5   Data Collection Mode

After timezero has been properly set up (Section 4: P65), 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.
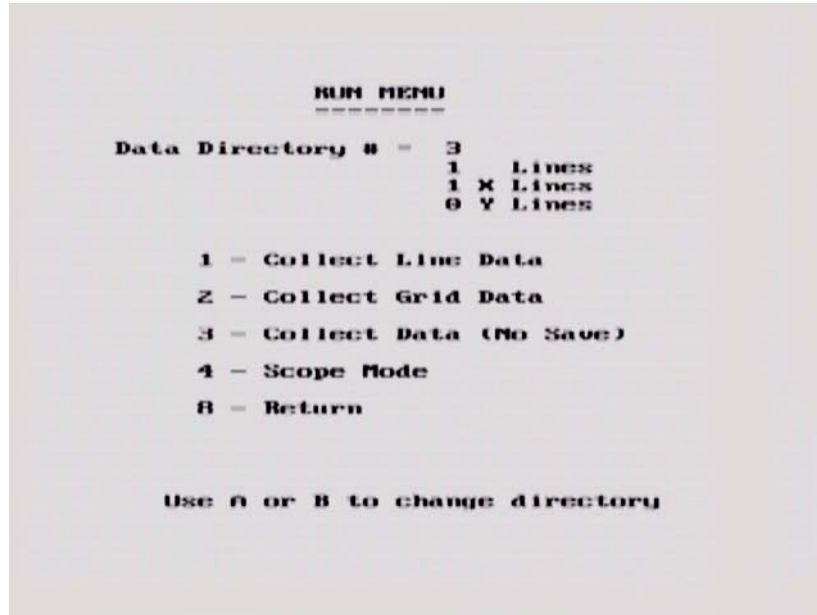

Figure 5-1: The Run menu allows the operator to find the pulse and set up timezero in Scope mode, collect Line data, Grid data or collect data without saving. If data are to be saved, the data directory number is selected using the A and B buttons.

5.1   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 3.4.4: P51).

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

5.2   Select Line Number

The first screen displayed after selecting Collect Line Data is shown in Figure 5-2. This screen is used to determine the number of the line to be collected.
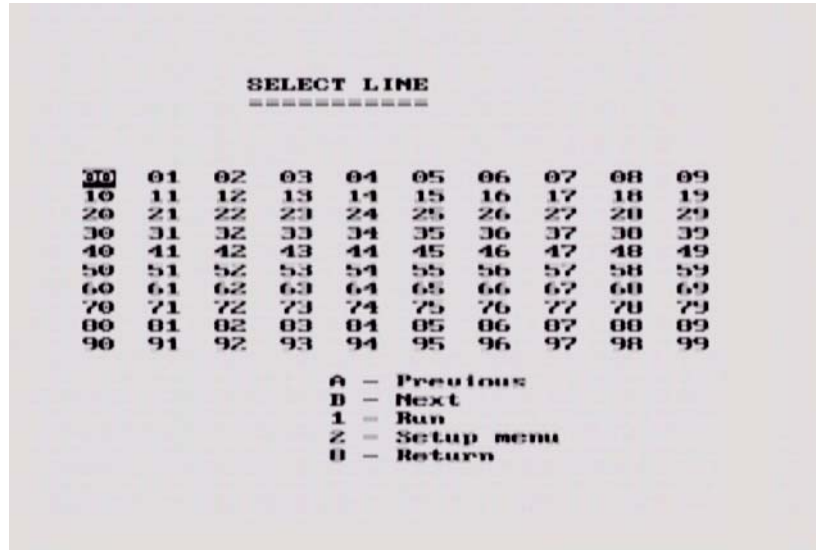
*Figure 5-2: Selecting Collect Line Data will display this screen. The user can select the line number to be collected. The default line number is the lowest line number available. As lines are collected, their associated number will appear in black on this screen. Use the A and B buttons to move to 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.*

5.3   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 5-3). The level of detail in these messages is control by the Display Info Mode (Section 3.6.4: P64).

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 7: P95).
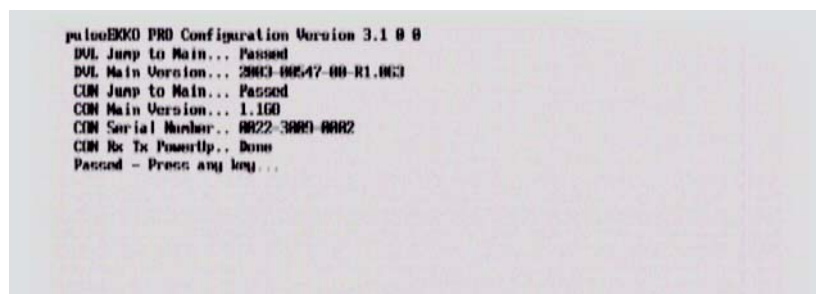

Figure 5-3: After a line name is selected, the system initialization process attempts to communicate with all the components and ready them for data acquisition. During this process, comments are written to the screen. If an error occurs during this process, a message will appear indicating where the 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 7: P95).

Collect Screen: A sample of a screen data plot while in COLLECT mode is shown in Figure 5-4.
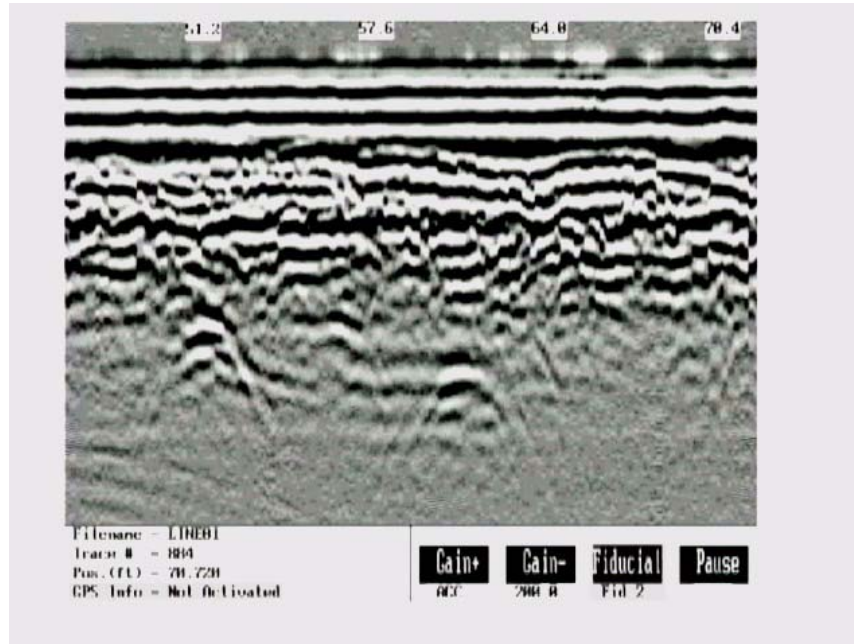

Figure 5-4: Data collection screen with traces plotted in grey scale. The horizontal distance of data plotted on the screen depends on the pixel width of the traces (Section 3.5.1: P56)
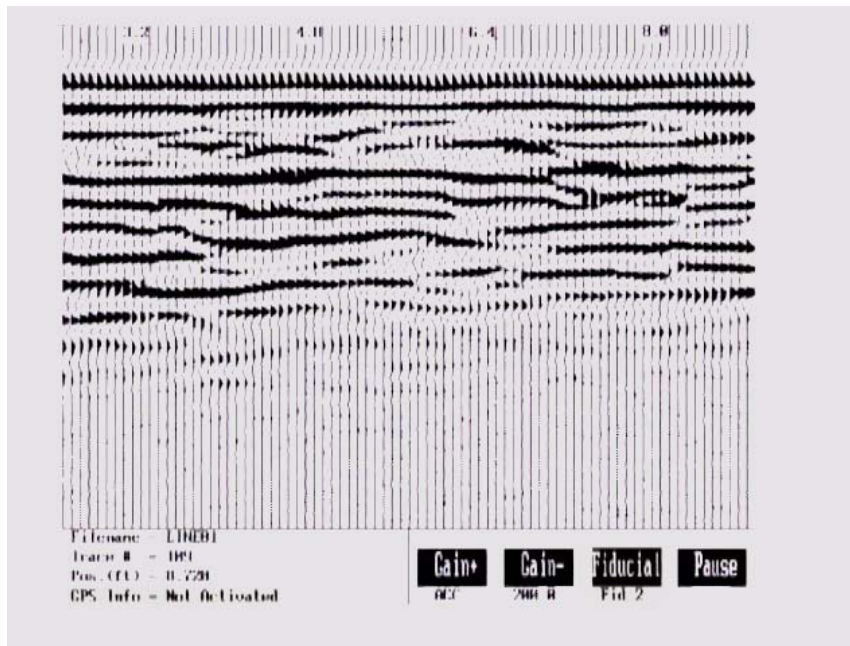

Figure 5-5: Data collection screen with traces plotted in wiggle trace mode with shading on the right (Section 3.5.1: P56)

Trace Type: Depending on the user's choice for Trace Plotting Type (Section 3.5.1: P56) the data will be plotted as either grey scale (Figure 5-4) or wiggle traces (Figure 5-5).

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.

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 3.5.2: P58).

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 5.5: P73).

5.4   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.
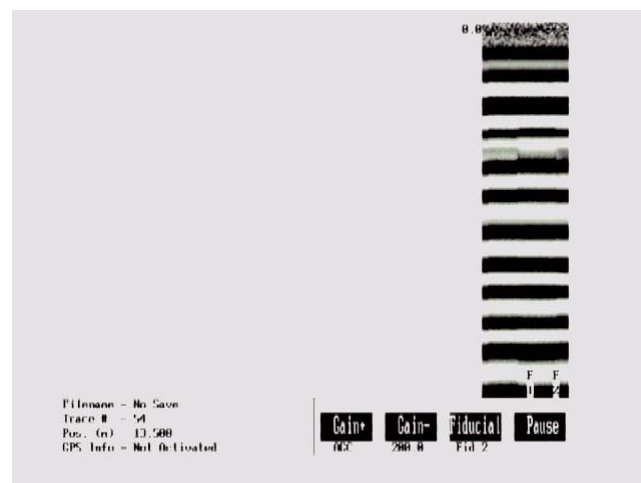

Figure 5-6: Fiducial markers can be added to the data by pressing the Fiducial button during data acquisition. Fiducial markers are written to the trace header of the next trace collected and displayed on the bottom of the data trace. Fiducial markers are always an "F" followed by an incrementing number, i.e. F1, F2, F3, etc.

