope Mode

Follow the same directions outlined in the pulseEKKO PRO manual in Section 14: p.101.

Before shifting the trace for timezero, set the borehole antennas at the borehole separation or the distance specified under the **Antenna Separation** parameter (see Section 13.2.4: p.71 in the main pulseEKKO PRO manual).

## I-4.2  Collect Mode

Follow the same directions outlined in the pulseEKKO PRO manual in Section 15: p.105 in the main pulseEKKO PRO manual.

Borehole data files should be collected under **Line Projects**.

Each borehole survey, including Calibration files, should be saved to a separate project. In other words, all the files from a MOG or VRP survey should be saved to the same project but do not mix files from different surveys into the same folder. Remember that MOG and VRP surveys use the line number to determine the fixed transmitter position so do not skip line numbers unless you are skipping a transmitter position.

Borehole data looks quite different than reflection data. A typical MOG will look similar to the data shown inFigure I9-2.
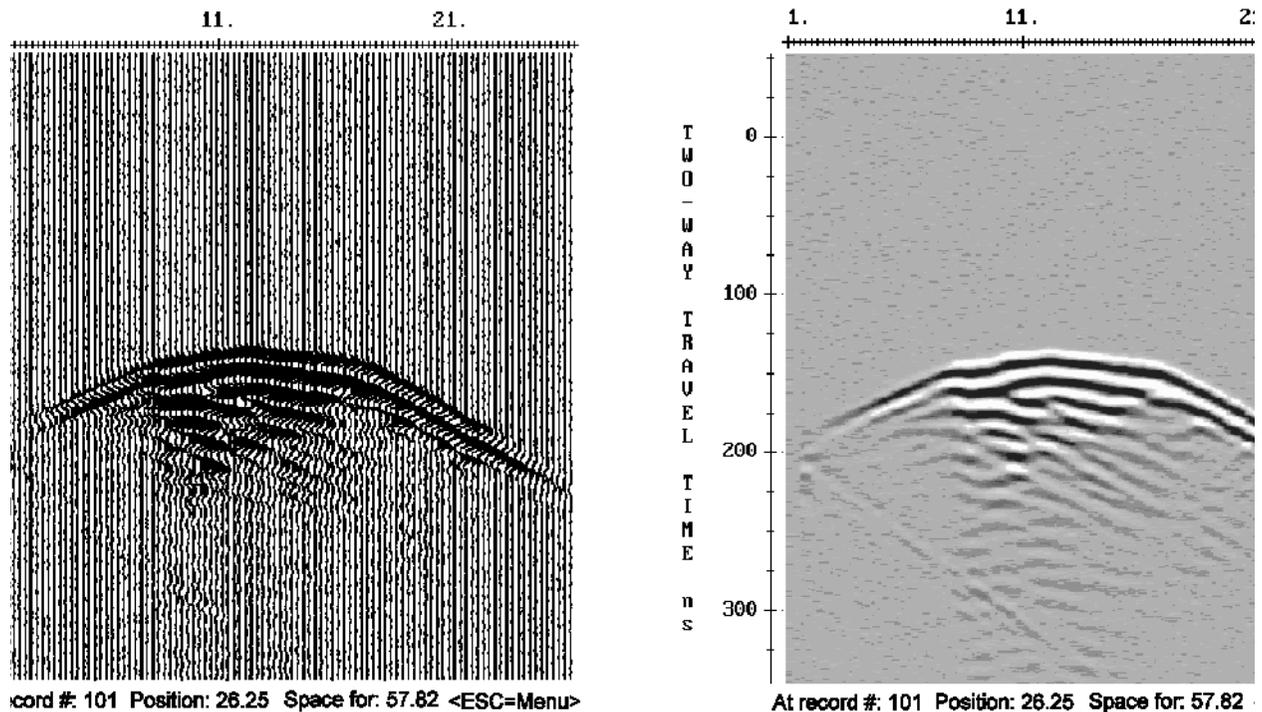


*Figure I9-2: Screen displays of a typical MOG survey. A Wiggle Trace display is on the left and a Grey-scale display is on the right.*

# I-5   Care and Maintenance

## I-5.1   Borehole Cables

These cables can stand a fair deal of abrasive wear but the user should avoid sharp bends in the cable and pulling the cable at right angles close to the connector, i.e. do NOT pull the borehole cable out of the borehole by holding onto the cable at one spot and walking (or running or driving) away from the borehole.

It is also important not to allow the unprotected ends of the cable to get dirty. When the antenna is not attached to the cable, always have the red dust cap over the end. If dirt does get in, clean the inside out with a pressurized air, a soft cloth or a Q-tip. It can also be cleaned with alcohol or even water but allow the inside to dry thoroughly before using. Avoid cleaning the inside with metal objects which may damage the nitrile o-rings and cause the connector to leak. If the o-rings become damaged they should be replaced.



*Figure I9-3: The borehole cable dust caps prevents the connection from getting dirty or damaged.*

The cable markings are made using a high quality, wear-resistant ink, but these markings will scratch and fade over time. The markings will last much longer if the Borehole Cable Guide is used whenever possible. If the Borehole Cable Guide cannot be used, try to avoid rubbing the borehole cable on the rough edge of the borehole.

# I-5.2    Borehole Antennas

The borehole antennas are made of fiberglass so care should be taken not to drop them on hard surfaces or they may crack. As well, they have limited flexibility and should not be flexed or bent.

It is best not to allow the screw threads on the antenna to get dirty or damaged. When the antenna is not attached to the cable, always have the black dust cap over the screw threads. If the screw threads do get dirty, clean them with a pressurized air, a soft cloth or a Q-tip. They can also be cleaned with alcohol or even water but allow them to dry thoroughly before using. Avoid cleaning the screw threads with metal objects which may damage the threads and cause the connector to leak or even prevent the antenna from screwing into the borehole cable.



*Figure I9-4: The borehole antenna dust caps prevents the connection from getting dirty or damaged.*

# Appendix J:    pulseEKKO PRO Multi-Channel Data Acquisition

## J-1  Overview

The pulseEKKO has the capability of collecting multi-channel data. This allows the operator to use any combination of transmitters and receivers (for antennas or transducers) that total 8 or less. They can be the same frequency or different frequencies.

Multi-channel data collection requires mostly standard pulseEKKO PRO parts with only the addition of the Multi-Channel Adapter and two Multi-Channel Adapter cables.

### J-1.1   Definition of "Channel"

In this manual, the term "channel" means data collected by a transmitter-receiver pair (see Channel Definitions in Section J-4.2.3: p.16).

# J-2  Multi-channel Configurations

Here are the four main multi-channel data acquisition methods:

## J-2.1   Fixed Frequency 2D Array

Up to 4 channels (pairs of transmitter-receivers) of the same frequency to acquire data over a swath.



*Figure J-1: Fixed frequency 2D array multi-channel data collection.*

## J-2.2  Multi-Frequency 2D Array

Up to 4 channels (pairs of transmitter-receivers) of different frequencies to acquire data at different depths and resolutions.



*Figure J-2: Multi-frequency 2D array multi-channel data collection.*

## J-2.3  Multi-Frequency Linear Array

Up to 4 channels (pairs of transmitter-receivers) of different frequencies to acquire data at different depths and resolutions.



*Figure J-3: Multiple-frequency, in-line mode of multi-channel data collection.*

## J-2.4  WARR Mode

One Transmitter and multiple receivers of the same frequency with data being collected between the one transmitter and each receiver in sequence.
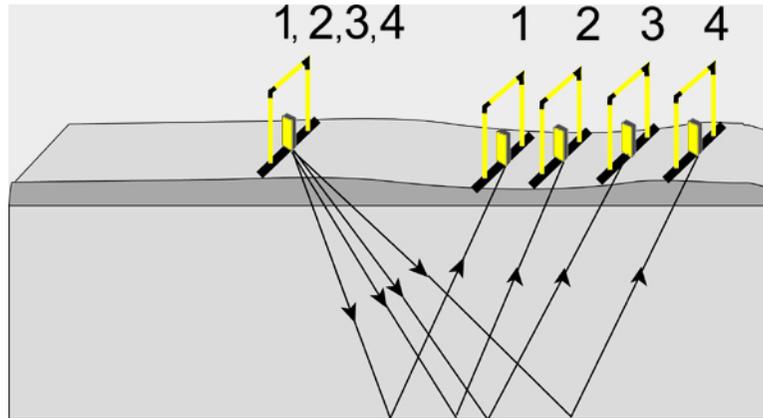


*Figure J-4: Wide Angle Reflection and Refraction (WARR) data collection uses one transmitter and multiple receivers.*

# J-3  Multi-Channel System Assembly

Before assembling this configuration, ensure the assembly of the DVL and Control module Section 2.1: P.3, the transmitter and receiver assemblies Section 2.2: P.6, and the transducers (Section 2.3: P.13) has been completed.

Two examples of complete multi-channel systems are shown in Figure J-5 and Figure J-6.



*Figure J-5: Fixed frequency 2D Array multi-channel system with transducers.*

*Figure J-6: Fixed frequency 2D Array multi-channel system with antennas.*

# J-3.1   Connecting the Multi-Channel Adapter

The Multi-Channel adapter allows the operator to connect up to 8 transmitters and receivers to the pulseEKKO PRO control module for data acquisition.



