RADAN® 6.6 Manual

MN43-171 Rev H

Geophysical Survey Systems, Inc.
40 Simon Street • Nashua, NH 03060-3075 USA • www.geophysical.com

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Part 3: Interactive 3D Module (if purchased)

Chapter 1: Getting Started

Thank you for purchasing RADAN 6.6 (hereafter referred to as RADAN). The packing list included with your shipment lists all of the items in your order. The RADAN program and example files are stored on a single CD-ROM disk included in the RADAN package.

System Requirements

- A Pentium 4 or better processor (1 GHz or greater recommended)
- USB Port required for hardware security key
- GSSI will only support RADAN running on Windows XP Professional or Vista Business Edition.

  Note: While some laptops or desktops will say Vista ready, a Windows Vista Business Edition requires a minimum 1 GHz 32- or 64-bit processor; 1GB of RAM; support for DirectX 9 graphics with a WDDM driver, 128MB of graphics memory, Pixel Shader 2.0, and 32 bits per pixel; 40GB hard drive with 15GB free space; DVDE-ROM drive; audio output capability, and the ability to access the Internet. While RADAN itself doesn't require all this, Vista does.
- 256 MB of RAM minimum (512 MB or greater recommended)
- A 32 MB video card running in at least 32-bit color mode that supports Open GL and has up-to-date video drivers. We recommend nVidia GeForce or higher chipsets. Avoid any chipset that is no longer manufactured including S3 and 3DFX products and avoid SIS integrated chipsets.
- All Panasonic ToughBooks currently supplied with the new SIR-20 and StructureScan Professional systems have been qualified to run RADAN 6.6. RADAN 6.6 is unavailable for Model CF-27 Panasonic ToughBooks. Please contact GSSI with your SIR-20's serial number before beginning any upgrade procedure. You may be required to send in your system for a factory upgrade.

USB Keys and GSSI Activation Policies

- RADAN requires a hardware key that fits into your computer's USB port. RADAN also has a software registration key that GSSI will provide you once you install the software. Please see the RADAN installation guide on the RADAN CD or online at support.geophysical.com for installation and activation instructions.
- Your RADAN license includes one USB key and five software activations. Once your software is activated, you can run your purchased modules unrestricted as long as the USB key is inserted. The software will only run if you have the key inserted. You may activate up to a maximum of five computers (or the same computer 5 times), but RADAN will only run if the key is inserted. GSSI recommends that you reserve at least 2 activations in case of computer failures or upgrades to a new Windows OS or a complete reinstall of an existing operating system.
- Additional USB keys are available at the site license price. Each site license includes an additional 5 activations.

- If your key is damaged, you can obtain a replacement at a cost of $150. The damaged key must be returned to GSSI within 4 weeks of receiving the new key. If it is not received, GSSI will have to charge you the cost for a site license. In order for GSSI to ship a new key prior to receiving the damaged one, you must supply a valid credit card number.
- If your key is lost or stolen, you may purchase a new key at the site license price.
- SIR-20 and PathFinder systems do not require the USB key and come with no extra activations for other computers.
- Please make sure that your chosen computer meets the minimum requirements for RADAN and is a stable platform. Reinstallation or upgrade of your computer's operating system that requires the re-activation of RADAN will be counted toward your 5 activations.

New Features Included on a Trial Basis

This version of RADAN 6.6 includes some new features. These features are identified as such in the section in which they are discussed. They are provided free of charge in RADAN version 6.6 on a trial basis. In future versions of RADAN, GSSI may, at its discretion, unbundle these features and establish them in a new module which will be available as a separate purchase. This may result in functionality being available for free to users of v.6, but requiring a separate fee for v.7. This fee will be in addition to any upgrade fee that GSSI charges. GSSI regrets any confusion that this may cause.

General Description

In order to solve the complex subsurface problems of today GSSI Subsurface Interface Radar (SIR®) Systems have the capability of acquiring data at very high rates (up to 1 MB per 10 seconds) resulting in very large data sets. This resulted in a need for a radar processing program that could manipulate and store large data sets and implement fast processing algorithms.

RADAN was created to fill this need, and to provide both novice and experienced GPR users with processing capabilities using a Windows XP Pro or Vista format, making processing radar images easy.

The RADAN software package consists of a Main module and add-on modules. The RADAN Main module (henceforth called RADAN) provides all of the tools to display, process, analyze, interpret and present ground penetrating radar data for most applications. The Main module is required when using the optional add on modules. This manual describes operation of the Main module only.

RADAN Main module can perform the following functions:

- Display multiple screens of radar data as linescan (color-amplitude plots), wiggle trace, oscilloscope.
- Manipulate color table and color transform parameters to enhance data display.
- Edit file headers and distance markers.
- Process individual files in Macro Programming Mode.
- Process multiple files using Project Processing.
- Modify or restore data gains.
- Correct position (shift data scans along the time axis).
- Provide horizontal scaling and distance normalization.
- Incorporate topographic changes with top surface normalization.
- Display the frequency spectrum of data.
- Apply Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) filters.

- Spatial Filtering (2 Dimensional/F-K filter).
- Perform migration.
- Perform Predictive Deconvolution.
- Perform Envelope processing functions (Hilbert Transform).
- Velocity analysis.
- Local Peak Interpretation.
- Interactive Interpretation.
- Print to all Windows supported printers.

How To Use This Manual

This manual is designed for both experienced and novice users of RADAN. We recommend that all users read the entire manual and go through at least some of the tutorials. However, if you are not sure you will do this, we can make the following recommendations:

All RADAN users should read Chapters 1, 2, and 3 to help install this program, input data, and get a general overview of RADAN features.

Beginners should go through the Tutorials (Chapter 4) to learn RADAN basic operation.

Installing and Starting RADAN

1 Insert the RADAN CD into your computer's CD drive.

2 The installation program should start automatically. Follow instructions on screen. If the program did not start automatically, move on to Step 3.