A fiducial marker is activated by pressing the **Fiducial** button or the **A** button on the keypad during data acquisition (see Figure 5-4).

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.

5.4.1 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.

5.4.2 Fiducial Markers for GPS

If a GPS receiver is attached to the DVL, a file containing GPS information can be saved (Section 3.3.4: P44). In "On a Tag" mode, a line of GPS information will be added to the GPS file (Section 3.3.4.1: P45) whenever a fiducial marker is added to the data.

5.5   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:

5.5.1 Exit

Exit from the data acquisition of the current line and go back to the Line Number screen (See Figure 5-2 on page 70) to prepare for the collection of the next line.

5.5.2 Continue

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

5.5.3 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 5-7, left). If **Scale** is pressed a second time, a depth axis will appear on the left of the data image (Figure 5-7, right).
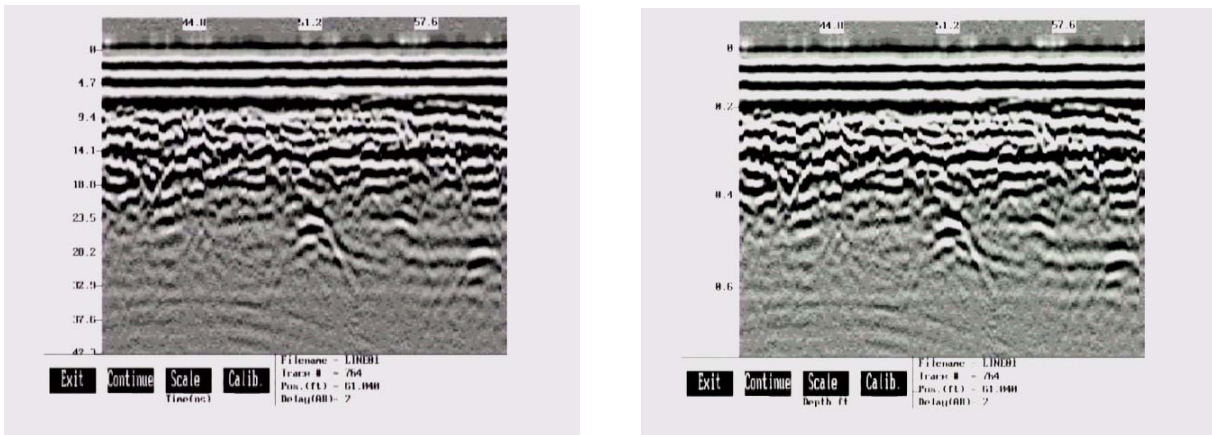
Figure 5-7: A time axis (left) and depth axis (right) can be plotted on the left of the data image by pausing the data collection and pressing Scale once for a time axis and twice for a depth axis.

The user should be aware that if an accurate depth axis is desired, the proper radar wave propagation velocity (see Section 3.2.6 Radar Velocity on page 39) must be used to generate the correct depth.

5.5.4   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 3.2.2.1: P35), 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.

5.5.4.1   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.
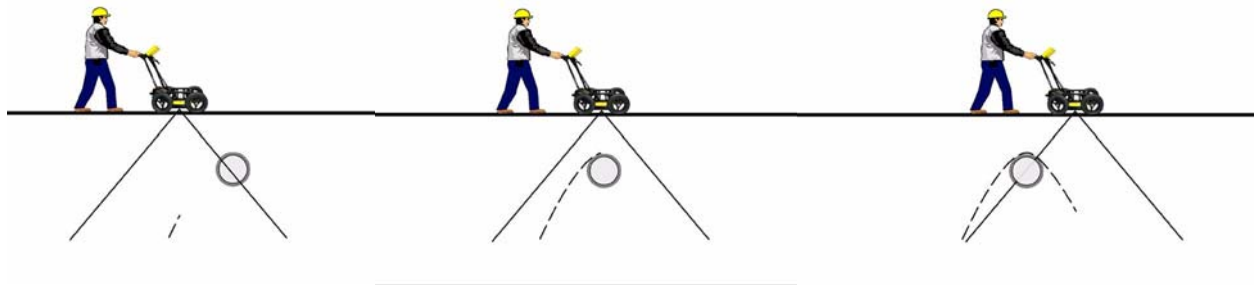

Figure 5-8: Hyperbolas in the data result from the conical shape of the GPR energy as it goes into the ground. Targets, like pipes, are detected as the GPR approaches them (left), passes over them (middle) and after it has passed by them (right) because the GPR energy propagates both in front and behind 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 5-9). 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.
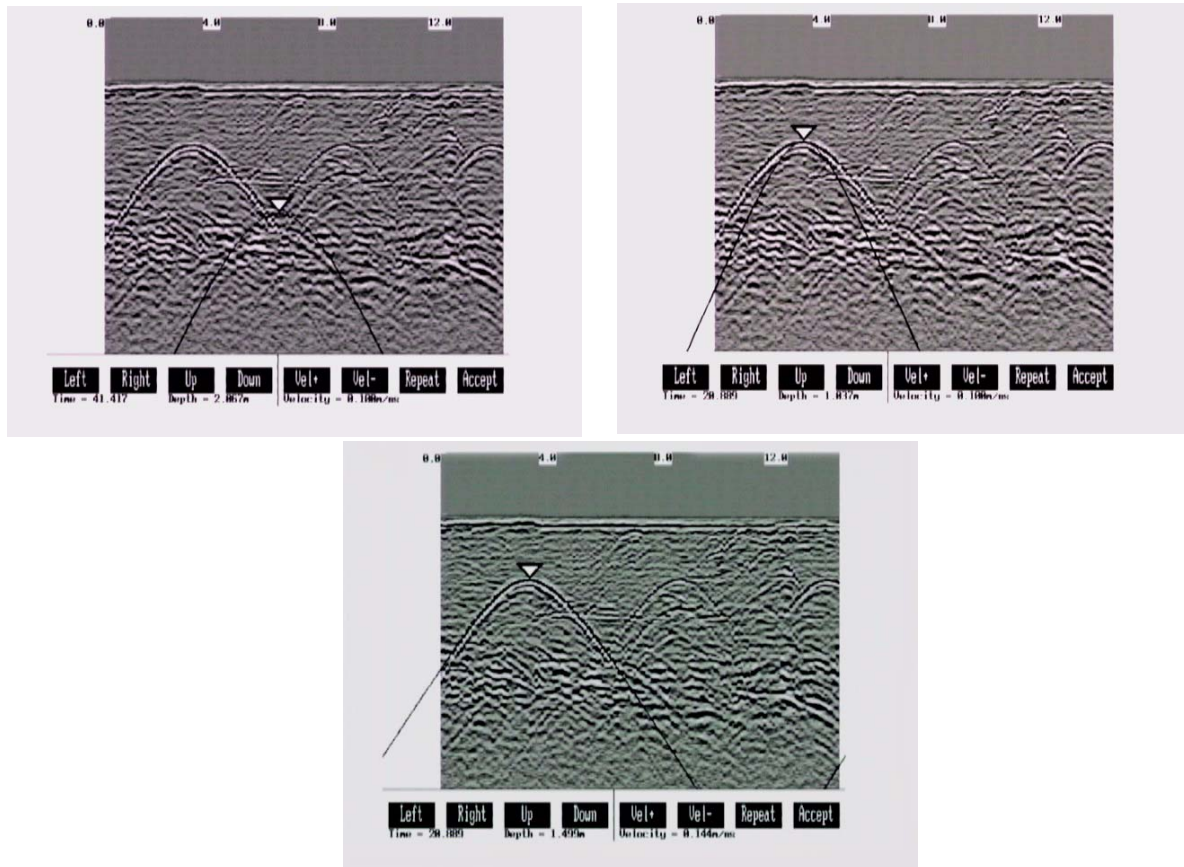

Figure 5-9: Hyperbola matching to extract velocity. After pressing the Calib button a hyperbola appears on the screen (top left). This hyperbola should be moved overtop of a hyperbola in the data using the Left, Right, Up and Down keys (top right). It can then be widened or narrowed to match the shape 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.

5.5.4.2   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).
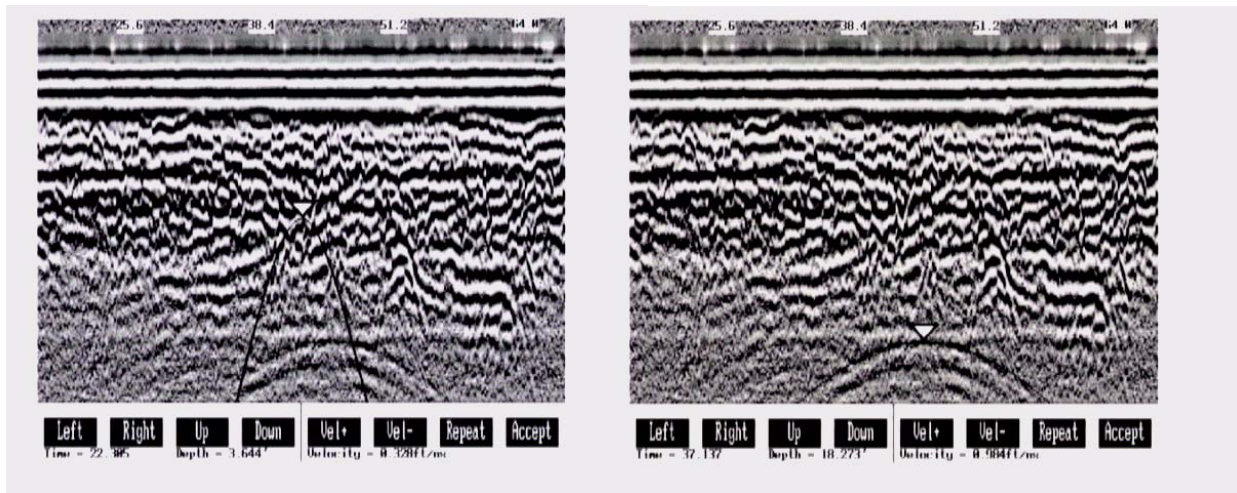

Figure 5-10: Hyperbola matching can be used to identify reflections from objects that are not in the subsurface but are from objects above ground. If the hyperbola matching velocity is near the speed of light (0.3 m/ns or 0.984 ft/ns) then the hyperbola was caused by surface object like a overhead wire, 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.