*Figure J-7: Multi-Channel Adapter. The ports labelled 1 to 8 are for connecting transmitters and receivers. Inputs A and B connect to the control module.*

The Multi-Channel Adapter connects to control module using two cables:

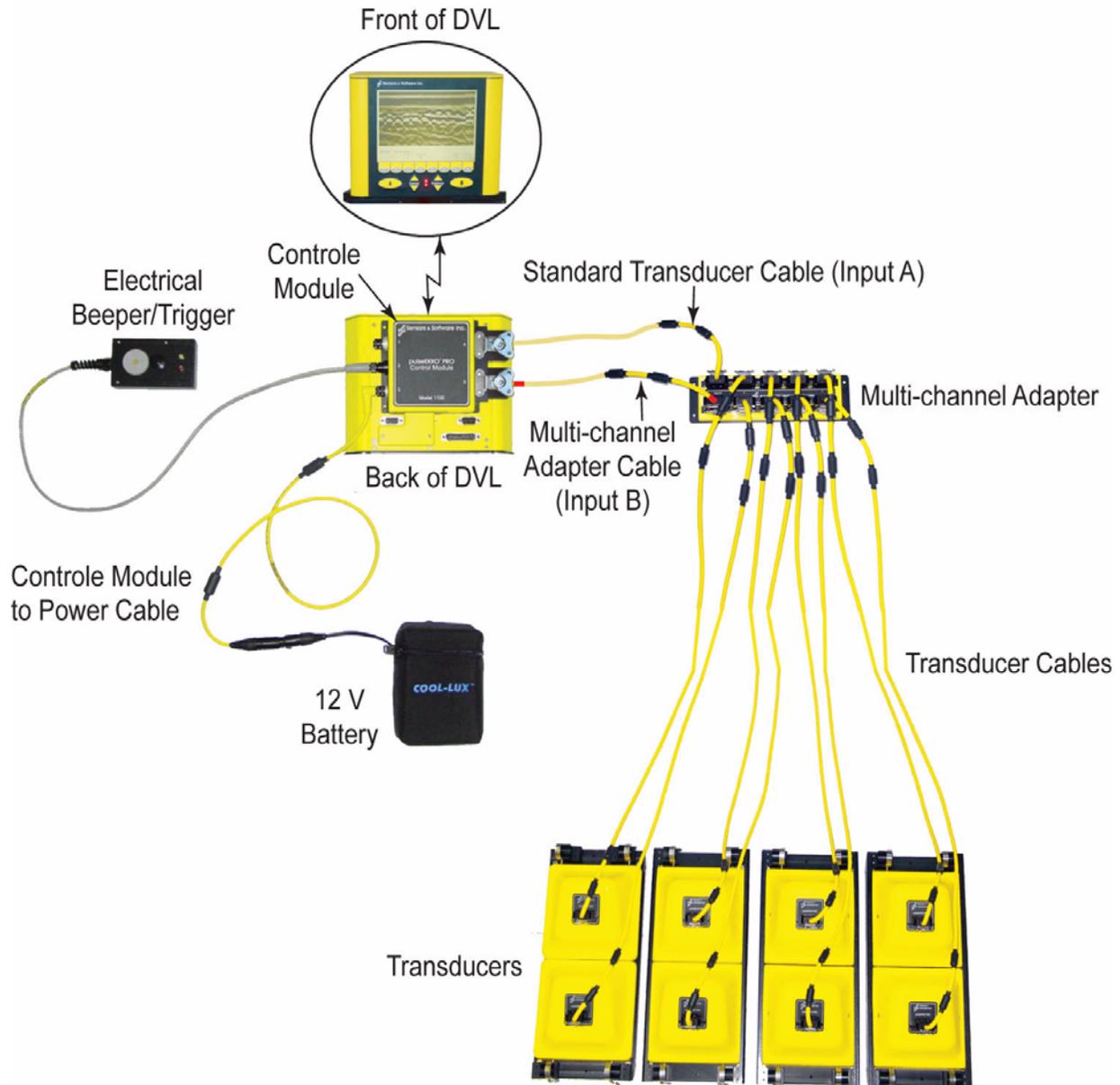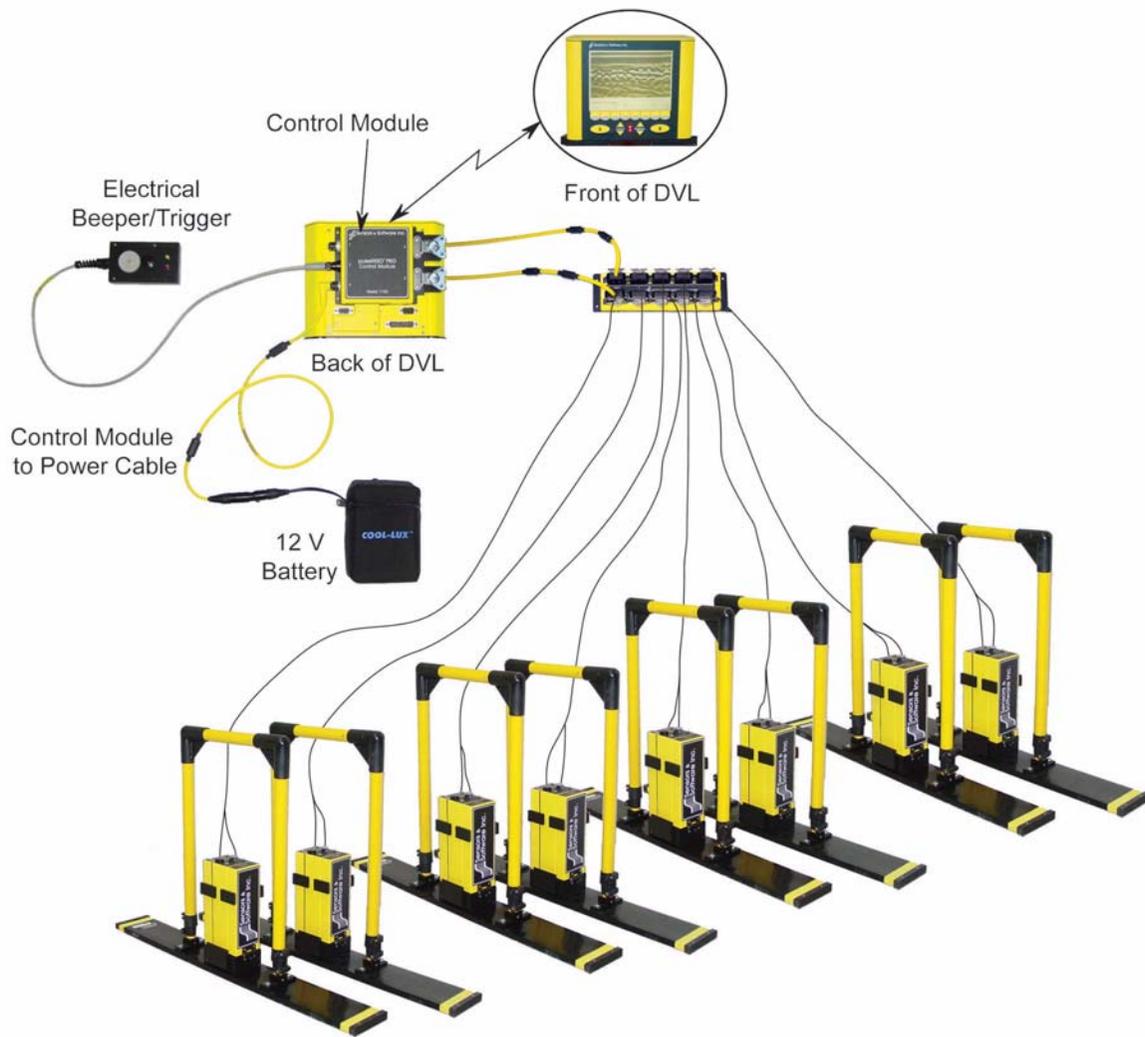   1)   A standard transducer cable that connects from receptacle 4 (top) on the control module to the Input A receptacle on the Multi-Channel Adapter.

   2)   A special Multi-Channel Adapter Cable, with red bands for easy identification, that connects from receptacle 5 (bottom) on the control module to the Input B receptacle on the Multi-Channel Adapter.



*Figure J-8: The Multi-Channel Adapter connects to the control module on the back of the DVL using the 2 cables shown. A standard transducer cable (left) connects from the top receptacle (#4) on the control module to the Input A receptacle on the Multi-Channel Adapter. The Multi-Channel Adapter Cable (right) connects from the bottom receptacle (#5) on the control module to the Input B receptacle on the Multi-Channel Adapter. The Multi-Channel Adapter Cable has red bands on either end for easy identification.*

*Figure J-9: A standard transducer cable is connected and latched to the top receptacle (#4) on the control module. The Multi-Channel Adapter Cable is connected and latched to the bottom receptacle (#5) on the control module.*

The other end of the transducer cable is connected and latched to the Input A receptacle on the Multi-Channel Adapter.