3 Double-click on the CD drive that the RADAN disk is in. It is probably Drive D: or E:.

4 Find the Start Icon and double-click it. 

5 Follow on-screen instructions.

Each time you open RADAN Main you will get a message with two choices;

1. Activate Now
2. Activate Later

If you select **Activate Later** you can proceed with using RADAN for a limited number of uses. A counter shows how many times you have used the RADAN software.

If you select **Activate Now**, you will see a window with 2 User Codes and 2 blank boxes for Registration Keys. Write down the User Codes and visit http://support.geophysical.com for software activation. You do not need to type in "www." You will be given Registration Keys to unlock those modules that you purchased.

Data Sources and Input for RADAN

For information on transferring data from different sources for analysis with RADAN please refer to Appendix A.

Changing Program Defaults

1 To change RADAN's file source and output default directories, after starting the program, close all data files.

2 Select View > Customize. There are four tabs under the Customize menu: Directories, Appearance, Linear Units and SIRveyor.

Directories: Source is the default directory for input data files and Output is the default directory for output data files. We recommend you set Source and Output as different directories. This will prevent accidentally saving over raw data. Create the directories in Windows. Clicking on the Source or Output buttons will open a browser that will allow you to select the appropriate folders.

Appearance: The appearance tab contains the following options:

- Enable Fly By: Auto help appears for menus. We recommend keeping this option On.
- Enable Tool Tips: Small descriptions of tools appear when moving over tools. We recommend keeping this option On.
- Large Buttons: Selecting this will make the toolbar buttons larger.
- Enable Sound Signals: This turns on program user indicator sounds.

Linear Units: Select the appropriate units you want to use for the vertical and horizontal scales.

SIRveyor: This tab is used to configure the SIR-20 for GPS data collection. This has no functionality for post-processing. If you are running RADAN on a SIR-20, see the SIR-20 User's Guide for additional information.

3 After making changes to the Customize options, click OK to save. The new defaults are now stored in the default parameter file Radan.pam (see below for description of this file).

RADAN File Types and Extensions

RADAN assigns various file extensions as defaults to identify the file type. RADAN default extensions are as follows:

1 ***.pam:** Program start-up parameter file, containing saved default or user-defined color tables, color transforms, file default directories, and printer type information used by RADAN. RADAN.pam is the default parameter file, found in the folder into which RADAN was installed. Custom .pam files can also be created by the user and stored in the default RADAN directory or within working folders.

2 *.**dzt:** RADAN data files.

3 ***.cmf:** Command file that executes a user-created macro program. This macro command file processes only one data file at a time.

4 ***.rpj:** Project file that tells RADAN how to automatically process a group of data files from the same project using a previously established macro file.

5 ***.vpx:** ASCII file containing the velocity picks generated by Variable Velocity Migration routine.

6 ***.vlc:** ASCII file contains the output from the Velocity Analysis routine.

7 ***.lay:** ASCII database file containing the output picks from the Layer Reflection Picking and Interactive Interpretation Modules.

8 ***.dxf:** Drawing exchange format. Output of Find Linear function and universal CAD format

9 ***.S3D:** Super 3D output file from 3D QuickDraw Module.

10 ***.m3D:** ASCII file output from 3D QuickDraw 3D project creation. Project file containing all positioning data required to build a 3D project from multiple 2D profiles.

11 ***.b3D:** 3D information file generated by the SIR-3000 during StructureScan Optical or Quick 3D operation.

12 ***.tmf:** Time-Mark-Format. A file generated during data collection with your SIR system which encodes system offset time and scan number for GPS locations.

13 ***.plt:** GPS location information and track log in OziExplorer format.

14 ***.txt:** ASCII file containing GPS locations.

15 ***.mdb:** Microsoft Access database file. This file will have the same root name as the .dzt file it comes from and will contain all of the marker and positioning information for that .dzt file. This file must be stored in the same directory as the .dzt file.

16 ***.shp:** RADAN shape file. This file stores information about any pipes or contours that you have drawn.

17 ***.ind:** Index files. The .ind file was used in previous versions of RADAN to denote a 3D file. If the 3D file was compiled in a version earlier than RADAN 6, the .ind file will be read and the necessary information will then be stored as a .mdb and the .ind will no longer be used. However, the .ind is still used in Terravision files but once the data is opened in RADAN, Terravision .ind files are converted to .mdb.

18 ***.gtr:** Any ground truth information entered in Interactive Interpretation is stored in this file.

19 ***.bmp:** Bitmap image format read in all Windows and Mac computers.

20 ***.kml:** Google Earth file output. RADAN will create this file as long as the data has GPS information. The .kml can be imported in Google Earth and the data will be located on the image.

Note: *.pam files from DOS-based RADAN I, RADAN BASIC and RADAN III files are incompatible with RADAN because RADAN uses a different set of color tables than DOS-based programs.

Opening a Data File

Inputting data from a previously saved *.dzt file is easy. Simply:

1. Choose File > Open. The software defaults to the directory you set as Source.
2. Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.
3. Click OK.
4. Your file will open up on the screen. To review the data use the Left ← or Right → scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.
5. Please note that files that have been saved to storage media, such as the hard drive, CD or other media as READ ONLY can be opened and displayed BUT NOT edited or processed. The user must change the Attributes of the file(s) from Read Only to Archive or RADAN will return a File Open Error when any processing is applied to the active file.

Working with Multi-Channel Data Files

There are two methods of processing multi-channel data. The first is to keep the multi-channel file together and simply perform a processing operation to the multi-channel file. In this case, all channels will be processed with the same parameters. For example, a 2-channel file with two different depth ranges can be processed with an IIR low pass filter at 700 MHz. Each channel will be filtered with a 700 MHz filter.