5.5.4.3   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.
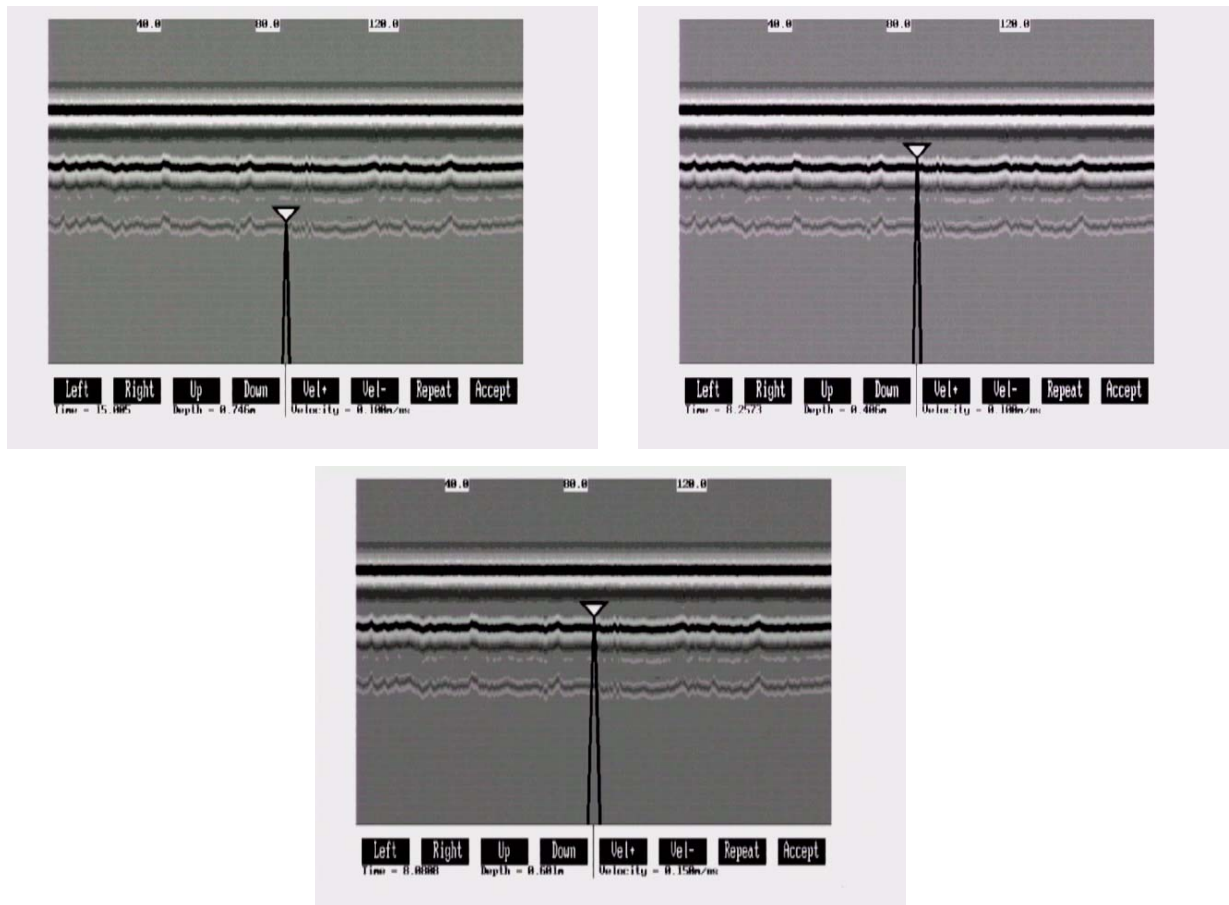

Figure 5-11: If a target of known depth is visible in the GPR data image, it is possible to use this target to determine the velocity of the material above the target. Ignoring the tails of the hyperbola superimposed on the data image (top left) and using the bottom tip of the triangle, use the Left, 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).

5.6   Collect Grid Data

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

5.6.1 Select Line Direction

The first screen will ask which line direction is being collected, X Lines or Y Lines. Refer to Section 3.4.6 GPR Grid Type on page 51 for definitions of X lines and Y lines.
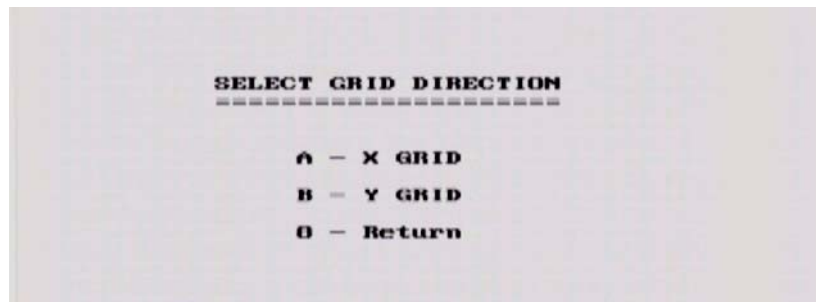

Figure 5-12: When collecting grid data, the direction of the lines (X or Y) needs to be determined.

5.6.2 Select Grid Line Number

The next screen displayed after selecting the line direction is shown in Figure 5-13. This screen is used to determine the number of the line to be collected.
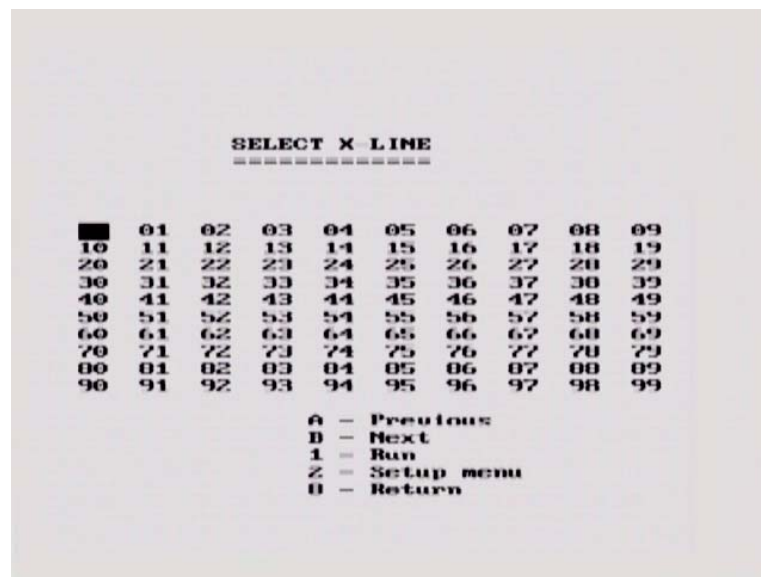
*Figure 5-13: Selecting Collect Grid Data from the menu shown in Figure 4-1 will display this screen used to select the number of the line to be collected. The default line number is the lowest line number available. As lines are collected, their associated number will appear in black on this screen. 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 5.3 Data Collection on page 70.

5.7   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.
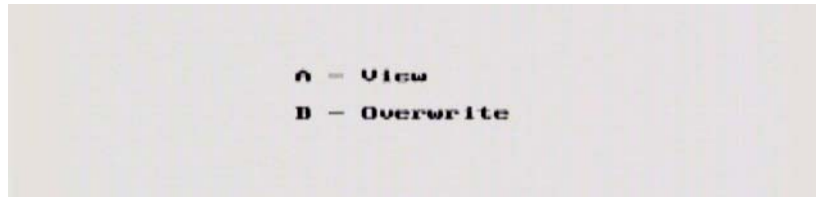
Figure 5-14: To view a previously collected data line on the DVL screen, select Collect Data and select an existing line number. When asked if you want to view the file or overwrite it, select View.

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

Figure 5-15: 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 5-16: Viewing an existing data line. The data image scrolls onto the screen just like during real data collection. The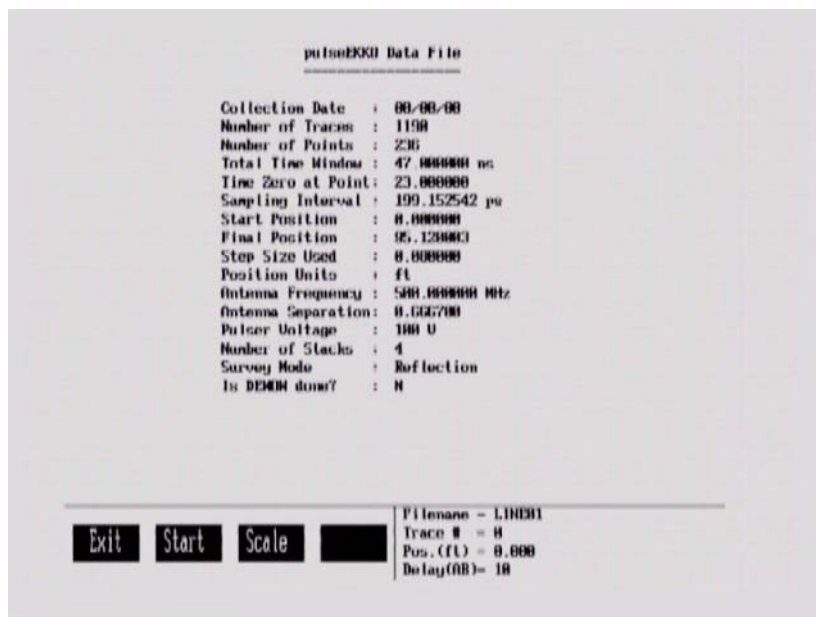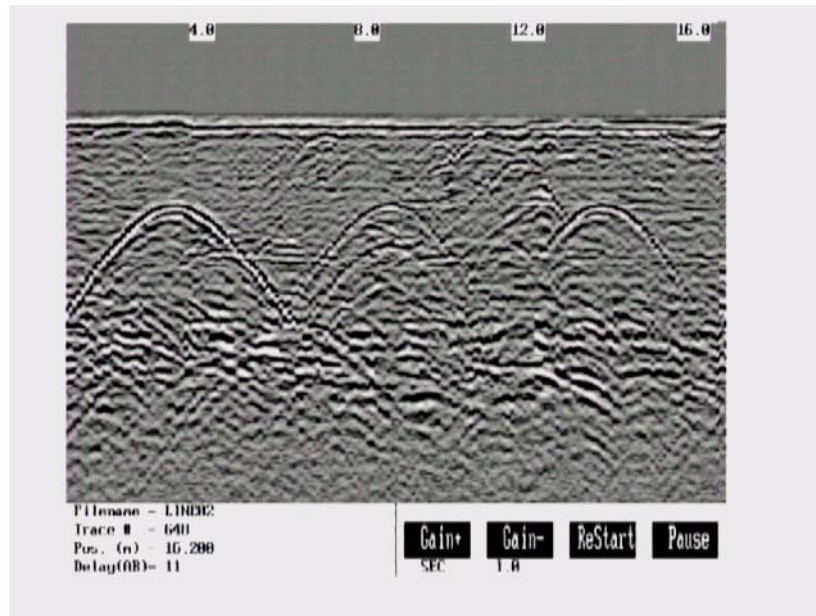 scroll speed can be increased and decreased using the A and B buttons. The line can be plotted with a different gain or use the Gain+ and Gain- buttons to increase and decrease the current gain value. ReStart will plot the line again.