The other end of the Multi-Channel Adapter cable is connected and latched to the Input B receptacle on the Multi-Channel Adapter.
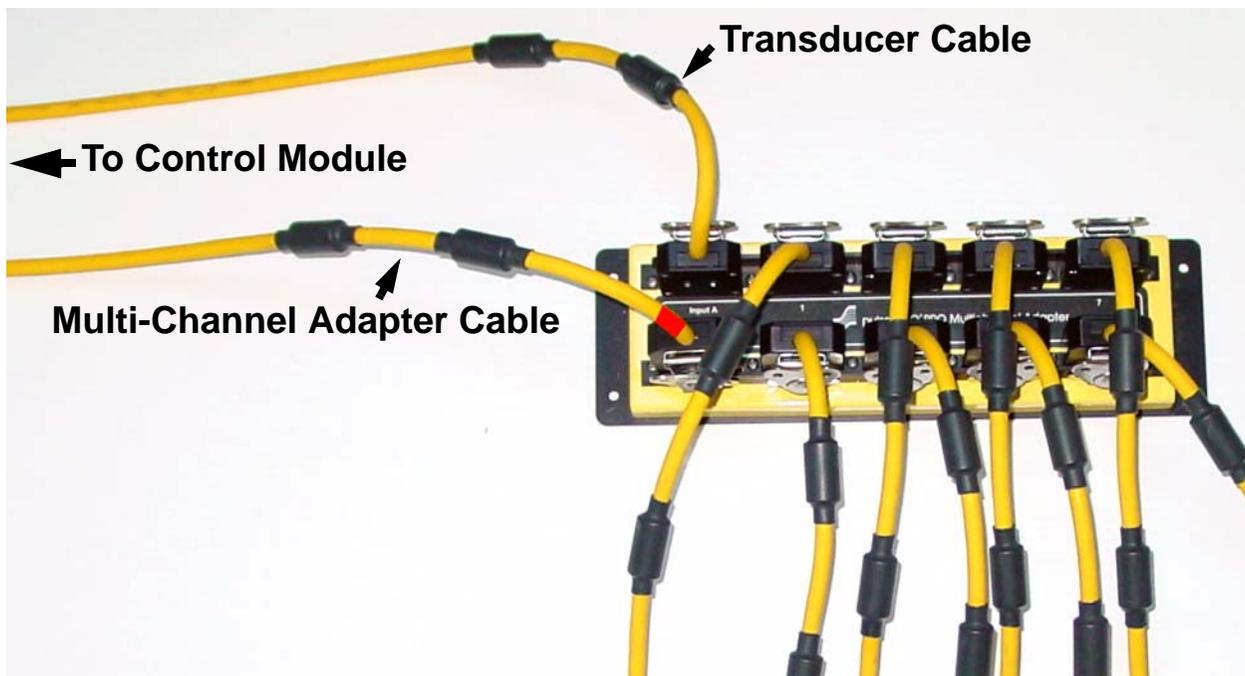


*Figure J-10: Cable connections to the Multi-Channel Adapter. The receptacle labelled Input A connects to Control Module using a standard transducer cable. The receptacle labelled Input B connects to the Control Module using the Multi-Channel Adapter cable. Ports labelled 1 to 8 connect to transmitter and receivers using either transducer cables (as shown) or fibre optic cables.*

## J-3.2  Starting the System

When the system is assembled and powered up it will automatically detect the presence of the Multi-Channel Adapter and run special multi-channel firmware designed for multi-channel data acquisition.
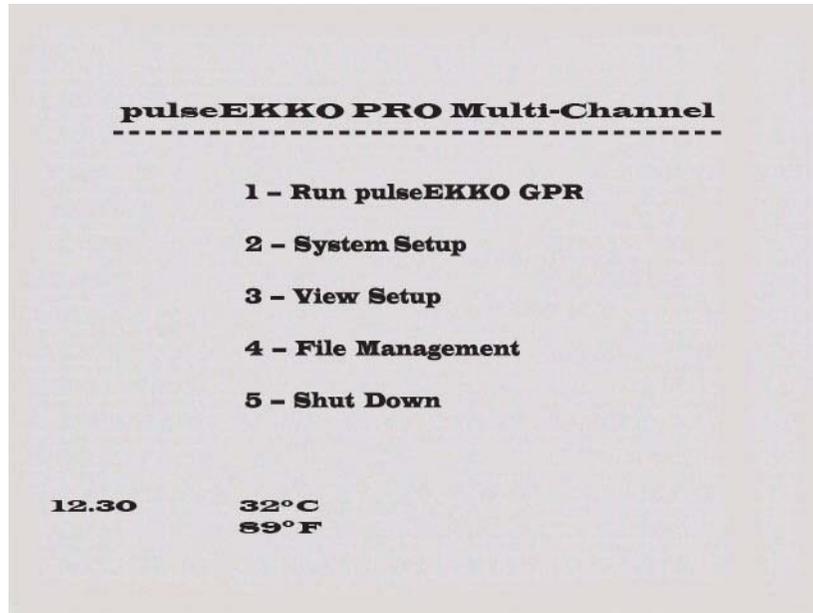


*Figure J-11: The main menu when the system is powered up with the Multi-Channel Adapter connected to the Control Module. Settings are changed under System Setup.*

# J-4  System Setup Parameters

The pulseEKKO PRO GPR parameters for standard (single-channel) data acquisition are described in detail in Section 13: p.65.

The following section describes the parameters that must be set up for multi-channel data acquisition.

The **System Setup** option from the main menu (Figure J-12) is used to set up the data collection parameters.
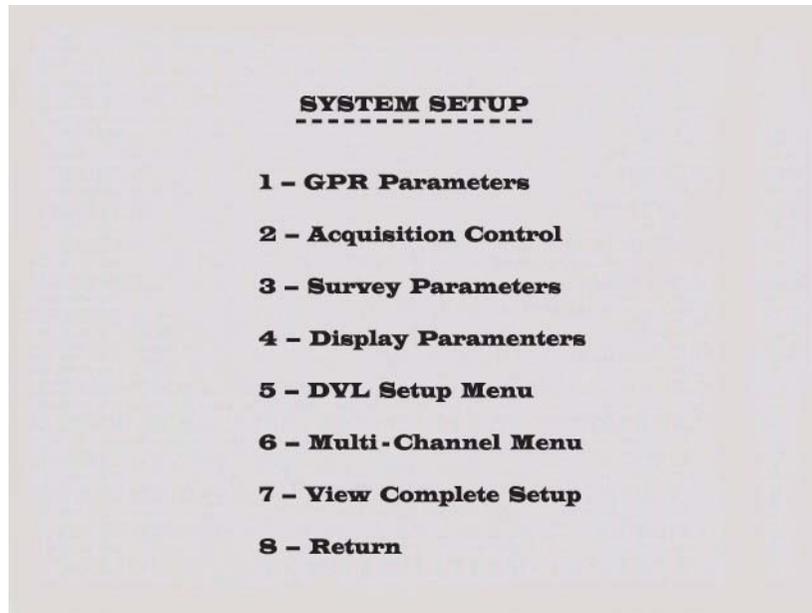


*Figure J-12: The System Setup main menu is used to access and change any parameter used for data collection. Related parameters are grouped under different menu headings. The Multi-Channel parameters are listed and edited by pressing number 6.*

# J-4.1   GPR Parameters

The **GPR Parameters** menu is accessed by pressing number 1 from the **System Setup** menu (Figure J-12).

The multi-channel GPR Parameters menu is very similar to the GPR Parameters menu for normal, single-channel data collection but there are some differences.

## J-4.1.1  Frequency

There is no option for frequency because the multi-channel system allows for multiple frequencies, not just a single frequency. The frequency set up menu is under Section J-4.2.4: p.20.

## J-4.1.2  Antenna Separation

Similarly, the Antenna Separation parameter does not appear on this menu as it does when collecting single-channel data because with multiple antennas, antenna separations can vary. The Antenna Separations are defined in the Section J-4.2.3: p.16.

```
           GPR SYSTEM PARAMETERS
           -------------------------

    Time Window          (ns):   200.00
                         (m):    9.00

    Sampling Interval    (ns):   0.80

    Antenna Step Size    (m):    0.50

    Radar Velocity      (m/ns):  0.100

    System Stacking        :     2


         A-B Edit Setting


   Down  Up                       Return
```
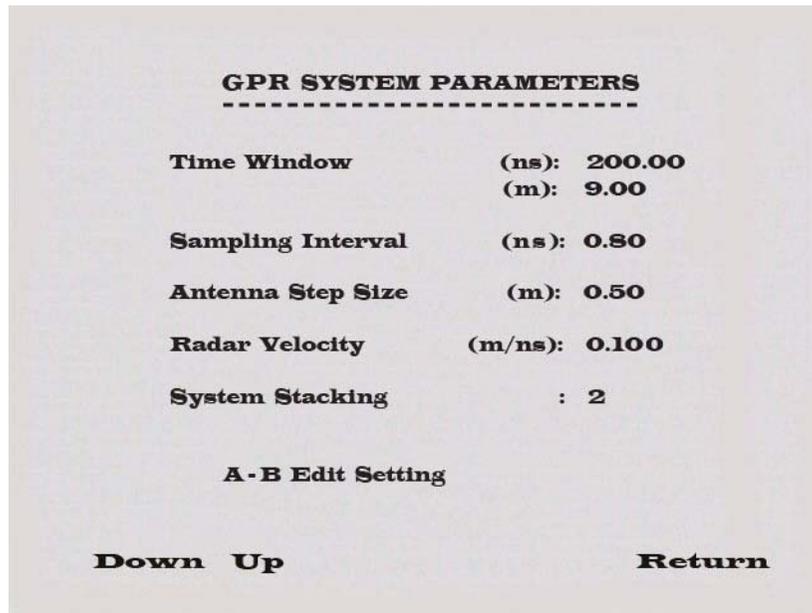
*Figure J-13: The GPR Parameters menu when the multi-channel adapter is connected to the system. Since multi-channel data collection can involve antennas and transducers of different frequencies, the frequency and antenna separation parameters are not set in this menu but the Multi-Channel Control Menu.*

# J-4.1.3  Sampling Interval

The Temporal Sampling Interval value is a frequency dependent variable, used to ensure that the GPR signals are properly digitally sampled so the waveform can be reproduced without aliasing (Figure J-14).
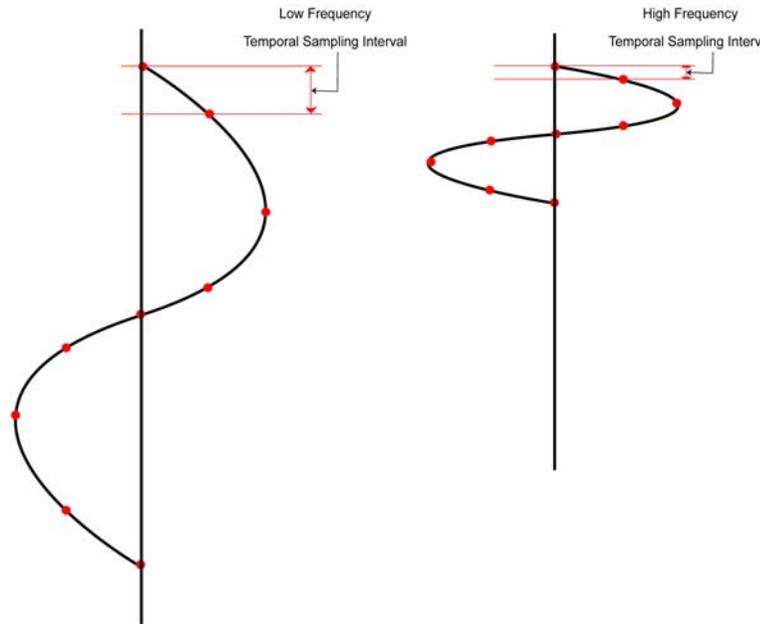


*Figure J-14: Lower frequency signals can be properly sampled with a longer temporal sampling interval than higher frequencies. However, with the multi-channel system, all antenna frequencies use the same temporal sampling interval so it is important that this value be set to the appropriate value for the highest frequency antenna or transducer being used. This is most important when collecting multiple frequency data.*

Although multi-channel data can be collected with antennas of varying frequencies, the signals from all frequencies are sampled at a single temporal sampling interval.