Inputting data from a previously saved *.dzt file is easy. Simply:

1. Choose File > Open.
2. Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.
3. Click OK.

The second method is to split the multi-channel file into separate files, one file for each channel and process each file separately. This method is preferable in cases where different antenna types are used on the different channels.

To Split Files

1. Repeat Steps 1 through 3 above to open the multi-channel file.
2. Next, choose File > Save As. A dialog box will appear and you will notice at the bottom right a small box that says Split Channels.
3. Check the Split Channels function.
4. From here, the file splitting procedure is then automatic. RADAN will split your file into sections and designate each section by a letter sequentially coded to the channel number. For instance, a four-channel file called Test.dzt may be split into four separate files called Testa.dzt, Testb.dzt, Testc.dzt, and Testd.dzt.

Chapter 2: Displaying, Editing & Printing Radar Data

General Overview

Because of the time needed to process and interpret large data sets, you should consider how much processing is necessary. Can an interpretation be made from the raw data? Will a modification of color table or color transform be sufficient for this interpretation? Or will filtering be needed to help clean up the radar record. Processing should be done for the following reasons:

- To remove unwanted signal (noise) from the data and thereby improve data interpretation.
- To correct for geometric errors and provide more accurate spatial and depth interpretation.
- To convert from time to depth and provide accurate information in depth sections.
- To provide displays to you (and your clients) that are easier to understand than the raw data.
- Data processing schemes should be designed to accomplish these overall objectives, and each processing step should be designed to fulfill a specific objective.

Recommended Data Processing Sequence

The following is a recommended sequence for processing a data file:

1. Open a data file.
2. View and edit the file header as necessary.
3. Choose View > Display Options.
4. View and edit the data.
5. Process the data.
6. Save the data.
7. Prepare figures for a report.
8. Print the data.

Note: Before opening any data files, use the Customize command in the View menu to set certain parameters essential for the processing, such as:

- Source and Output Folders (Directories).
- Desktop Appearance (Help tools, sound, button size).
- Linear Units (meters, feet, etc.). The selected units will be used by RADAN wherever units of distance or depth are required for processing.

Editing the File Header 

A header accompanies each data file and describes the setup of the radar system at the time of data collection. Some of this information can be edited to correspond to post-processing changes or for report generation. Also, the file header should include field information such as location, client, date, job number, surface material, or other information useful in characterizing a site.

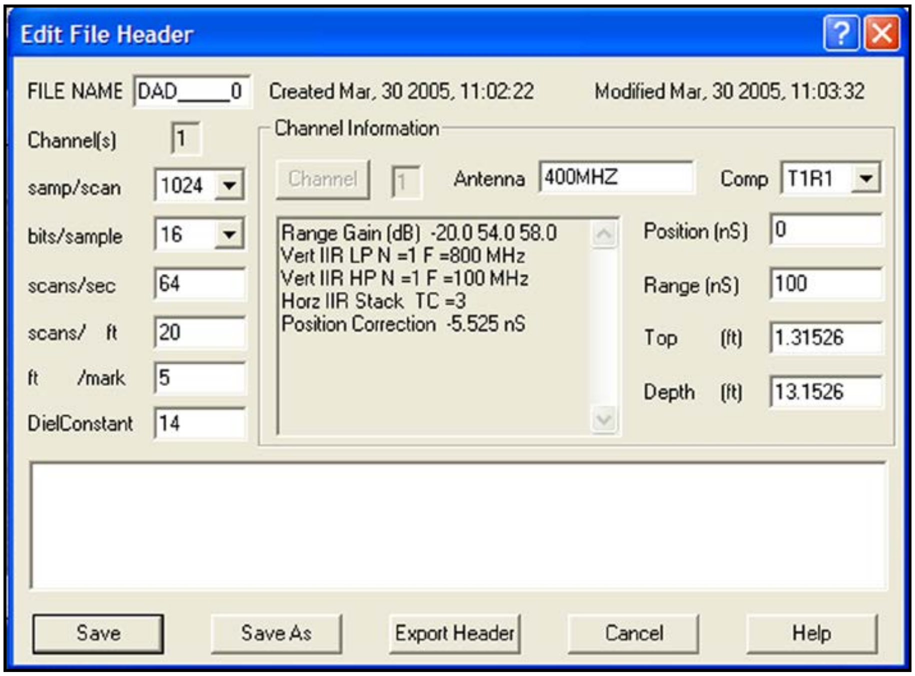


Figure 1: Edit File Header Dialog Box.

File header parameters include: file name, antenna frequency, range, transmitted pulse position, channel, samples/scan, bits/sample, scans/unit, units/mark, dielectric constant, and approximate depth range. Scans/unit will be English (Imperial) or Metric units depending on what linear units you selected in View>Customize.

1 To open the file header choose Edit > File Header or by select the  button on the Toolbar.

2 Review and change as necessary the following information in the file header: Position (ns), ft/mark, scans/meter and dielectric constant.

- The scans/sec, ft/mark, and Range should be known parameters from the survey, and the scans/meter will have to be estimated if the data was not collected with a survey wheel
- Use the Position parameter to shift the time-zero of the vertical scale up or down. For example, to align it with the ground surface/top of the time window.
- Dielectric constant values vary from material to material. The value you enter for the dielectric constant will define the vertical depth scale. Selection of the proper value of this is very important to obtain reasonable depth estimates of subsurface features. For a complete discussion, refer to Appendix B. The Depth parameter, if different from 0, will take priority over the dielectric-based depth scale.

3 After changes are made, choose the Save button to save any changes that you made to the File Header.

The grayed-out box in the center contains some of the initial setup information that the GPR system used to collect data. It also keeps a running track of any post-processing steps done in RADAN. Also, if you used a GPS with a SIR-3000, the GPS coordinate information is stored here in two parts: Starting GPS Info and Ending GPS Info.

GPS Entry Explained

GPR Tick Count: This is an internal system time clock. It can be ignored.