Replaying data can be very useful because it allows the user to quickly modify the plot with different gains (Section 3.5.2: P58), and Trace Plotting Type (Section 3.5.1: P56) 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 5.5.4: P75).

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

5.8   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.

6   Surveying Techniques

6.1   Low Frequency Reflection (Profiling) Mode

6.1.1   Two Person Operation

The most common method of data acquisition in rough terrain will be with two people in a configuration shown below (Figure 6-1). 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 3.3.1.1: P43). A third option is to run the system in free Run mode (Section 3.3.1.3: P43) with a time delay between traces (Section 3.3.3: P44).

Figure 6-1: 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 6-4).

6.1.2   One Person Operation

One person operation is performed in the configuration shown below (Figure 6-2) with the optional DVL carrier (Section 2.5.3: P23) and the fibre optic beeper/trigger (Section 2.5.2: P20).

Figure 6-2:   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.

6.1.3   Strain Relief for Fibre Optic Cables
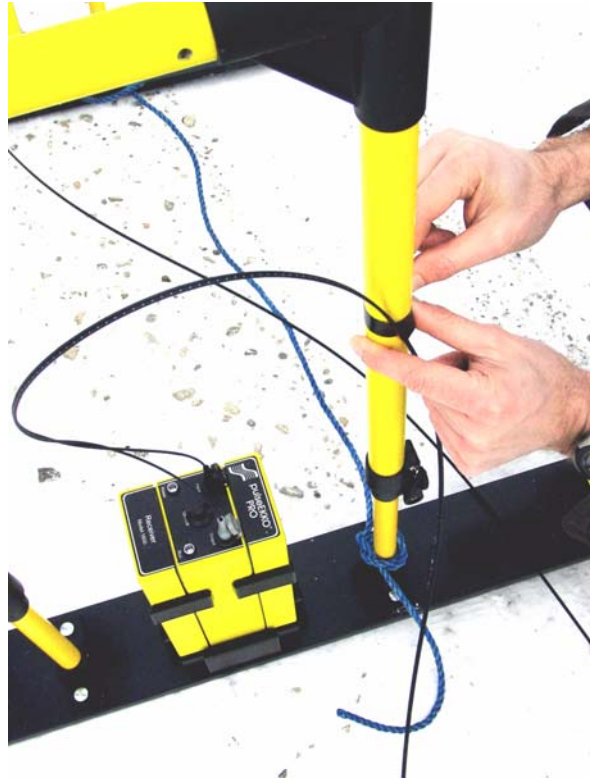
Figure 6-3: Fibre optic cables can be broken or damaged if care is not taken. The most common breakage point is right at the connectors when the cables are snagged or pulled hard. Protect the fibre optic cables by making a strain relief. Take an extra loop of cable and tape it to the handle. That way, if the cable gets pulled, the strain is taken up by the tape and not the cable.

6.1.4   Maintaining Proper Antenna Separation
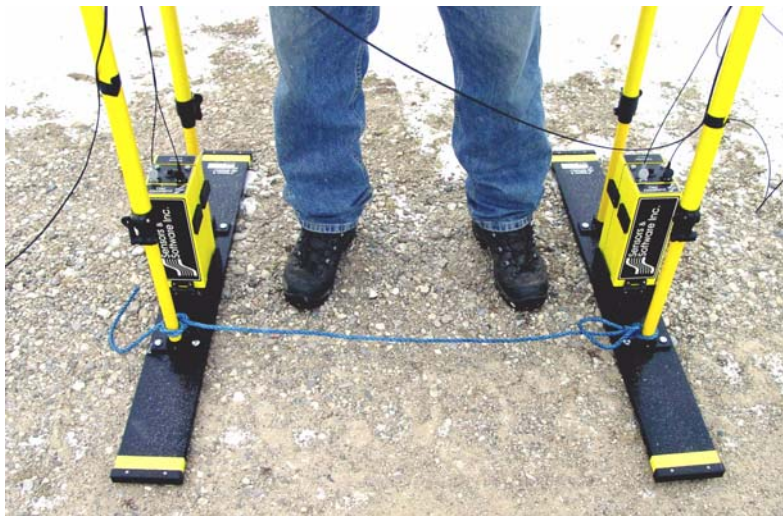
Figure 6-4: When using the adjustable handles, the antenna separation can be maintained by using a length of rope tied between the antennas.

6.1.5 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 6-5).

6.2   High Frequency Reflection (Profiling) Mode

6.2.1 Tow Mode Operation

One method of data acquisition in smooth terrain is the tow mode configuration shown below (Figure 6-1). 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 the Big Wheel odometer, as shown below.

It is also possible to remove the odometer and control data acquisition using the electrical beeper/trigger or the DVL button (Section 3.3.1.1: P43).

A third option is to run the system in free Run mode (Section 3.3.1.3: P43) with a time delay between traces (Section 3.3.3: P44).

Figure 6-5: High frequency tow mode 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.

6.3   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.
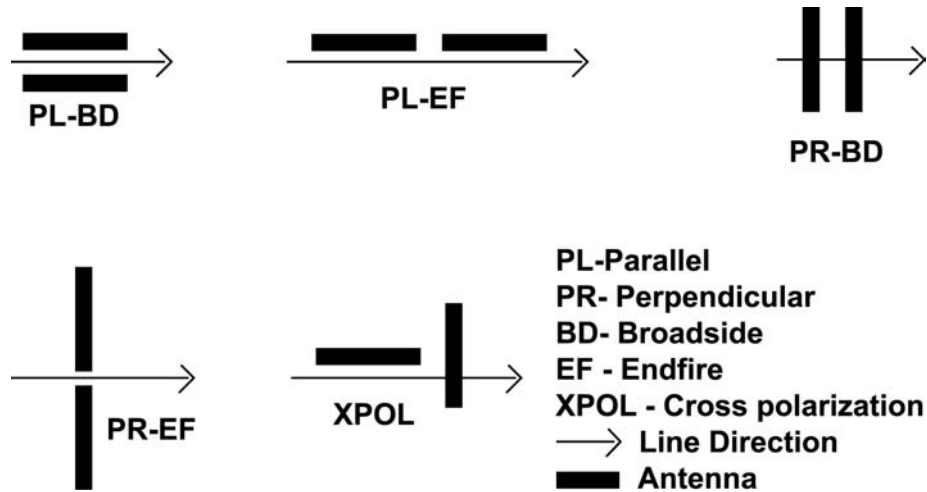
Figure 6-6: Definitions of antenna orientations available with bistatic antennas. Perpendicular-Broadside (PR-BD) is most commonly used for reflection surveys.

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 6-7: 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.

6.4   Triggers

If the Trigger Method is set to CANBUS, 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 6-7.

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 5.4.1: P73) can be added at known positions so the data can be "rubberbanded" during post-survey editing.

6.5   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 6-7.

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 5.4.1: P73) can be added at known positions so the data can be "rubberbanded" during post-survey editing.

6.6   Odometer Data Acquisition

Data acquisition can be controlled by an odometer triggering the radar system to collect data at specified step sizes (Section 3.3.1.2: P43). There are several odometers available for the pulseEKKO PRO system including the Big Wheel Odometer (See Figure 2-23 on page 17), SmartCart odometer (Figure 6-8) and the vehicle odometer (contact Sensors & Software for more details).

Figure 6-8: The pulseEKKO PRO SmartCart has an odometer to trigger the system to collect data at an equal step size defined by the user.

6.6.1 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.

If maintaining speed is important, the other option is to reduce the time window (Section 3.2.2: P35) or number of stacks (Section 3.2.7: P40) 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 3.2.3: P36).

6.6.2 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.

6.7   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).

6.8   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 3.2.5: P38).

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.

6.9   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.

6.10   Adding GPS for Positioning

Figure 6-9: Two person (left) and one person (right) system configurations with GPS added. Ideally, the GPS should be positioned near the mid-point of the GPR antennas.

6.11 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 6-10). The resulting data can then be processed using a semblance analysis routine to extract average velocities to the reflectors (Figure 6-11). The extracted velocities can then be used when adding a depth axis for other GPR survey lines collected in the area of the CMP.
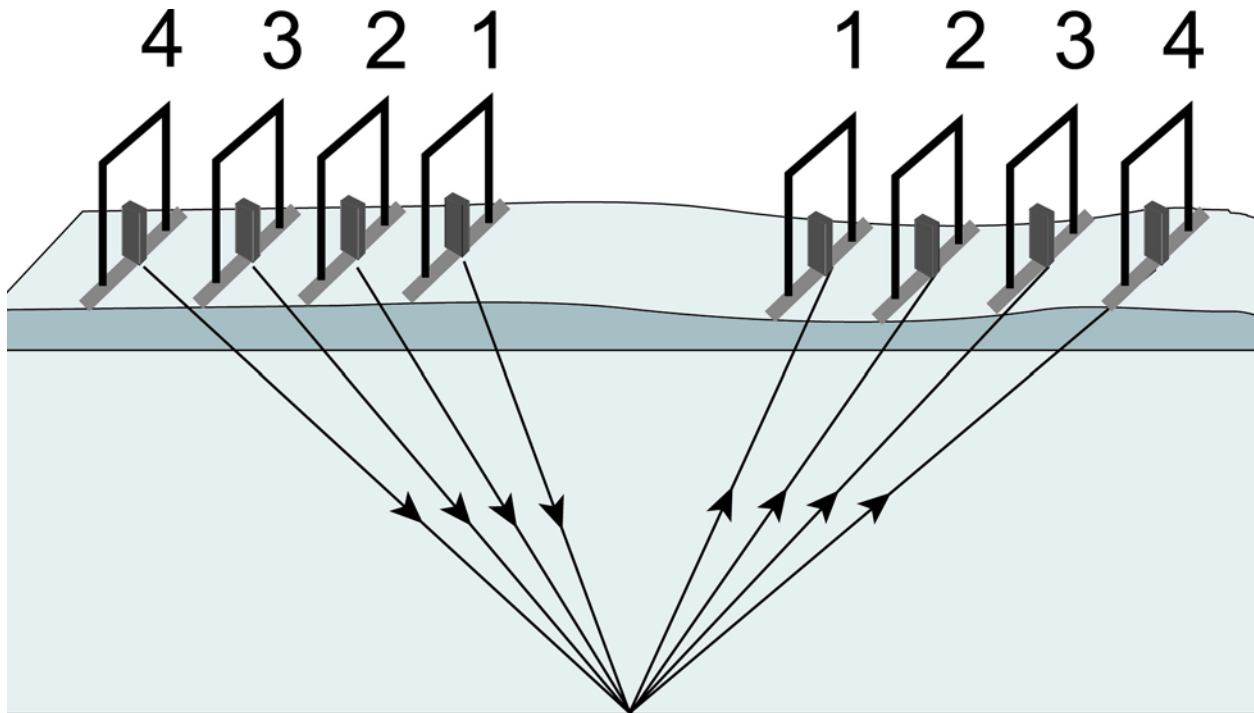

Figure 6-10: CMP setup. CMP surveys are used to measure the GPR velocity to a reflector or series of reflectors. Each trace is collected with the antennas at a larger separation resulting in an increased travel path length and therefore increased travel time. The data can be analyzed with a semblance 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.