**Thus, when collecting multi-channel data with varying frequencies, it is very important that the sampling interval value be set to the appropriate value for the highest frequency antenna (see the table below).**

The recommended temporal sampling interval versus antenna frequency is reproduced below:

| Center Frequency (MHz) | Recommended Sampling Interval (ns) |
|:---:|:---:|
| 12.5 | 6.4 |
| 25 | 3.2 |
| 50 | 1.6 |
| 100 | 0.8 |
| 200 | 0.4 |
| 250 | 0.4 |
| 500 | 0.2 |
| 1000 | 0.1 |

## J-4.1.4  Step Size

The Step Size setting is the distance between data traces. The position value for each trace increments by the step size value starting at the Start Position value.

There are special considerations when setting the Step Size value when collecting data with the multi-channel system.

**Odometer:** When collecting multi-channel data with an odometer, a trace is collected from **one** channel (transmitter-receiver pair) each time the odometer triggers the system. This means that it takes multiple odometer triggers to collect all the traces from all the channels in the sequence.

For example, if the step size is set to 0.05m on a multi-channel system with 3 channels in the sequence, any one channel collects a trace every 0.15m (Figure J-15).



If Step Size = 0.05m:

Tx-Rx #1 collects traces at:
0.00, 0.15, 0.30, 0.45 etc.

Tx-Rx #2 collects traces at:
0.05, 0.20, 0.35, 0.50 etc.

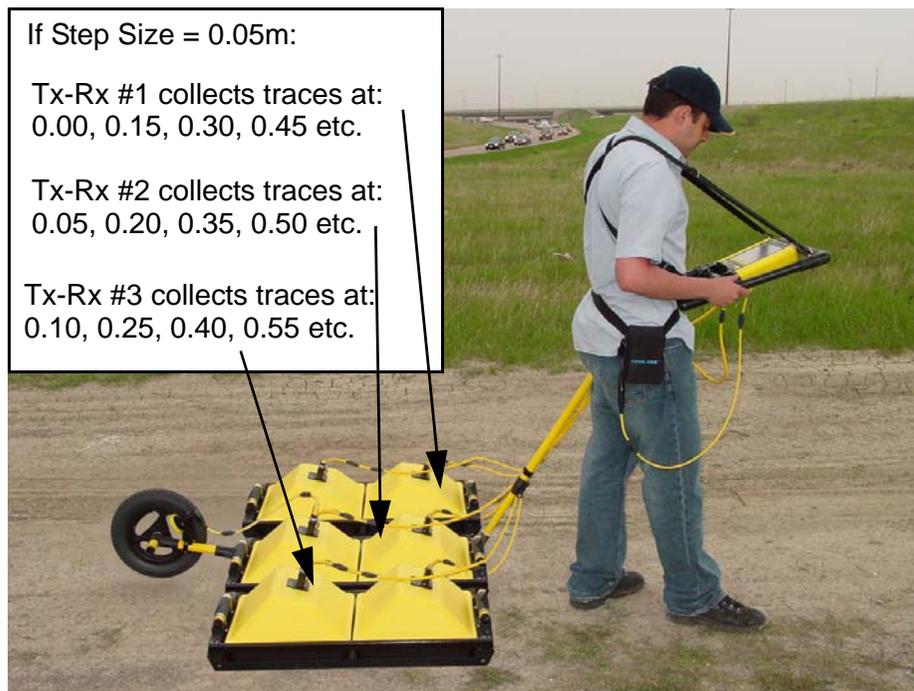Tx-Rx #3 collects traces at:
0.10, 0.25, 0.40, 0.55 etc.

*Figure J-15: Multi-channel data collection with an odometer. Each odometer trigger collects a trace from one channel (transmitter-receiver pair). To collect data from all the channels in the sequence takes several triggers. The step size should be set to the desired step size divided by the number of channels in the sequence. In this case the desired step size is 0.15m so the actual step size was set to 0.05m (0.15 / 3).*

The step size value should be set to desired step size divided by the number of channels (same as the Number of Sequences, see Section J-4.2.2: p.16).

**Step Size = Desired Step Size / Number of Sequences**

Another example: to collect Multiple Line with pairs of 500 MHz transducers like Figure J-17 at a desired step size of 0.04m, set the Step Size value to 0.01m (0.04m / 4 Tx-Rx pairs). This will ensure that a particular channel collects data every 4th trace, that is, every 0.04m, as desired.

**Buttons and Triggers:** When collecting data using the DVL B button or electrical trigger, the data collection method is controlled Sequencing Control (Section J-4.2.1: p.15). The fibre optic beeper/trigger cannot be used for multi-channel data acquisition.

"Single" Sequencing Control means that a button or trigger press will collect a single trace from **one** channel in the sequence. With this method, multiple triggers are necessary to collect traces from all the channels in the sequence.

"Complete" Sequencing Control means that a button or trigger press will collect all the traces from all the channels in the sequence.

The position of each trace is still determined by the total numbers of triggers, independent of the Sequencing Control so, when using buttons and triggers to collect data, the step size should still be set the way as when using the odometer.

**Free Run:** When collecting multi-channel data in Free Run mode, data traces are collected sequentially in time. The step size value is just an estimate of the actual step size. The actual step size is based on how quickly the system is collecting traces and the system towing speed.

To determine the towing speed to collect data at approximately the desired step size, do the following calculation:

1) Set the GPR Parameters for Time Window/Depth and Sampling Interval.

2) Set the Trigger Method to Free Run (Section 13.3.1: P.77).

3) Set the Free Run Trace Delay to zero (0.0) seconds (Section 13.3.3: P.79).

4) Set the number of Stacks to 1 (Section 13.2.7: P.74).

5) Without moving the system, using a stopwatch, time the system to collect and save data in Line Mode (Section 15.3: P.106) for 120 seconds (2 minutes) and pause the data collection.

6) Record the number of traces that were collected in the 120 second time period. This will be visible on the bottom of the data collection screen beside "Trace #".

7) Divide the number of traces by the time in seconds to calculate the number of trace per second (trc/sec) that were recorded.

8) To calculate the towing speed necessary to collect traces at approximately the desired step size, perform the following calculation:

   For kilometers/hour:        (trcs/sec * step size(m)) / (number of sequences) * 3.6

   For miles/hour              (trc/sec * stepsize(ft)) / (number of sequences) * 0.68

9) If the calculated towing speed is too fast, increase the number of stacks in Step 4 and repeat the calculation.

10) Create a speed chart by doing this calculation at different numbers of stacks and different time windows/depths.

To avoid confusion, it is usually best to set the Step Size to 1.0 so that it the "position" that is saved with each trace is actually the trace number.

Data collected in this manner uses another means of determining the actual position of each trace, typically by collecting GPS data in parallel or by adding fiducial markers into the data at known locations during data collection and rubberbanding the data in post-processing.

# J-4.2   Multi-Channel Control Menu

The Multi-Channel Control menu is accessed by pressing number 6 from the System Setup menu (Figure J-12).

The Multi-Channel parameters menu allows the user to set up multi-channel data acquisition including defining the transmitters and receivers attached to each of the eight available ports, the sequence of data collection of channels (transmitters and receiver pairs), the total number of sequences being collected and the way the sequence control.
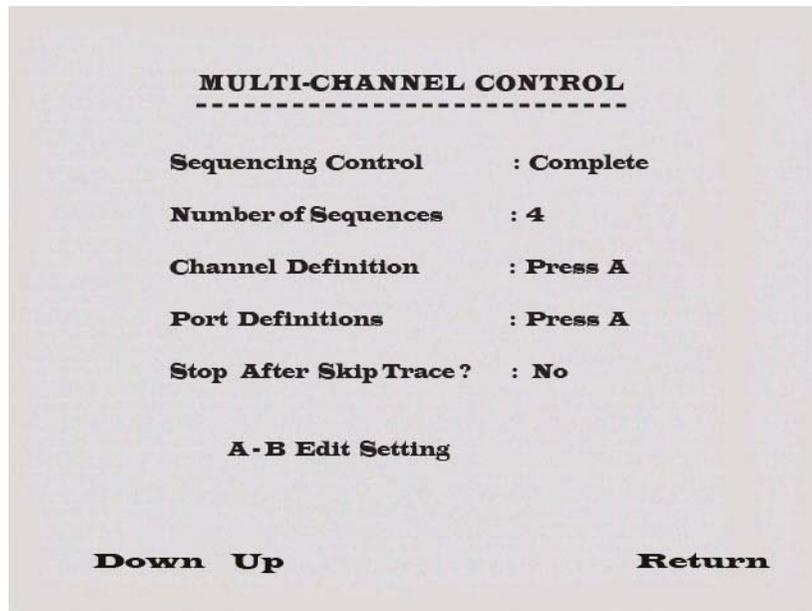


*Figure J-16: The Multi-Channel Control menu is used to modify the multi-channel settings.*

## J-4.2.1  Sequencing Control

The **Sequencing Control** is accessed by using the **Up** and **Down** buttons to move down through the menu in Figure J-16 to **Sequencing Control** and then and editing the parameter using the **A** and **B** buttons.