Latitude: This is a coordinate either North or South of the Equator. The first two digits are degrees. The remaining digits are minutes.

Longitude: This is a coordinate either East or West of the Prime Meridian. The first two digits are degrees. The remaining digits are minutes.

Altitude: This is the height of the GPS receiver in meters above sea level.

UTC: This is a Universal Time Count that the GPS is receiving from the satellite. The format is hours/minutes/seconds, or hhmmss.ss

Data Display Options

Radar data can be displayed in five different formats:

Linescan : In the Linescan format your data is displayed in a color-amplitude form, and a color is assigned to a specific positive or negative amplitude value of the recorded signal, depending upon the color table and color transform selected. The vertical scale represents time (or depth) while the horizontal scale represents the horizontal distance traveled by the radar antenna. The Linescan display is the most useful for mapping man-made objects, such as underground storage tanks, pipes, and drums.

Wiggle : In the Wiggle format the data, consisting of multiple radar scans, are displayed as waveforms or "wiggle traces." Wiggle plots are more useful for identifying geologic features, such as a clay layer or a water table. In both formats, the whole data file is displayed, with time zero (beginning of each scan) on top and time (or depth) increasing downward.

O-Scope : In the O-Scope format, you are able to view your data one scan at a time and as an individual waveform or wiggle trace. In O-Scope, time zero is at the left of the display, with time (or depth) increasing to the right.

Linescan with Wiggle : In the Linescan with wiggle format your data is displayed in the Color amplitude form as described above with the addition of a Vertical wiggle trace display that appears on the right hand margin of the active file. Display Gains and Transfer Functions can be applied separately to either the Linescan display or the Wiggle trace display.

The trace that appears in the wiggle trace window will scroll automatically when the display cursor is placed in the linescan window and the Left mouse button is clicked on the display.

3D Display: The 3D display is only active if you have purchased the 3D QuickDraw module for RADAN. The 3D Display allows you to view 3D files or to view a single profile in 3D and use the 3D display tools to analyze it.

- Once a file has been opened in one of the formats by selecting the appropriate toolbar button or View drop down menu display, it can be closed by clicking on that toolbar button again, providing that at least one view remains active.
- If a file is open in a format and you wish to see it in a different format, simply click on the appropriate button. The new display will not preserve any display gain that you applied to the profile. You will need to reapply display gain.
- For a detailed analysis of a radar wavelet, open both the Linescan and O-Scope views for the file.). Move the two views so they are visible, either manually or by using the tile function (under Window > Tile > Vertical or Horizontal view) and click on the Linescan view at the point of interest. Note that the O-Scope view will display the corresponding scan number. This is a good way to correlate waveform attributes with features found in the Linescan representation. (See also Linescan with Wiggle display). You can also display gain the scan wave as well as the linescan image.

Note: A display format is active when the button is in a lighter background in comparison to its disabled state. One of the three display buttons must be active at all times. It is impossible to disable all three.

Display Parameters Setup

The Display Options command under the View menu allows you to review and modify the display parameters for your data. There are four icons for the different display formats: Linescan, Wiggle, O-Scope, and 3-D (available only with the 3D option) as well as the Print icon.

Double-click on a display format icon to open the Parameters dialog box for the selected format.

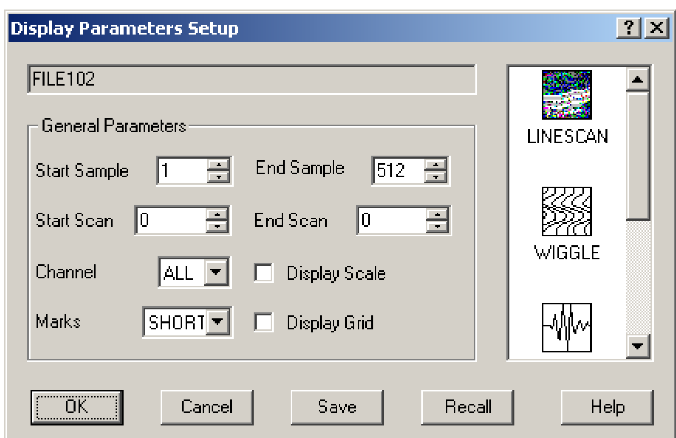


Figure 2: Display Parameters Setup dialog box.

Linescan Display Parameters

Select the Linescan icon on the toolbar to create a color-amplitude image of the data file as it is loaded. The Linescan Parameters dialog box (Figure 3) can be opened by selecting the Linescan icon in Display Parameters Setup.

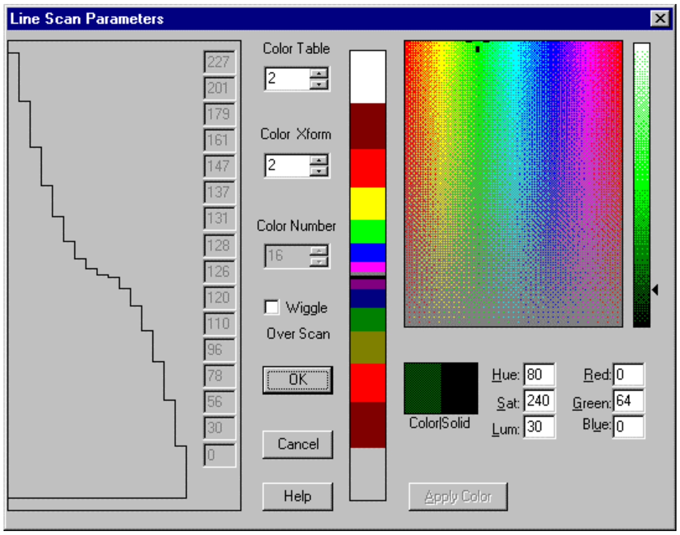


Figure 3: Linescan Parameters Setup dialog box.