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 10.2: P117) 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 3.2.4: P37). 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 3.4.5: P51).

6) Under **Survey Parameters**, set the **Start Position** value to the starting antenna separation (Section 3.4.1: P50).

7) Set the **Step Size** (Section 3.2.5: P38) 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 3.3.1.1: P43). If a third person is available for data acquisition, set the system in CANBUS 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 3.3.1.3: P43) so data collection occurs based on time and put a 2-5 second (or longer) delay between traces (Section 3.3.3: P44) 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 6-11 is a good example.
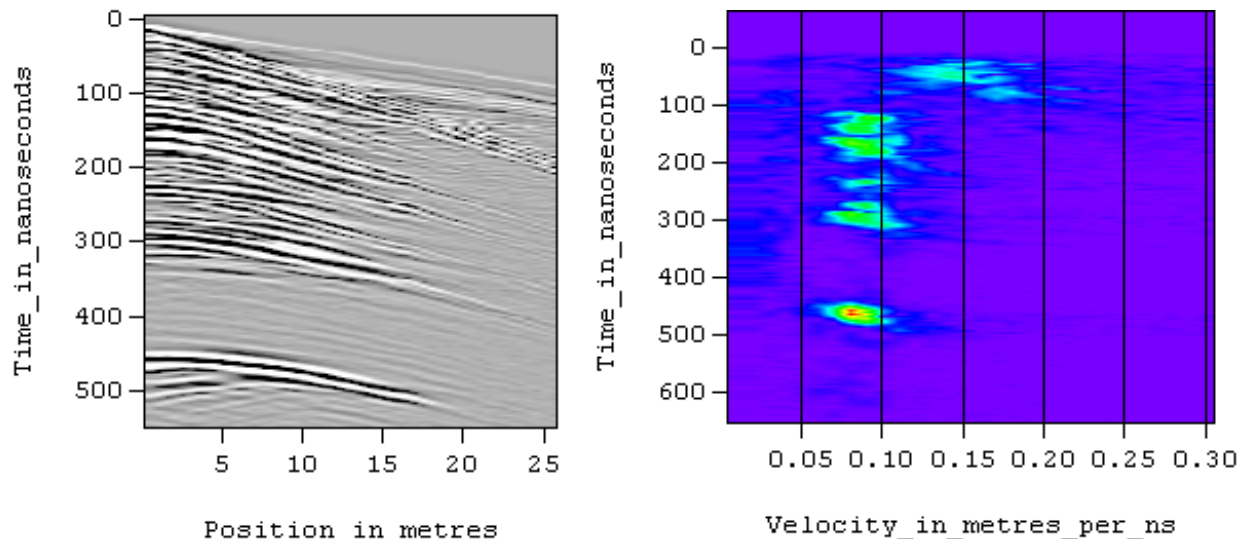

Figure 6-11: CMP survey data (left) can be processed to produce an average velocity section (right) that shows high amplitudes (bulls-eyes) indicating the average velocity to each reflector.

6.12 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 5: P69) with a trigger used to initiate trace acquisition once the transmitter and receiver are properly positioned.

6.12.1 Borehole GPR

The most common type of transillumination survey is cross hole GPR conducted between boreholes (Figure 6-12) or from a borehole to the surface. This type of survey requires the use of borehole antennas (Figure 6-13).

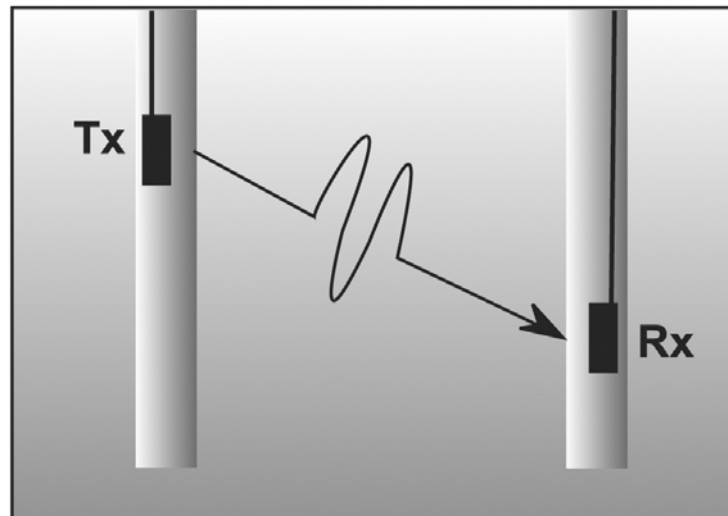*Figure 6-12: Cross hole transillumination surveys send signal from the transmitting antenna in one borehole to the receiving antenna in another borehole. If this is done with the antennas at many different positions to collect data at many different raypaths between the boreholes, travel times, amplitude variations and signal period changes can be analyzed to produce images of velocity, attenuation and dispersion.*

Figure 6-13: 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.

6.12.2 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 6-14: Transillumination survey setup. 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.

7   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 7-1).

Figure 7-1: 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 3.6.4: P64).

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 7-2) 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 2-29 on page 22).

Also, ensure that the software settings for the transmitter are correct for the transmitter that you are using with the system (Section 3.2.8: P41).

Figure 7-2: 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.

7.1 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.

7.1.1 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 2-34 on page 25). The input voltage tolerance is 10.2 volts to 15 volts. The standard belt battery supplied with the system (See Figure 2-34 on page 25) is a 7 Amp-hr. battery that should power the DVL and the control module for approximately 8 hours.

If there is enough power to run the DVL, the upper red LED on the front of the DVL 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.

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 the DVL turns on, the voltage of the battery can be monitored from the main menu (See Figure 2-36 on page 27).

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.

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 7-3) and try running the system again.

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

Figure 7-3: Belt battery (right) used to power the DVL and Control Module. The battery charger is shown on the left.

Smart System 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.

7.1.2 Transducer Power Requirements

The pulseEKKO PRO high frequency transducers (See Figure 2-19 on page 14) 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.

7.1.3 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.

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 7-4).

Charge batteries at room temperature whenever possible.

The receiver and transmitter contain a voltage monitoring circuit that will cause the Power LED on top of the units to slowly flash when the battery voltage is getting low. When this occurs, batteries should be replaced as soon as possible. If the batteries are not replaced and the voltage continues to drop, the unit will eventually turn off.

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 7-4: 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.

7.1.4 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.

7.2   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 7-5. The feedthrough connector located in the spare parts kit (See Figure 9-1 on page 111). 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 9.6: P113).
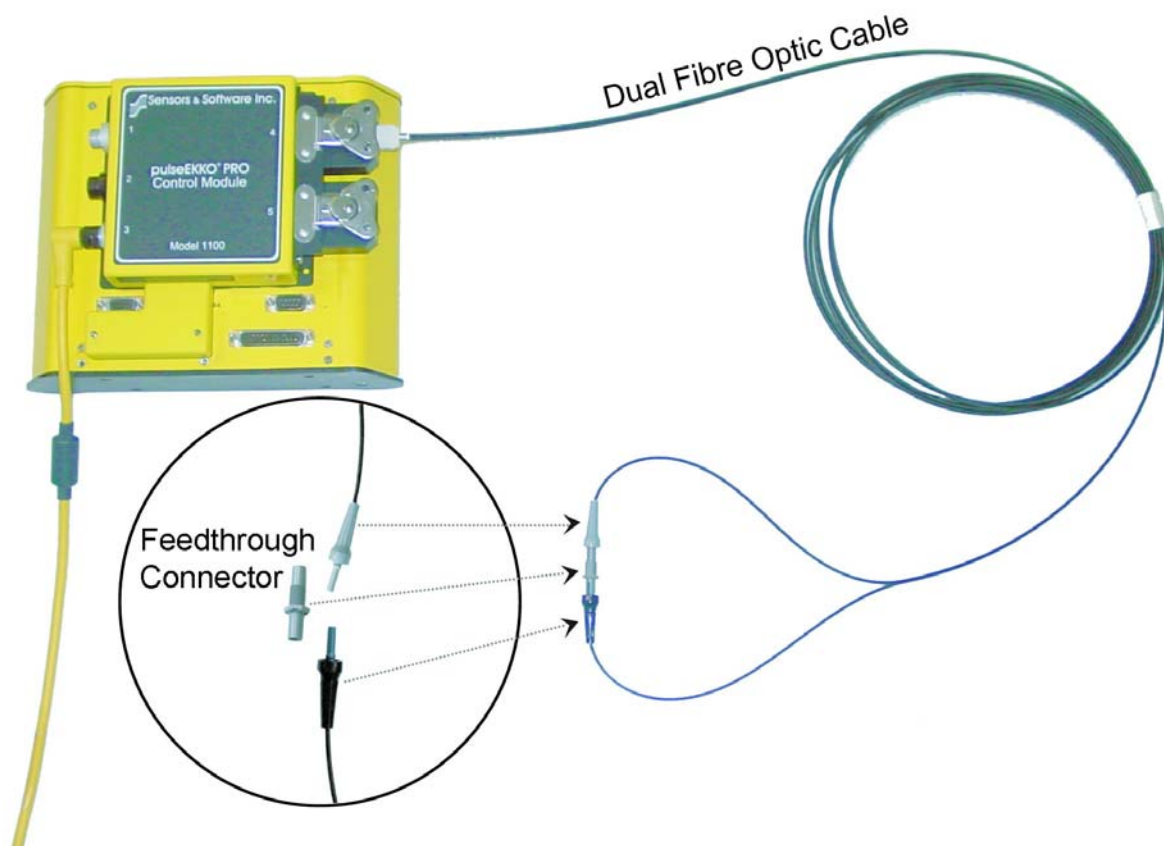
Figure 7-5: Setup for fibre optic cable testing. Make sure that the cable is plugged into the control module receptacle number 4 and the loose ends of the cable are connected together using the feedthrough connector.