The Sequencing Control defines whether, during data acquisition, the channels defined in the Channel Definition are collected by individual channel (Single) or all channels (Complete) after the system is triggered to collect data.

There are two options for Sequencing Type: Complete and Single.

Sequencing Control becomes important when the user is using a manual button press to trigger the system to collect data, for example, using the DVL B button or the electrical beeper/trigger (the fibre optic beeper/trigger cannot be used for multi-channel data acquisition). For these trigger methods, the user can select to collect the data from each channel singly per button press or completely, that is, up to 16 channels per button press.

Complete Sequence Control CANNOT be done when data collection is in Free Run or Odometer mode. In these modes, data collection is always Single.

**Table 1:**

| Trigger Method | Single Sequence Type | Complete Sequence Type |
|---|---|---|
| DVL B button | Yes | Yes |
| Electrical Trigger | Yes | Yes |
| Free Run | Yes | No |
| Odometer | Yes | No |

## J-4.2.2  Number of Sequences

The **Number of Sequences** is accessed by using the **Up** and **Down** buttons to move down through the menu in Figure J-16 to **Number of Sequences** and then and editing the value using the **A** and **B** buttons.

The Number of Sequences determines the total number of channels that will be used during data acquisition. The maximum possible number of sequences is 16 but not all 16 sequences need to be defined (see Section J-4.2.3: p.16).

As well, not all the sequences that are defined need to be collected. In other words, it is valid to define 4 sequences but set the Number of Sequences to 2, if you only want to collect data in the first 2 sequences.

For example, in the Fixed frequency 2D array Channel Definition in Figure J-18, there are 4 sequences defined. If the operator decided that they only wanted to collect data from transmitter-receiver pairs 1-2 and 3-4 (defined in sequences 1 and 2) and not 5-6 and 7-8 (defined in sequence 3 and 4), they can set the Number of Sequences to 2 and only the first two sequences will be collected.

The Number of Sequences defined in this menu controls the number of Channels displayed on the Channel Definition menu (Section J-4.2.3: p.16). The number of sequences may need to be increased before a particular channel is visible on that menu so it can be edited.

## J-4.2.3  Channel Definition

The **Channel Definition** menu is accessed by using the **Up** and **Down** buttons to move down through the menu in Figure J-16 to **Channel Definition** and then and pressing the **A** button.

The Channel Definition menu is used to set the transmitter - receiver pairs in each channel and set the order of data collection. The **Start** position of each channel can also be entered, as well as the separation between the transmitter and receiver (**ASep**).

Typical Antenna Separation values for various frequencies are found in Section 13.2.4: p.71.

The number of Channels displayed on this menu is controlled by the Number of Sequences defined (Section J-4.2.2: p.16). The number of sequences may need to be increased before a particular channel can be defined in this menu.

The examples below show typical setting for this menu, depending on the type of multi-channel survey being conducted, i.e. Fixed Frequency 2D Array, Multi-Frequency Linear Array and Multi-Frequency 2D Array.

**Fixed Frequency 2D Array**

The Channel Definition for a Fixed frequency 2D Array, like the one shown below, is displayed below in Figure J-18.



*Figure J-17: Fixed frequency 2D array system parameters. In a 2D array, typically all the transmitter-receiver pairs start at the same Start Position. The Antenna Separation is measured from the centre of the transducers (or antennas). In this case, with 500 MHz transducers, the antenna separation is 0.23m.*



*Figure J-18: Possible Channel Definition for the Fixed frequency 2D array shown in Figure J-5. This configuration has all the channels at an equal Antenna Separation (in this case 0.23m for 500 MHz transducers) and starting at the same Start Position.*

**Multi-Frequency Linear Array**

The Channel Definition for a multi-frequency linear array, like the one below, is shown below in Figure J-20.



*Figure J-19: Multi-frequency Linear Array System parameters. In a linear array, the transmitter-receiver pairs are lined up with the back pair centred on the 0.00 Start Position and the Start Position of the other pairs measured from the 0.00 Start Position. The Antenna Separation is measured from the centre of the transducers (or antennas). In this case, with 1000 MHz, 500 MHz and 1000 MHz transducers are 0.15m, 0.23m and 0.38m apart respectively.*



*Figure J-20: Possible Channel Definition for the Multi-frequency linear array shown in Figure J-19. This configuration has each channel at varying Antenna Separations and Start Positions. Note that the Start Positions for the front channels are positive values because the back channel is defined to start at position zero (0.00).*

**Multi-Frequency 2D Array**

The Channel Definition for a Multi-frequency 2D array, like the one below, is shown below in Figure J-22.



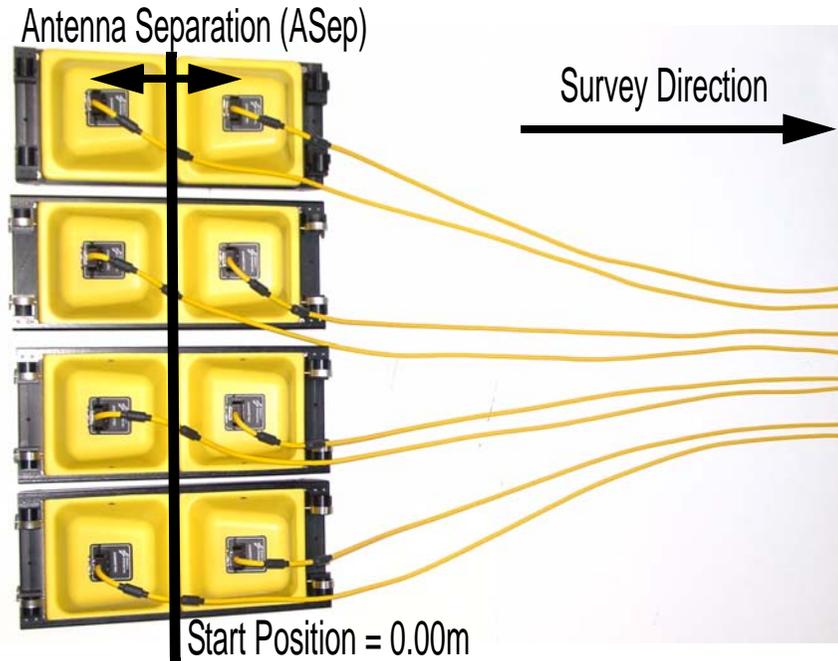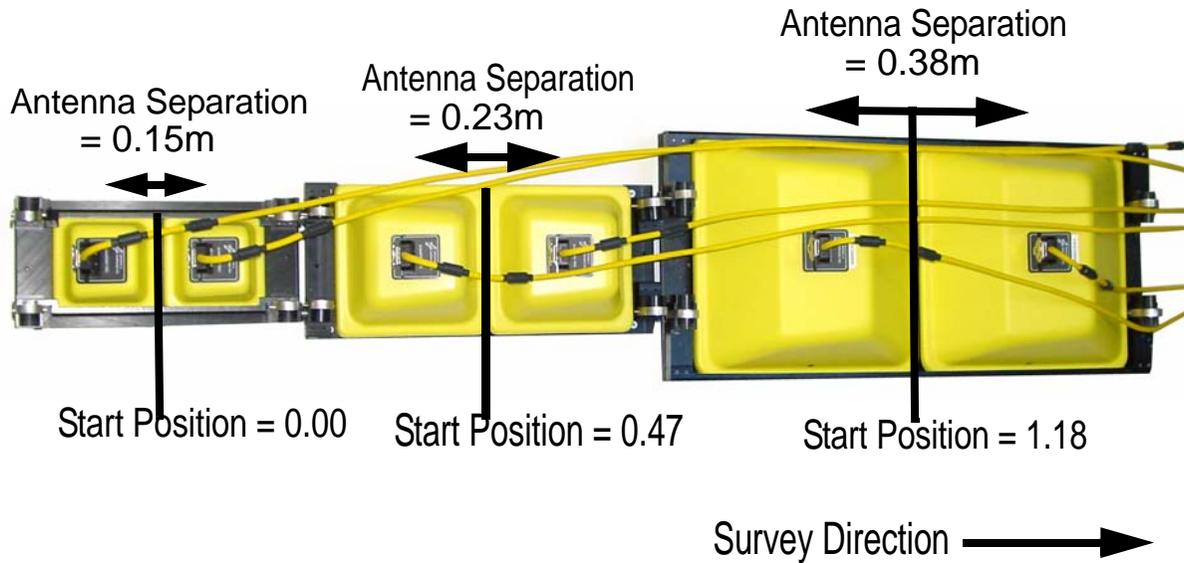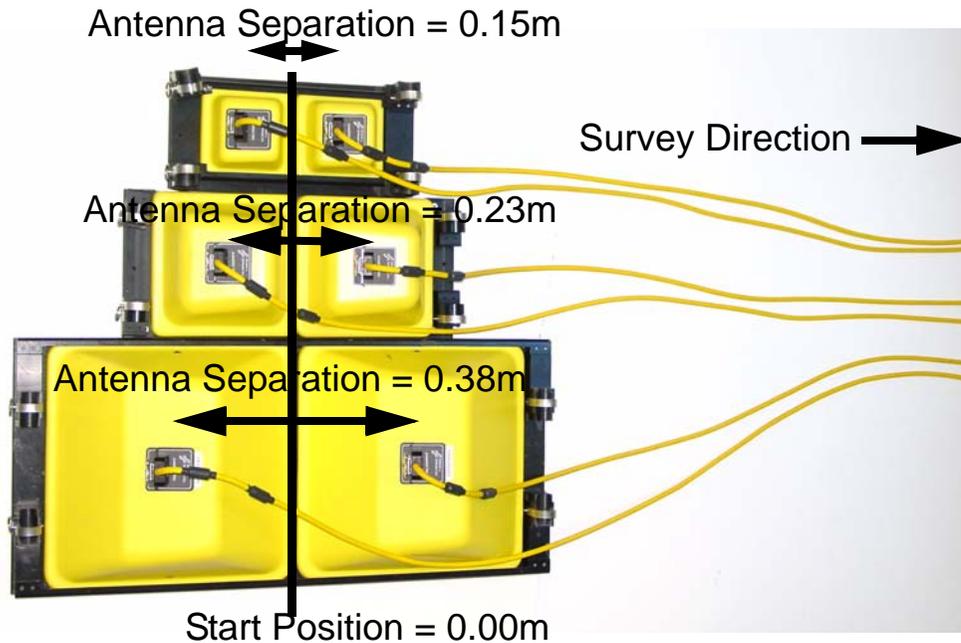*Figure J-21: Multi-frequency 2D Array system parameters. In a 2D array, typically all the channels start at the same Start Position. The Antenna Separation is measured from the centre of the transducers (or antennas). In this case, with 1000 MHz, 500 MHz and 1000 MHz transducers are 0.15m, 0.23m and 0.38m apart respectively.*