Color Table: Color is used to code the amplitude of each scan (i.e., the recorded radar signal) as shown in Figure 3. You may choose one of the standard display color tables from a list of twenty-five tables. A color table represents the amplitude of the recorded radar signal mapped to different colors.

For instance, white in color table 1 corresponds to the highest positive amplitude pulse; therefore, when it appears on the radar record, it means that there is a strong reflection (or a high dielectric contrast).

- Generally, dark means low amplitude signal. Therefore, a large black region on the linescan plot could be indicative of a uniform structure (such as a homogeneous sand deposit) with little or no dielectric contrast.
- The first eight color tables are preset.
- Tables 9 - 16 may be customized.
- Tables 17, 18, and 19 are high-resolution (256 shades) gray scales.
- Tables 20-25 are high-resolution 256 shade 2-color tables.

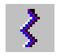
RADAN defaults to Color Table 17.

Color Transform: You can also change the Color Transform to enhance weak amplitude or small contrast reflectors. The color transform determines whether the color scale applied to the radar wave's amplitude is linear, logarithmic, exponential, or customized. This function can also be used to de-emphasize certain features.

- For example, in a logarithmic map, all low amplitude signals are assigned into a compressed lower color range, and the range of high amplitude signals is extended.
- If white represents a high-amplitude signal, then there will be more white area for a given data set than in a linear transform.
- There are 16 color transforms (transforms 9 - 16 may be customized), with the default being linear (Color Transform = 1).

In addition, a Wiggle display may be superimposed onto the Linescan plot by checking the Wiggle Over Scan box.

Note: Care must be taken when selecting wiggle parameters for the Wiggle Over Scan, because the wiggle trace may obscure certain color table transform combinations.

Wiggle Display Parameters 

Wiggle format is used to create a wiggle trace representation of the data as it is loaded into RADAN. Again, the vertical axis corresponds to the time (or depth) while the horizontal scale represents the distance traveled with the antenna. You may choose for presentation purposes to vary the wiggle trace parameters.

Figure 4 shows the Wiggle Parameters dialog box that can be found by selecting the Wiggle icon in the Display Parameters Setup.

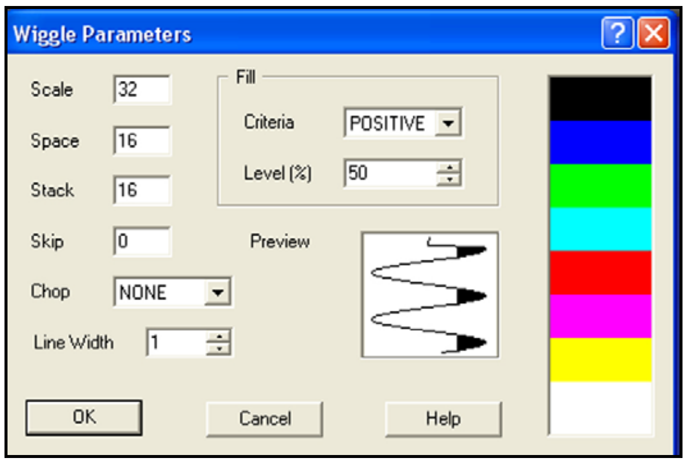


Figure 4: Wiggle Parameters dialog box.

Scale: Determines the relative amplitude of the wiggle trace.

Space: Determines the relative spacing between wiggle traces.

Stack: Averages several scans and presents the results as one wiggle trace. In a strict sense this is not true stacking because the antenna may have been moving, thereby averaging out features as well as random noise.

Skip: Determines the number of scans to omit between wiggle traces. Unless otherwise specified, this value will be zero.

Fill: Determines how much (Level (%)), if any, as well as the polarity of pulses (Criteria) that are filled.

- You may choose to fill either the Positive or Negative pulses, Both, or None.
- You may choose the fill color by clicking on the color palette and the wiggle trace width using the Line Width option.

Chop: Zeroes out either the positive or negative side of the return radar signal. It defaults to None.

O-Scope Display Parameters

O-Scope display represents an oscilloscope trace of one scan of radar data in a file and is configured by pressing the O-Scope icon on the Display Parameters Setup (see Figure 5). The scan number is displayed below the trace, and the entire radar file may be viewed in this format by pressing scroll right or scroll left. (You can use the Stop Processing button to stop scrolling, or, you can use the scroll keys in the data window to scroll at a slower rate.)

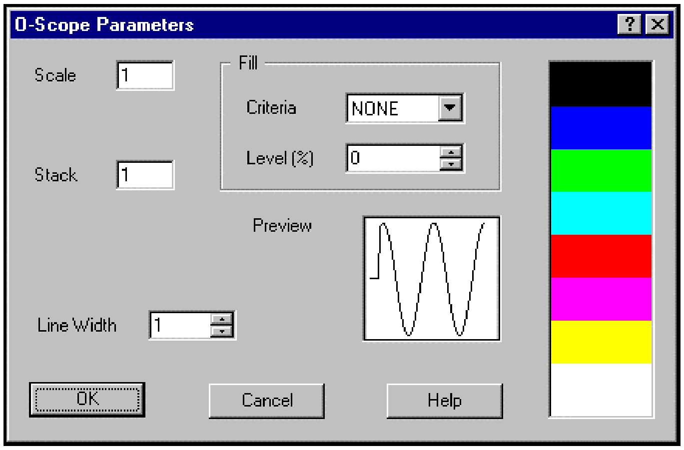


Figure 5: O-Scope Parameters Setup dialog box.

Scale: Determines the relative amplitude of the wiggle trace.

Stack: Averages several scans and presents the averaged results as one wiggle trace. In a strict sense this is not true stacking because the antenna can be moving, thereby averaging out features as well as random noise.

Fill: Determines how much (Level (%)), if any, as well as the polarity of pulses (Criteria) that are filled.