Figure 7-6: After connecting the fibre optic cable as shown in Figure 7-5, select System Setup - Acquisition Control - Fibre Optic Testing.

Figure 7-7: The fibre optic test routine will continuously test the cable. During the tests, gently move the cable around, especially near the connectors, to see if a failure occurs. If so, repair or replace the fibre optic cable.

7.3   Control Module Related Errors

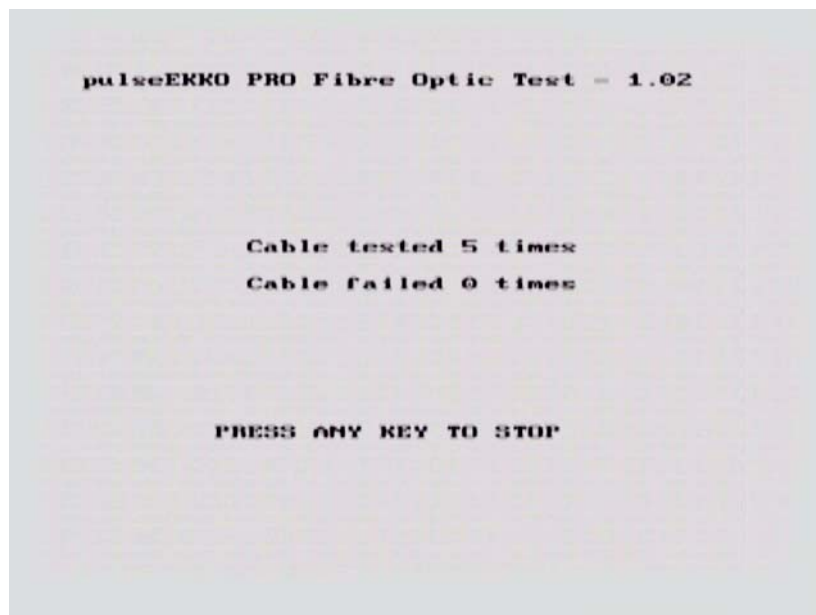Control Module related errors are generated whenever the DVL fails to communicate with the control module for any reason.

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.

7.4   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.

7.5   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 7.10: P103).

7.6   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 7.10: P103).

7.7   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 7.10: P103).

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.

7.8   Timezero Jitter

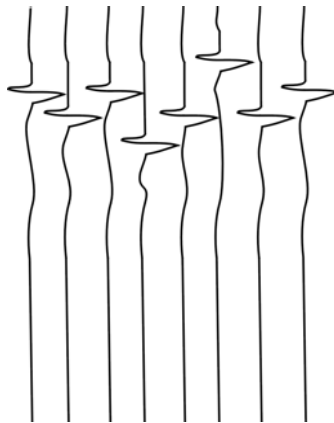If the first break is shifting up and down as shown below:

Figure 7-8: 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 7.2: P99) 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 9-1). Before attempting to clean or replace these cables, contact Sensors & Software (see below).

7.9   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 6.9: P90). 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.

7.10   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.).

8   File Management

From the main menu (See Figure 2-36 on page 27), pressing the 2 button selects **File Management**.

GPR data directories and files collected on a DVL can be transferred to an external computer or deleted from the DVL.

```
FILE MANAGEMENT
================

1 - Transfer Directory
2 - Transfer File
3 - Delete Directory
4 - Delete File
5 - View Disk Space



8 - Return
```

File Management Options 1 and 2 (Transfer Directory and Transfer File) require that the DVL be connected to a PC to allow for data transfer.

8.1   Connecting the DVL to a PC

To transfer all the data files in one directory 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 8-1). 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 (Section 8.2 on page 106).

To transfer data from a DVL a cable called the parallel XFER (PXFER) cable is required. This cable is designed to connect the DVL to an external computer.
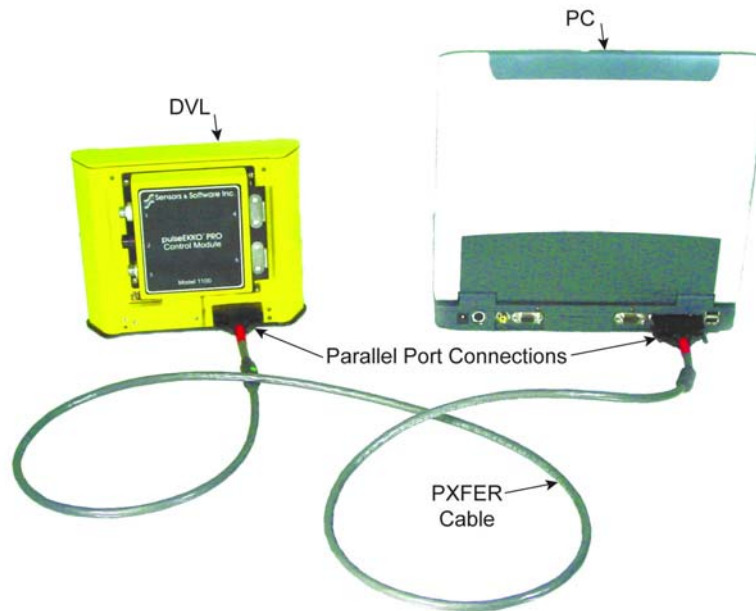

Figure 8-1: Parallel PXFER cable connections

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 Digital Video Logger, 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.

8.2   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.

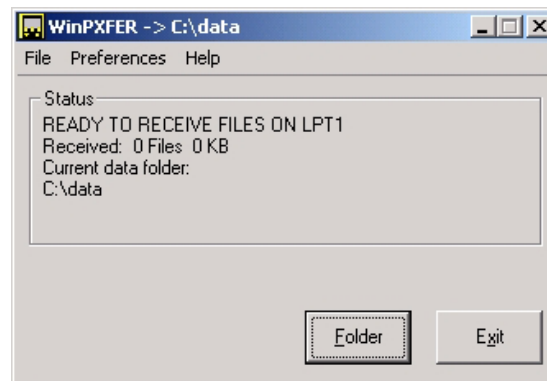The first time that WinPXFER is run, it will install a driver.

Figure 8-2: 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.

8.3   Transfer Directory

Once the parallel XFER cable is connected (Section 8.1 on page 105) and the WinPXFER software is installed and running (Section 8.2 on page 106), 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 8-3). 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.
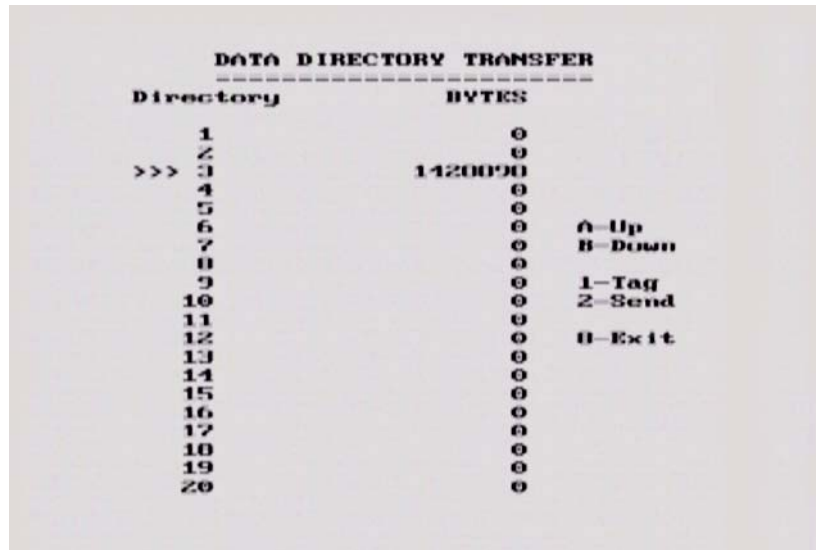
Figure 8-3: Data Directory Transfer screen. The triple arrows (>>>) on the left indicates which directory is currently selected. Use the A and B buttons to move the arrows up or down to different directories. To transfer the directory to the PC, press the 2 (Send) button. It is also possible to use the 1 button to Tag several directories so they can all be sent at once.

8.4   Transfer File

Once the parallel XFER cable is connected (Section 8.1 on page 105) and the WinPXFER software is installed and running (Section 8.2 on page 106), 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 8-4), 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.
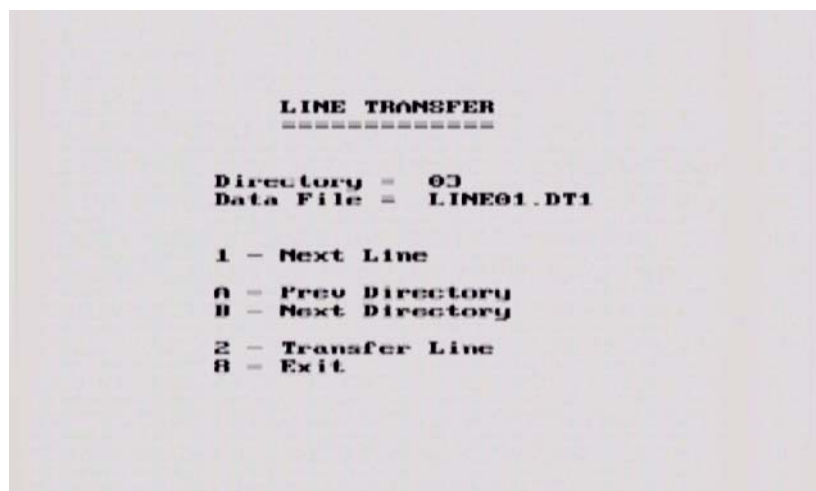

Figure 8-4: Line Transfer screen. Use the A and B button to select one of the 20 available directories, then use the 1 button (Next Line) to move through the data lines in the directory. When the name of the data line to transfer appears, press 2 (Transfer Line) to send it to the PC.

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.

8.5   Delete Directory

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 8-5). 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

Figure 8-5: 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.

pulseEKKO PRO   8-File Management

8.6   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 8-6), 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 8-6: 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.

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8.7   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.

```
APPROXIMATE DISK SPACE REMAINING
================================
          (using FIXED disk)
    Total Disk       = 512180  kB
    Total Used       = 464330  kB
    Total Free       = 47841 kB
    Disk Space       = 10%
    Total Traces     = 76180
    Total Distance   = 38090.2 m


          PRESS ANY KEY
```

Figure 8-7: 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.