*Figure J-22: Possible Channel Definition for the Multi-Frequency 2D Array shown in Figure J-21. This configuration has the channels at varying Antenna Separations and the same Start Position.*

## J-4.2.4  Port Definitions

The **Port Definitions** menu is accessed by using the **Up** and **Down** buttons to move down through the menu in Figure J-16 to **Port Definitions** and then and pressing the A button.

The Port Definition menu is used to define what the type of unit, transmitter or receiver, and what frequency are connected to each port of the multi-channel adapter. When transmitters are defined on a port, the voltage must also be defined.

In most cases the transmitter voltage setting will be set to Auto PRO so the system can automatically determine the transmitter voltage by interrogating the transmitter. However, the transmitter voltage setting for the optional VP (variable power) transmitter is done differently. The VP transmitter can be used with antennas from 12.5 to 200 MHz and allows the operator to set any voltage from 200 to 1000 volts. If the operator wants the maximum voltage, 1000 volts, they can set the transmitter voltage setting to Auto PRO. However, if the operator wants to use a transmitter voltage less than the maximum, he must enter the desired transmitter voltage.

To edit one of the ports, use the **Up** and **Down** buttons to move the arrows through the channels to the desired one. Then, set the channel to **Tx** (transmitter), **Rx** (receiver) or **Empty** using the **Type** button. Set the frequency using the **Freq** button and, for transmitters, set the Voltage using the **V+** and **V-** buttons.

**Fixed Frequency**

The Port Definitions for a Fixed frequency system, like the one in Figure J-5 is shown in Figure J-23.



*Figure J-23: Port Definitions for a Fixed Frequency system like the one shown in Figure J-5.*

**Multi-Frequency System**

The Port Definitions for the Multi-Frequency systems shown in Figure J-2 and Figure J-3 is shown in Figure J-24.



*Figure J-24: Port Definitions for a Multi-Frequency system using 250, 500 and 1000 MHz transducers shown in Figure J-2 and Figure J-3.*

## J-4.2.5  Stop After Skip Trace?

The **Stop After Skip Trace?** option is accessed by using the **Up** and **Down** buttons to move down through the menu in Figure J-16 to **Stop After Skip Trace?** and then selecting Yes or No using the **A** and **B** buttons.

This option is only applicable if the multi-channel data are collected using an odometer. If the odometer is triggering data collection faster than the system can collect, it is possible for traces to be skipped.

This option specifies what happens if a trace is skipped. Selecting Yes means that data acquisition will terminate. Selecting No means that data collection will continue.

# J-5  Running in Scope Mode

Running in Scope Mode is necessary to ensure that the system is running correctly and timezero is in the correct location before starting data collection.

Multi-Channel Scope Mode is very similar to running the single-channel system. Refer to Section 14: p.101 for details about Scope Mode.

The main difference between Scope Mode for Multi-Channel and normal (single-channel) systems is that each channel must be initialized before the system starts running and data traces are displayed on the screen. This takes more time and may require several button presses to proceed through the initialization sequence.

After entering Scope mode, the user is prompted to specify to run in **Auto** or **Manual** mode. Manual mode is highly recommended because after initialization, it displays the traces from each channel in sequence by prompting the user to press the A button. This allows the user to ensure that each channel is operating properly and to set timezero (see below). Auto mode displays each channel in sequence but often so quickly that it is very difficult to see the trace from a particular channel. This makes it difficult to ensure that each channel is operating correctly and set timezero.

## J-5.1  Setting Timezero

Setting timezero (also called the transmit pulse or first break) is also different in multi-channel than normal (single-channel). In Multi-Channel, the system is constantly switching to different channels so the timezero may appear to jump back and forth to the left and right.
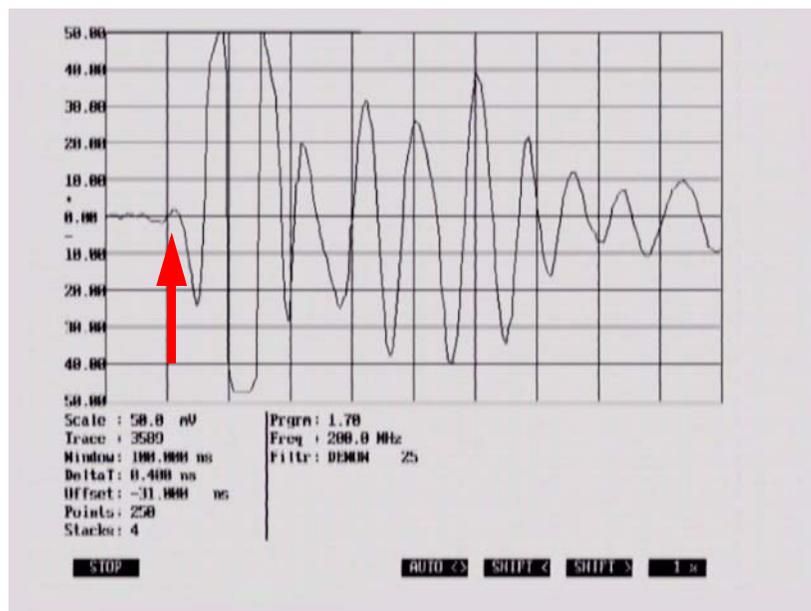


*Figure J-25: The multi-channel system, when run in Scope mode, will display, in sequence, the trace from each channel defined under Channel Definition and Number of Sequences. The key to setting timezero correctly is to find the trace with the timezero furthest to the left and set the first large deflection to the start of the second vertical division as shown by the red arrow.*

For the purpose of setting timezero, find the transmit pulse in the sequence that is furthest to the left and make sure that the first large deflection is set to the start of the second vertical division as shown in Figure J-25.

If timezero is set correctly, the transmit pulse for other channels may be further to the right in the Scope window. It is important to make sure that the time window length is long enough for the channel with the transmit pulse furthest to the right. For example, if the time window is set to 100 ns and the transmit pulse for the channel furthest to the right is set at the 25 ns point in the vertical divisions, there is really only 75 ns (100 - 25) of usable data for this channel. If this time window is too short, it must be increased before starting data collection.
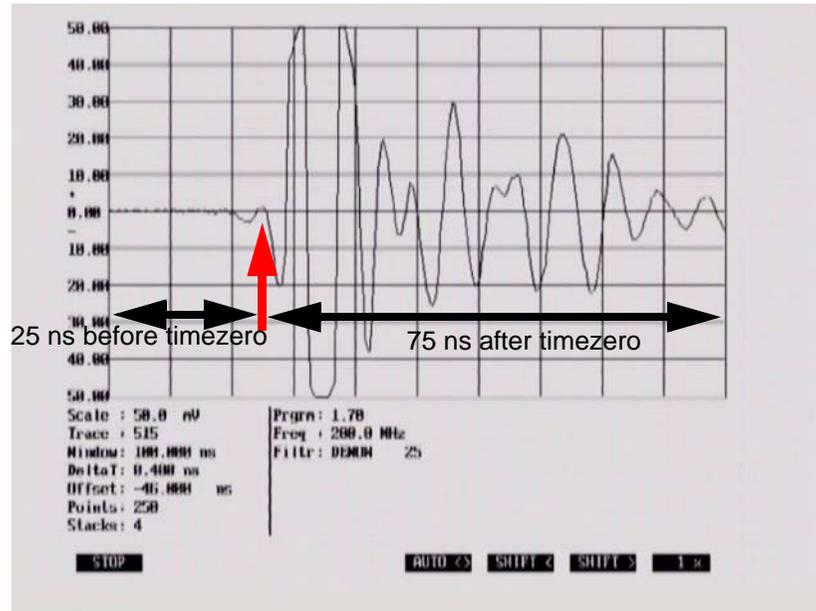


*Figure J-26: After setting the timezero point using the transmit pulse furthest to the left, find the channel in the multi-channel sequence that produces the transmit pulse furthest to the right and make sure that the time window is long enough. In the example shown, the total time window is 100 ns but the transmit pulse occurs at the 25 ns point. This means that there is really only 75 ns (100 - 25) of usable data for this channel. If this time window is too short, it must be increased before starting data collection.*

# J-6 Data Collection Mode

Multi-Channel Data Collection Mode is very similar to running the single-channel system. Refer to Section 15: p.105 for details about Data Collection Mode.

The main difference between Data Collection Mode for Multi-Channel and normal (single-channel) systems is that each channel must be initialized before the system starts running and data traces are displayed on the screen. This takes more time and may require several button presses to proceed through the initialization sequence.