- You may choose to fill either the Positive or Negative pulses, Both or None.
- You may choose the fill color by clicking on the color palette and the oscilloscope trace width using the Line Width option.

Other Display Options

The user may also choose to change the display using General Parameters in the Display Parameters dialog box (Figure 2).

Start/End Sample: RADAN allows you to enter the start sample (default 1) and end sample (default 512 or 1024) to show the portion of each scan that interests you. For example, if the data is recorded at 1024 samples per scan, but most of the important information is located between sample 1 and 512, you may enter an End sample of 512 to show only the upper half of your data. Essentially, this expands the vertical scale of your data by a factor of 2.

Also, if you have a large data file and you are interested in viewing an object located in the middle of the file, you may change the Start Scan and End Scan so that only that portion of the file is displayed.

Display Scale: Allows you to display the position scale along the horizontal axis. Vertical grid can be displayed by selecting the Display Grid option.

Display Parameters Dialog Box: Allows the user to change how the markers are displayed. Click on the Marks option to display Short or Long marks; select None if you do not want any marks displayed on your data.

Channel: For SIR-20, PathFinder, SIR-10, SIR-10A, SIR-10B and SIR-10H users, the Channel option allows you to display all multi-channel data simultaneously or one channel at a time.

Save: Allows you to save your favorite display setting for Recall at another time. To save changes as a new user parameter file, click Save and choose a name. The new pam file will be stored in your output directory. To make any changes permanent, click Save and browse for the RADAN XP program directory. You will see a RADAN.PAM file there. Overwrite that file with your new pam file and call it RADAN.PAM. Changes are now permanent. See also: RADAN File Types (.pam files).

Interactive Display

The main data display window of RADAN is designed so that different menus and functions can be accessed by right-clicking at particular places. (right mouse button functionality): Key features and functions of the RADAN interactive display are summarized in Figure 6.

Certain functions can be accessed by clicking the right mouse button with the mouse cursor in the data window or within the gray vertical scale area in any display format. This shows small menu boxes that provide a fast access to some functions also available in the main menu or on the toolbar (Gain, Select, Horizontal and Vertical Units, Color Table, and Color Transform selection). The user may choose to display the horizontal scale in distance units or scan number, or the vertical scale as time, depth or sample number. They also allow the user to display a frequency spectrum of data (see Frequency Spectrum of Data).

The menu options are slightly different in each display format. For example, only the horizontal scale parameters can be modified in O-Scope format; the Color Table and Color Transform only apply to the Linescan display, etc. Depth and Distance/Scale options are active only if the necessary parameters (dielectric constant and Scans/Unit value, respectively) are entered in the file header.

Dragging the vertical split bar (left edge of the data window) to the right or left allows you to display or hide the vertical scale. The horizontal split bar at the bottom of the data window splits the data window in two. Each of them may then be modified separately using the same interactive tools.

The name of any current Region will also be displayed next to coordinate info on the status bar.

Note: Cursor position boxes at the bottom of the RADAN main data display window are also affected by the display format, selected units, and data window content. These appear in the Status Bar. In order to view them, make sure that the Status Bar is checked under the View menu.