8.8   Viewing Data Files on the External PC

Once GPR data files have been transferred to a PC they can be edited, processed and plotted using other software from Sensors & Software like EKKO_View, EKKO_Mapper and EKKO_3D. These programs are available from Sensors & Software Inc.

9   Care and Maintenance

9.1   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.

9.2   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 9-1, are shown in Figure 9-2.

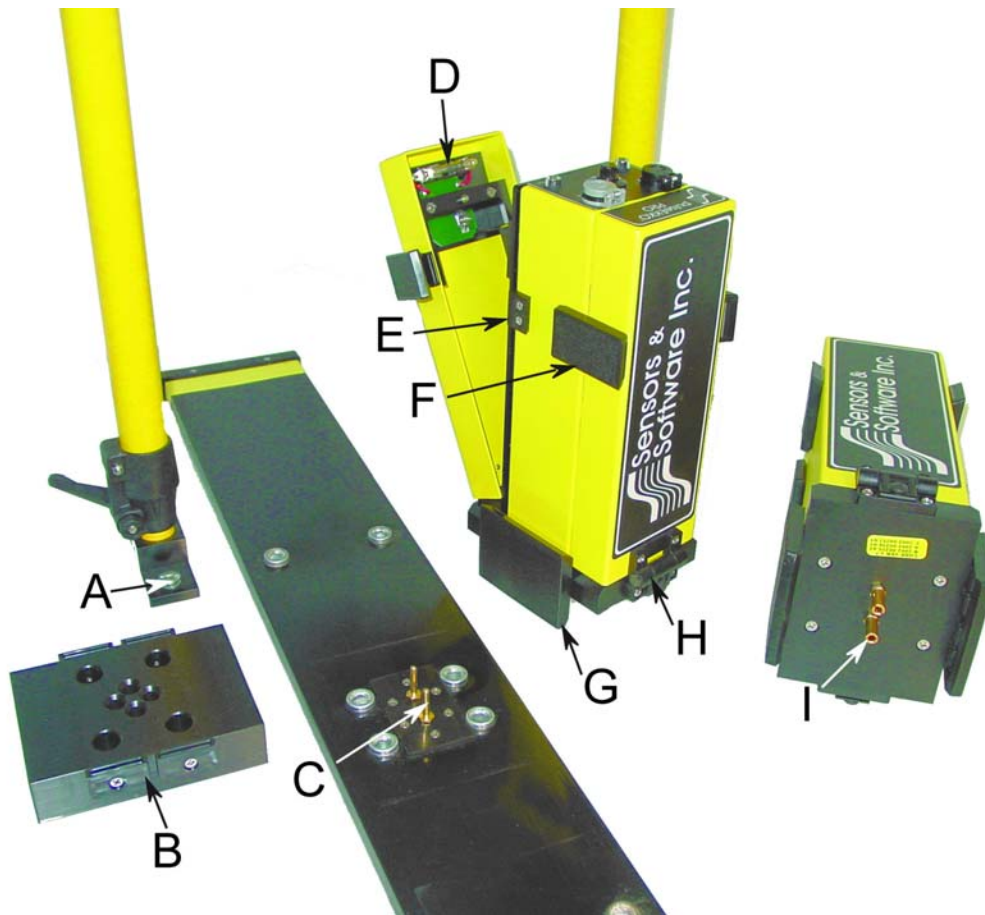*Figure 9-1: Electronic spares kit.*

Figure 9-2: Location of spare parts shown in Figure 9-1.

9.3   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.

9.4   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.

9.5   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 6-3). 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 7.8: P102). 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 9-1). These short cables may need cleaning and polishing from time to time.

9.6   Fibre Optics Cable Repair

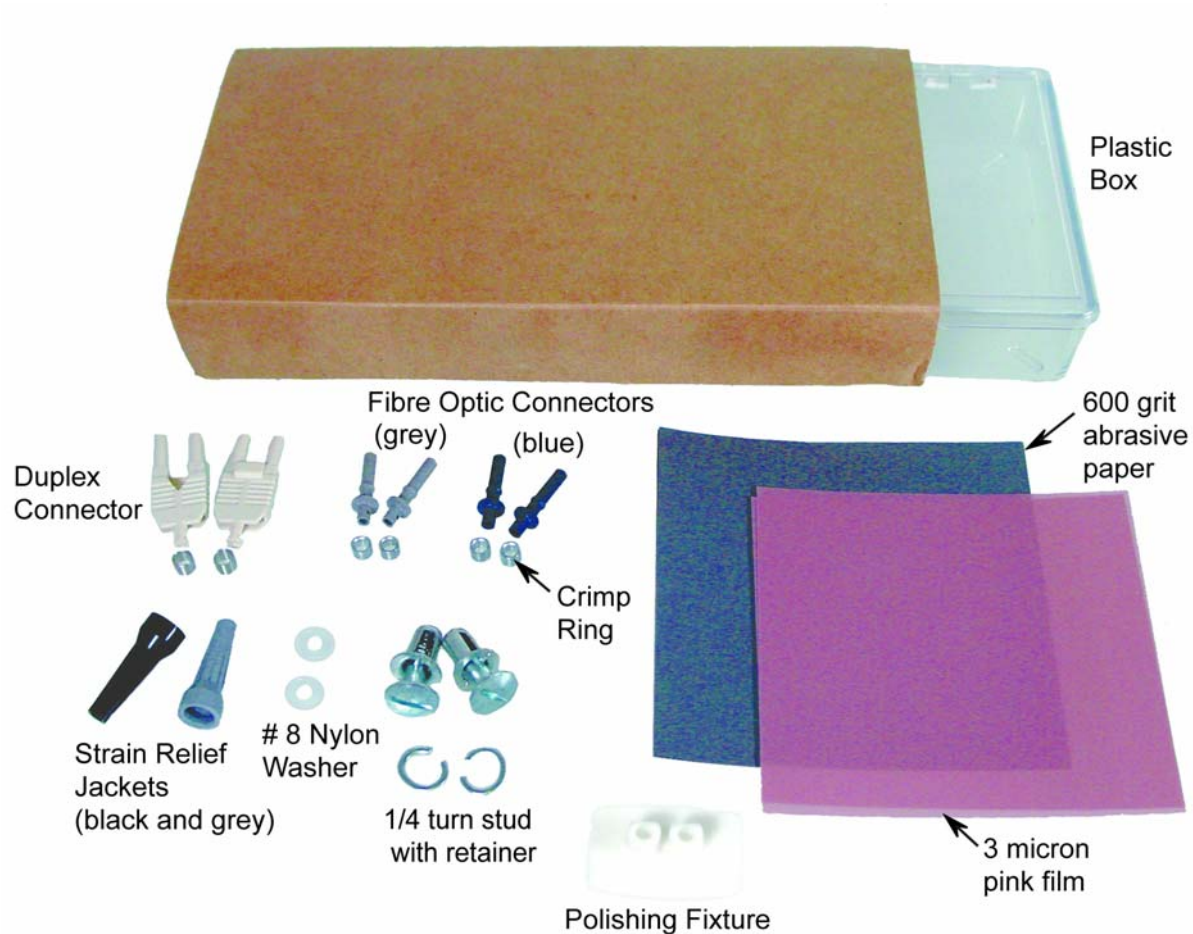The low frequency pulseEKKO PRO comes with a fibre optic repair kit (Figure 9-3).

Figure 9-3: 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)
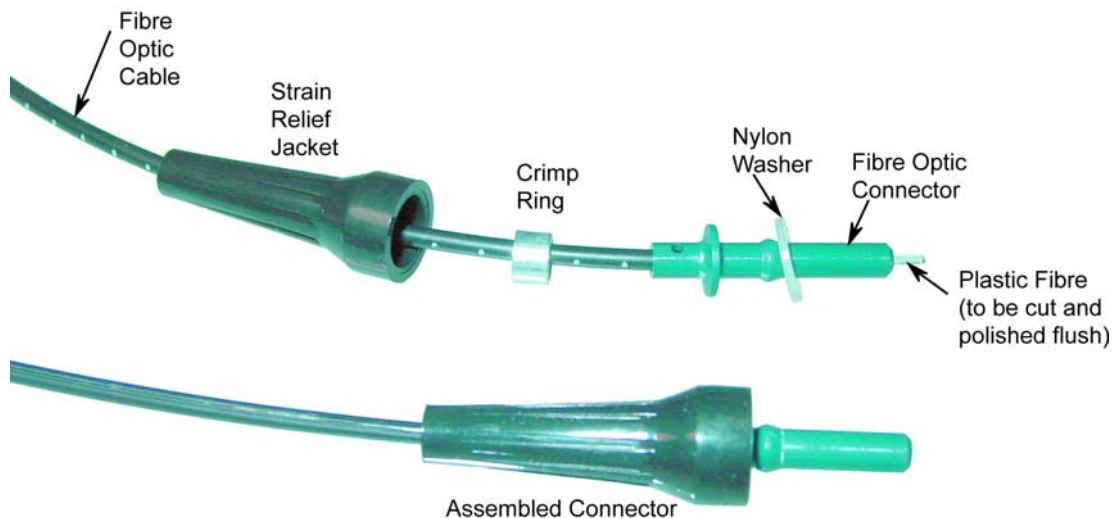

Figure 9-4: Assembling fibre optic connectors.

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.

10 Helpful Hints

10.1 Batteries

Replace batteries before they go dead. Nothing is more annoying than losing data in the middle of a traverse. Carry plenty of spares.

10.2 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.

10.3 Data Files

Backup data often or at least at the end of each survey day.