A second difference is how the multi-channel data are displayed on the DVL screen. The width of the screen is divided into the total number of sequences defined (Section J-4.2.2: p.16) and the data traces from each channel are plotted into this smaller portion of the screen. These smaller windows of data are arranged from right to left, that is, the first sequence is displayed in the window on the right edge of the screen and the last sequence on the left edge of the screen.
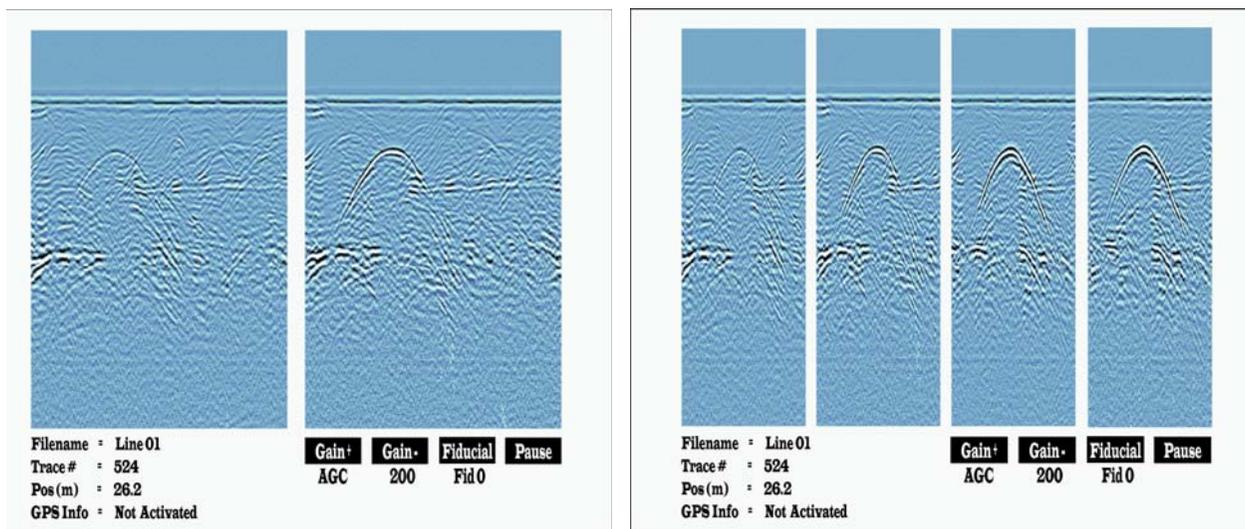


*Figure J-27: Multi-Channel data collection with traces plotted in grey scale. The screen is divided into smaller windows depending on the number of sequences defined. There can be 1 to 16 sequences. Two (left) and four (right) sequences are shown in this example. The horizontal distance of data plotted depends on the pixel width of the traces. The narrower the pixel width, the more distance is plotted.*

Although the traces from each channel are plotted to the screen in a separate windows on the data collection screen, keep in mind that the traces are actually being saved in sequence to a single data (DT1) file so they are mixed together (multiplexed). Therefore, if a previously-collected data file is viewed on the DVL, the display will be similar to Figure J-28.
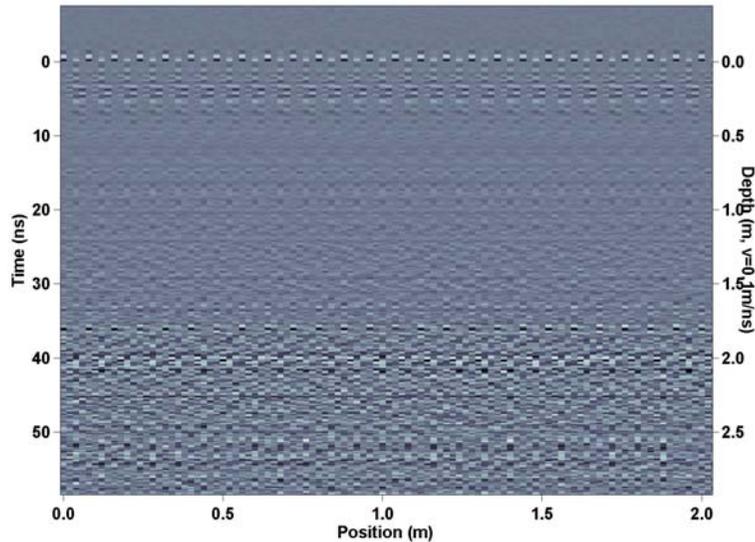
*Figure J-28: A plot of multiplexed data. Although data traces from the same channel are plotted together to the screen, the actual data traces are stored in the data file in the order they were collected so the traces from different channels are mixed together. The multiplexed data is visible when replaying a previously-collected data file on the DVL or when collecting data traces in wiggle trace mode. Multiplexed files are de-multiplexed using a PC-based software program.*

When traces are wiggle trace format (Section 13.5.1: p.92), the traces are plotted in the order that they are collected so they are NOT sorted into separate windows like the grey scale traces are.

In post-acquisition, the data traces must be sorted and extracted using the De-multiplexer software described in Section J-8: p.29.

## J-6.1   Using GPS

If data were collected with GPS, the GPS positional data must be integrated into the multiplexed data BEFORE it is de-multiplexed (Section J-8: p.29). GPS data cannot be successfully integrated into the de-multiplexed data files.

## J-6.2   Fiducial Markers

If Fiducial markers are added to the data during data acquisition they only be saved to the first channel in the sequence. However, when the data are de-multiplexed (Section J-8: p.29) fiducial markers are copied to the closest trace in all channels. This means that adding a Fiducial marker applies to all channels.

# J-7  Multi-Channel File Format

All pulseEKKO PRO survey line data consists of two files: a header file with a .HD extension and a data file with a .DT1 extension. The format details are described in Appendix A: Data File Formats.

pulseEKKO PRO multi-channel data files have additional information added to the header (.HD) file and trace headers in the data (.DT1) file.

## J-7.1  Header (.HD) File

Multi-channel files have extended the header file format by adding extra lines to the end of the file describing the unit (receiver or transmitter) connected to each port and the channel definitions.

As well, unlike standard header files, in the multi-channel header file, the Receiver (Rx) and Transmitter (Tx) battery voltages and serial numbers have been moved to a special line containing channel information.

For example, a multi-channel header file may have the following lines added:

Multi-Channel Port Definitions

PORT_2 =  Rx,1000.0MHz,11.1V, 0033-3350-0052

PORT_3 =  Rx,1000.0MHz,11.1V, 0033-3350-0051

PORT_5 =  Tx,1000.0MHz,11.1V, 185V, 0034-3356-0003

PORT_7 =  Rx,1000.0MHz,11.8V, 0033-3350-0050

PORT_8 =  Rx,1000.0MHz,11.1V, 0033-3350-0053

Multi-Channel Channel Definitions

CHAN_1 = 5 TX, 7 RX, 59.44, 0.20 m, 0.10 m

CHAN_2 = 5 TX, 3 RX, 88.86, 0.40 m, 0.20 m

CHAN_3 = 5 TX, 2 RX, 98.25, 0.60 m, 0.30 m

CHAN_4 = 5 TX, 8 RX, 1.00, 0.80 m, 0.40 m

### J-7.1.1  Port Definitions

Each port definition (PORT_#) lists 4 values for Receivers and 5 values for Transmitters:

> 1) Type of unit (Rx or Tx).
>
> 2) Frequency in MHz.
>
> 3) Battery voltage in Volts (for Tx and Rx's with 2 batteries, the maximum voltage is listed.
>
> 4) For transmitters, the fourth parameter is the pulser voltage in Volts.
>
> 5) Last parameter is the serial number of the unit.

There can be up to 8 ports.

## J-7.1.2 Channel Definitions

Channel definitions describe relationships between transmitter and receiver ports. Each channel definition line (CHAN_#) contains:

1) Transmitter (Tx) port number (from the ports listed above in the file),

2) Receiver (Rx) port number (from the ports listed above in the file),

3) Time-zero point on the trace,

4) Antenna separation between the Tx and Rx (metres or feet),

5) Start Position of the mid-point of the Tx-Rx pair along the line in the survey direction (metres or feet).

There can be up to 16 channels.

## J-7.1.3 Previous Definitions

Older versions of the multiplexed header file definition used a slightly different naming for certain fields:

1) "Multi-Channel Port Definitions" was called "Multi-Channel Channel Definitions"

2) "Multi-Channel Channel Definitions was called "Multi-Channel Sequence Definitions"

3) "PORT_# was called CHAN_#

4) "CHAN_# was called DATASRC_#

# J-7.2  Trace Headers in the Data (.DT1) File

A trace header consists of 25 4-byte fields and 28 1-byte characters for a total length of 128 bytes. Trace headers are described in detail in Appendix A: Data File Formats.

The 23rd field in the trace header has 4 bytes that contains additional multi-channel information:

**Byte #1**

The first byte contains trace status flag bits:

Bit number 6 of the first byte is 0 if the trace is not a skipped trace and 1 if the trace is a skipped.  If the trace is a skipped trace, it should be ignored.

**Byte #2**

The channel number is stored in the 4 least significant bits of byte number 2 in trace header field #23.

The channel number written to this location corresponds to the CHAN_# written to the header (.HD) file (Section J-7.1 ).

For example, if the channel number is read as 2, this corresponds to the CHAN_2 information line in the header file that says that the trace was collected between the transmitter plugged into port 5 on the multi-channel adapter and the receiver plugged into port 3.

Byte #3 and #4 are not used.

**In summary:**

The first 2 bytes of field 23 may look like this

| Status Flag | Channel Number | Comment |
| --- | --- | --- |
| 00000000 | 00000001 | Channel 1 trace not skipped |
| 00000000 | 00000010 | Channel 2 trace not skipped |
| 00000100 | xxxxxxxx | Channel, probably 3, trace skipped (i.e. ignore, data) |
| 00000000 | 00000011 | Channel 3 trace not skipped |
| 00000000 | 00000001 | Channel 1 trace not skipped |

etc.