Interactive Display Options

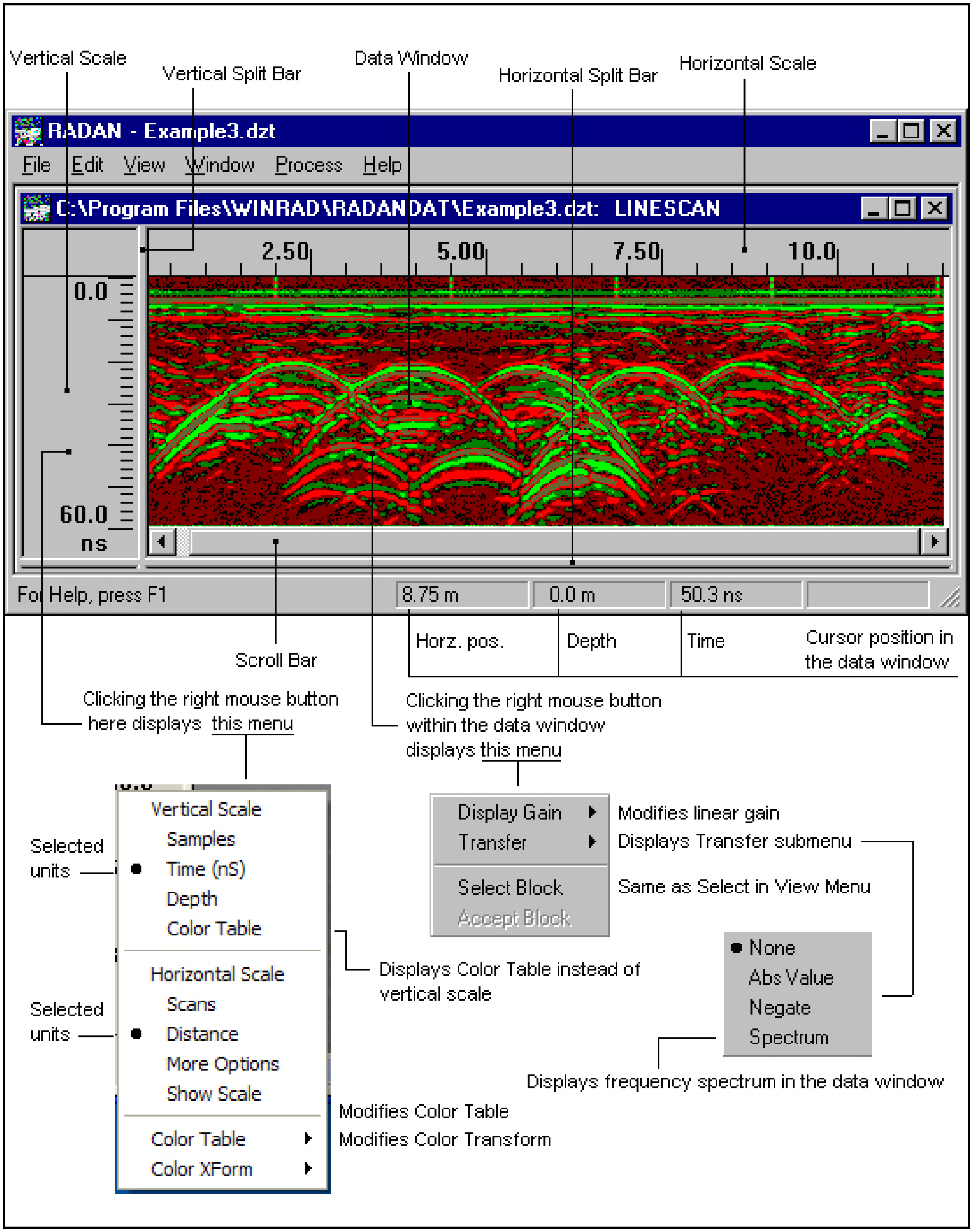


Figure 6: Interactive display options (Linescan format).

Editing the Data

Viewing the Data

To view data use the Left and Right scroll arrows located in the Command Toolbar. The scroll buttons are useful for a quick review of long data files where it is impossible to view the entire file on the screen at once.

- These will allow you to scroll continuously towards the beginning (Left arrow) or the end (Right arrow) of large files.
- There is a scroll bar at the bottom of the display to show the relative position of the displayed data within the file
- Use the Stop Processing button (located in the Command Toolbar) to stop scrolling at any point.
- Use the scroll arrows in the data window to scroll at a slower rate.

Removing Unnecessary Information (Select Block)

You may choose to remove (Cut) unnecessary information from the data file for processing or report presentation purposes.

1 Choose Edit > Select to selecting a rectangular overlay.

Note: Depending upon how your monitor is configured, the rectangular overlay may be similar in color to your data file and therefore not be apparent. The overlay will appear at the left of the file screen. If you are having difficulty seeing the overlay, try changing your color table.

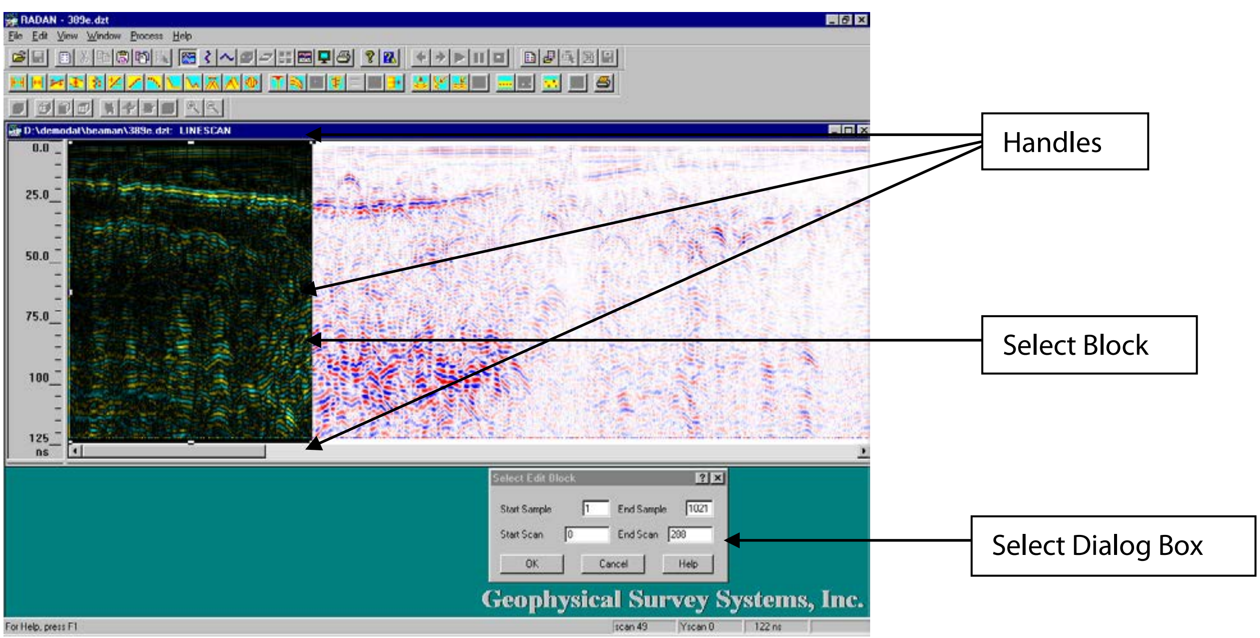


Figure 7: Example1.dzt showing the rectangular Select Block.
(Color Table 25. 256 shade Red, White and Blue)

2 Next, move and/or adjust the overlay to fit over the section you wish to edit and save as a separate file or eliminate by clicking on it with the mouse. You can either drag the overlay to move it, or simply type in sample and scan values for the beginning and end of the overlay.

- This overlay may be adjusted in both the horizontal and vertical directions. The Select Block contains tiny squares either centered on each face or located on each corner. These squares act as handles that can be used to resize the Select Block.
- You will see within the dialog box the starting and ending scan and sample number that will tell you the horizontal and vertical limits of the rectangular overlay. You may also move the entire overlay by placing the cursor within the overlay and dragging the mouse until the overlay is centered over the section of interest.