10.4 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	(not used)
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.
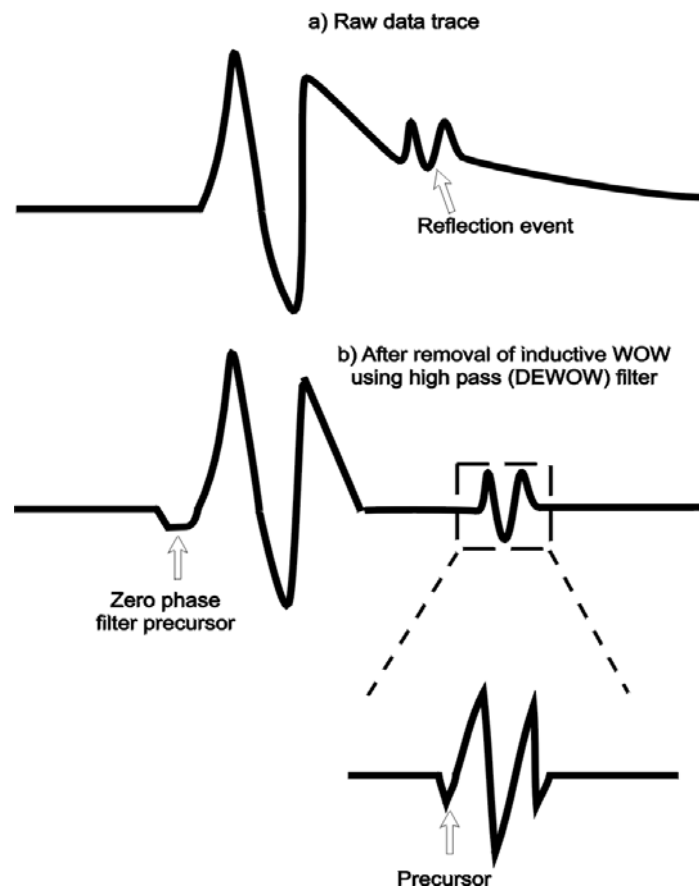

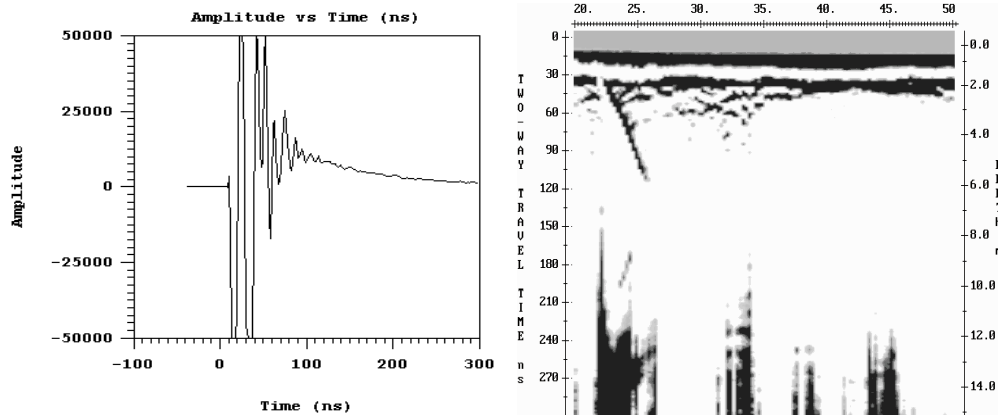*Figure B-1:   Effect of inductive WOW on GPR data.*

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.
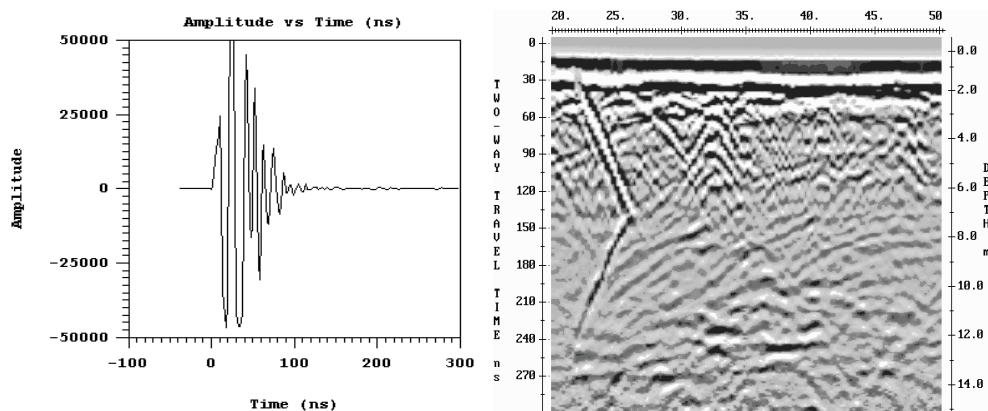

Figure B-3:   Display of a single data trace (left) and data section (right) where the Wow seen in the figure above has been removed with the Dewow high pass filter.

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.
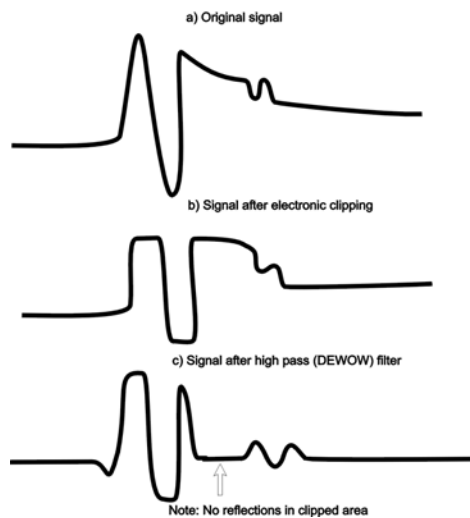

a) Original signal

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
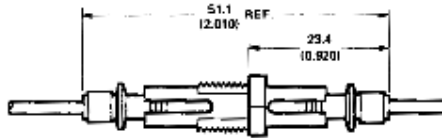
DIMENSIONS IN MILLIMETRES (INCHES)

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		α_{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 α_{CC} are for 0°C to 70°C temperature range. Typical value of α_{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.
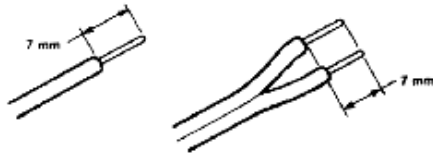

Step 2

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.*
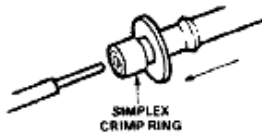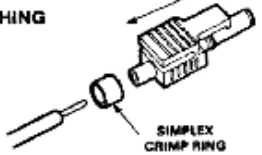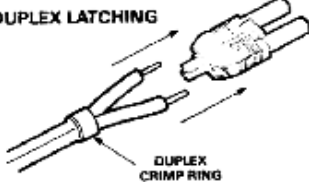

Step 3

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.
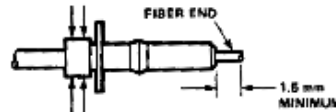

Step 4

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.*
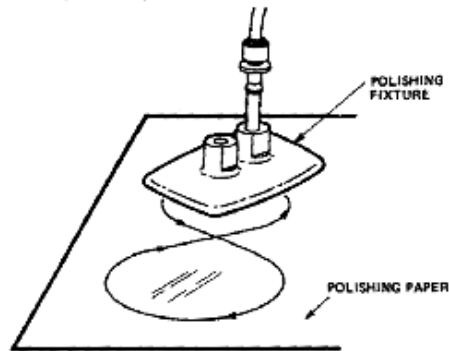
For simultaneous multiple connector polishing techniques please contact Hewlett-Packard.

HFBR-4593 POLISHING KIT
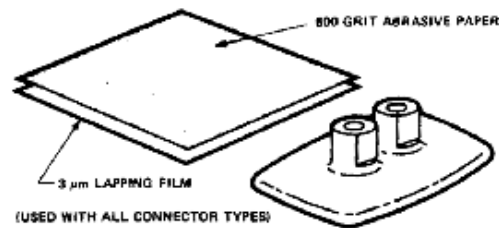
Appendix D: Health & Safety Certification

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.
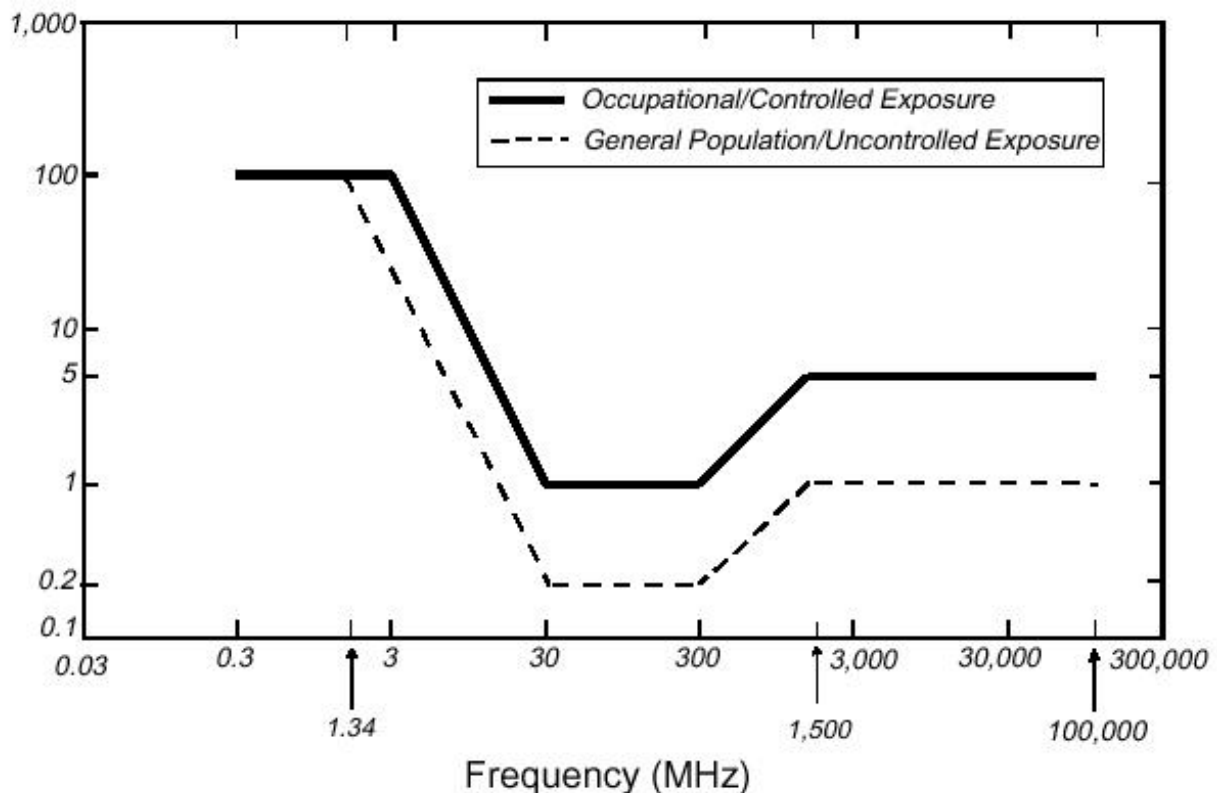

Figure D-1: FCC limits for maximum permissible exposure (MPE) plane-wave equivalent power density mW/cm^2.

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: 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) requires users of GPR equipment to coordinate the use of their GPR equipment as described below:

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 the following address:

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

ATTN: UWB Coordination

The form given on the following page is a suggested format for performing the coordination.

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 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination
Fax: 202-418-1944

INFORMATION PROVIDED IS DEEMED CONFIDENTIAL

Appendix F: Instrument Interference

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

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

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

Appendix 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.