# J-8  De-Multiplexing Multi-Channel Data

The multi-channel system saves the traces from all the sequences (channels) to one data file. To view and process data from one channel, the data must be sorted or de-multiplexed into two or more separate data files. Once the data have been transferred to a PC, the de-multiplexing process is performed using the EKKO_Demux program.

It is critical that if multi-channel data were collected with GPS, the GPS data must be integrated into the GPR data BEFORE the GPR data is de-multiplexed. GPS integration is performed using the EKKO_View Deluxe software. See the EKKO_View Deluxe User's Guide for details.

The main screen of the EKKO_Demux program is shown in Figure J-29.



*Figure J-29: The main screen of the EKKO_Demux program.*

The program is very simple to run. First, enter the path and name of the multiplexed file. Use the **Browse** button to find the file. Once the file is loaded into the program, the table will automatically be filled in to list the details of each data file that will be extracted from the multiplexed file. Pressing the **De-Multiplex** button will initiate the de-multiplex process. Note that the extracted files are automatically named the original file name followed by the transmitter port number and receiver port number, for example, LINE00Ch01Tx1Rx2. The de-multiplexed data files are saved to the same folder as the multiplexed data.
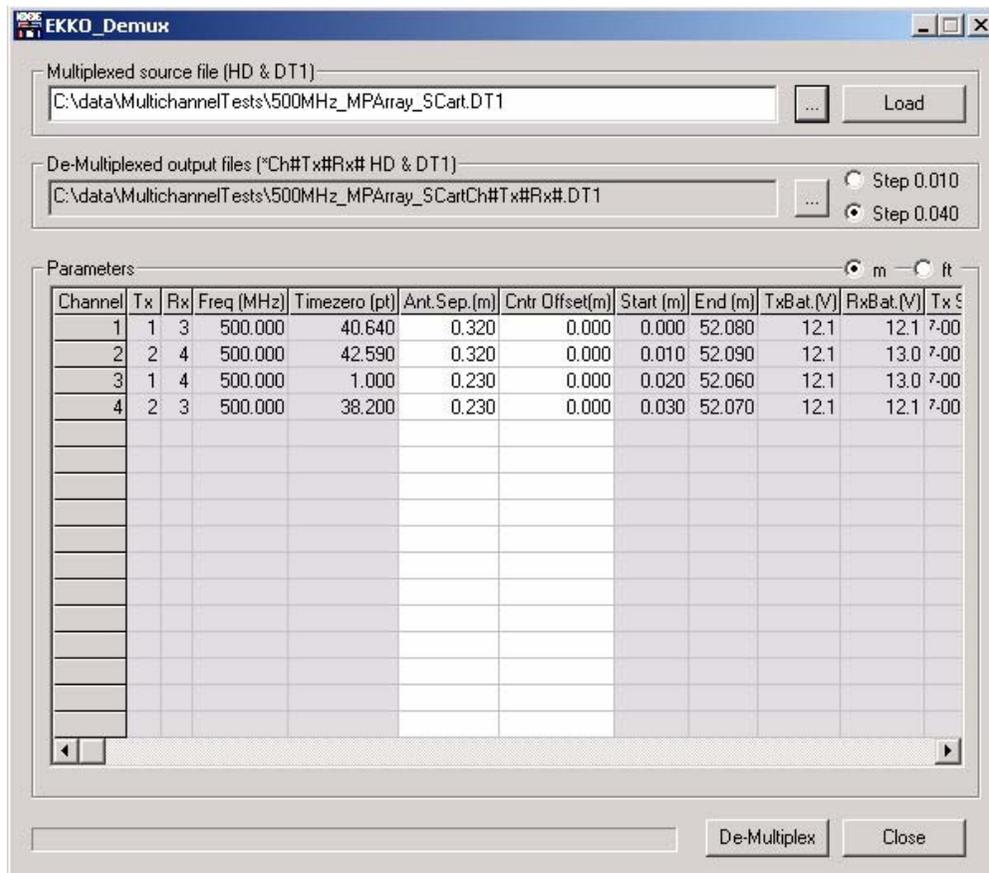
*Figure J-30: When a multiplexed file is loaded into the EKKO_Demux program, it automatically lists the details of the data from each channel to be extracted. The de-multiplexing process occurs when the De-Multiplex button is pressed. The user has the option of editing the Step Size, Antenna Separation and the Centre Offset Position parameters but, in general, the default values should be used.*

The user can select the Step Size (Step) for the de-multiplexed data files. The Step value defaults to the actual distance between traces for each channel (recommended) but the user can also select to interpolate data traces for each channel to the step size used for the multiplexed data collection (J-4.1.4 Step Size).

# J-8.1   Working with De-Multiplexed Data Files

After the data have been de-multiplexed, they can be plotted, edited and processed using various Sensors & Software software programs such as EKKO_View, EKKO_View Deluxe, EKKO_Mapper and EKKO_3D.

The data file generated from each channel has a timezero point number (which can be fractional) written to the header (.HD) file. The timezero point number is picked using an average timezero point number of all the traces in the channel. A timezero point of 1.0 indicates that timezero for that channel could not be found so it defaulted to a value of 1.0. The timezero value can be re-picked using a routine in the EKKO_View Deluxe program.

# Appendix K:  GPR Glossaries

## K-1  Basic GPR Terms

alpha          exponential attenuation coefficient - normal units dB/m (see attenuation)

K          relative permittivity or dielectric constant

sigma          electrical conductivity - normal units mS/m

v          propagation velocity - normal units m/ns

dB/m          decibels/metre, common unit for attenuation,

m/ns          metre/nanosecond, common unit of  GPR velocity, v (see nanosecond)

mS/m          milli-Siemens/metre, common unit for conductivity,

ns          nanosecond, normal unit of GPR time (see nanosecond)

ps          picosecond = 0.001 ns $=10^{-12}$s, occasion unit of GPR time

us          microsecond = 1000ns $=10^{-6}$s, occasion unit of GPR time

COR          common offset reflection (survey type where a constant antenna separation is maintained).

CMP          common mid-point (survey type where a transmitter and receiver antenna separation are changed but the mid point remains constant)

GPR          ground penetrating radar

EM          electromagnetic (common abbreviation)

antenna          Device used to couple electromagnetic energy into the ground. Sometimes called a transducer.

antenna separation Spacing between transmitting and receiving antennas.

attenuation          A reduction in signal amplitude caused by energy dissipation in the transmitting media (see alpha).

bandwidth          The range of frequencies over which a given device transmits or detects signals above a specified amplitude or power

centre frequency      Middle of the frequency band defined by a device's bandwidth

conductivity          The ability of a material to conduct electrical current. In isotropic materials the reciprocal of resistivity. Sometimes called specific conductance. Units are siemen/m or S/m. (Or occasionally, mhos/m). For GPR, usually expressed as mS/m. Common symbol

nanosecond          $10^{-9}$s (One Billionth of a second)

radio wave          Electromagnetic fields that travel through a material as waves and typically have oscillating frequencies in the 1 GHz to 10 GHz range

receiver (Rx)　　　General term for electronics devices used to detect fields and translate signals into records or displays

resolution　　　　　The minimum separation of two objects before their individual responses merge into a single response

signal amplitude　　A measure of the strength of the radio wave signal

station interval　　　Spatial distance between observation points along a survey traverse line or mesh points on a grid

step size　　　　　See station interval

transmitter (Tx)　　General term used for electronics devices used to create propagating electromagnetic fields

transducer　　　　Name used where GPR antenna, electronics, and shield are combined into one physical unit

sample point　　　Signal amplitude measured at specific point in time

trace　　　　　　　Sequence of sample points from a single GPR channel that indicate time variation of signal amplitude

cross section　　　Image that results from side-by-side display of a number of traces which are from adjacent spatial measurement position

gain　　　　　　　Process of amplifying signals to match recording device or display dynamic range

## K-2　Common GPR Terms

zone of influence　　The size of an area on a reflecting feature that can be uniquely resolved. (See lateral resolution length).

fresnel zone　　　　See zone of influence.

range resolution length　The radial distance separation between two objects that is needed so that a GPR clearly detects two responses.

lateral resolution length　The lateral separation between two objects that is needed so that a GPR clearly detects two responses.

ringing　　　　　　Impulsive GPR signals can give rise to reverberating responses that oscillate for a much longer time than the GPR pulse or wavelet. Such a response is referred to as a "ringing" response or "ringing" for short.

hyperbola　　　　　Characteristic inverted "U" GPR response from a point target. (Mathematical form of the position-travel time response from a point target)

signal to noise ratio　The ratio of GPR signal amplitude to the average noise amplitude. A large ratio results in a larger penetration depth or detection of weaker signals.

system performance　Measure of system exploration depth indicated by the ratio of transmitter output power or voltage to receiver noise power or voltage.

wavelet or EM pulse    Impulsive GPR's emit an oscillatory electromagnetic pulse which is short in time and space and is often referred to as a wavelet.

penetration depth    The depth of a GPR wavelet can penetrate to before it is attenuated to an undetectable amplitude.

air waves    GPR systems can create and detect energy which travels through air above the ground. Undesired responses from above ground targets are often called 'air waves'.

## K-3   Advanced GPR Terms

GPS    global positioning system (satellite based positioning).

DMI    distance measuring indicator.

stacks    number of repeated measurements averaged to get resulting measurements.

reflectivity    measure of amplitude returned by a target.

reflection coefficient    normally named fresnel reflection coefficient and quantifies GPR signal reflection amplitude from a flat interface between two materials.

3 dB bandwidth    Range of spectrum over which the GPR signal amplitude remains above a value equal to the (peak amplitude).

6 dB bandwidth    Range of spectrum over which the GPR signal amplitude remains above a value equal to the (peak amplitude).