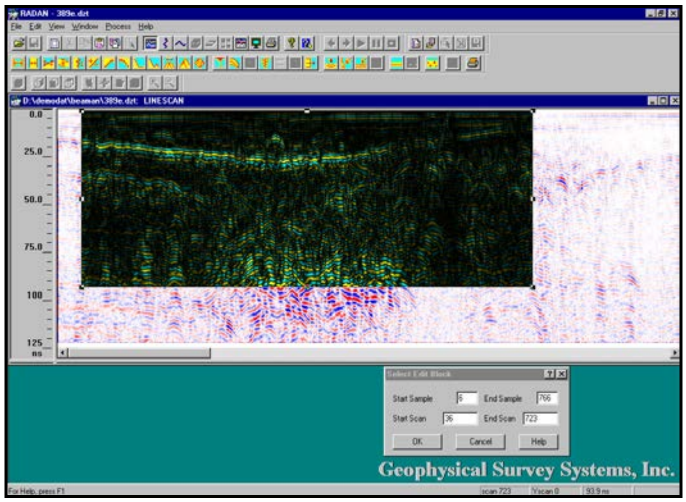


Figure 8: Example1.dzt. Showing the edit block moved to the desired location.

3 To remove radar scans at the beginning and end of the file (these occur when the antenna may be stationary and running in continuous mode), simply align the mouse at the midpoint on the right side of the overlay. The mouse cursor will change into a left/right arrow symbol when you are in the right place.

4 Then, drag the mouse until the box is at the desired width.

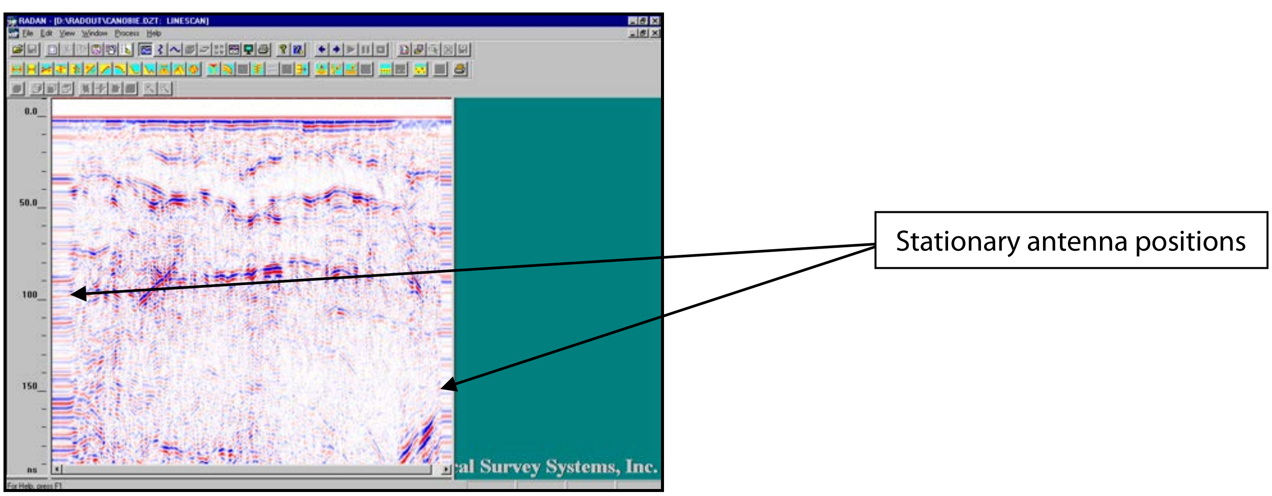


Figure 9: Example2.dzt. Stationary antenna positions to be edited.

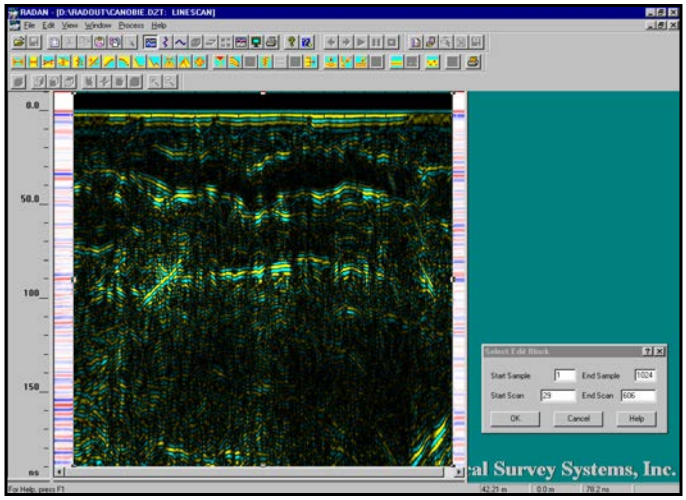
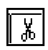


Figure 10: Example2.dzt. Select Edit Block positioned over file segment to be saved.

Note: If the overlay or the midpoint box on the right side of the overlay is difficult to see, you may enter the starting and ending scans corresponding to the overlay's desired horizontal width. This display limitation may be overcome in many cases by changing the color table being used.

5 Once you are satisfied with the section you have selected, click OK.

6 Choose Edit > Save or use the Scissors  button located in the toolbox to remove undesired sections of the file.

- The cut file action will remove the section of a radar file selected by the mouse-driven rectangular overlay.
- RADAN will automatically save the remaining data using a new, user-defined name.
- If you are not satisfied with the box you have selected or with the edits you have made, you may choose not to save the new file and all the edits will be undone.

Note: If you make a mistake and cut the wrong section, the edits made to the original file will be undone if you select Cancel when RADAN goes to save the changes under a new file name.

Saving the Selection in a Separate File

In large data files, you may find it easier and less time consuming to process by saving a small section of data and process it.

1 Select the desired portion of the file.

2 Choose Edit > Save. You will then be prompted for the new file name under which the new data will be stored.

Zooming In: Expanding the Vertical Scale of a Data File

The rectangular overlay may be adjusted in the vertical direction as well as horizontal.

1 Choose Edit > Select.

2 Move the rectangular overlay to the area you wish to enlarge.

3 Use the handles located at the rectangular overlay's corners and midpoints to shape the rectangle. As described above, this is accomplished by moving the mouse to the box and dragging the mouse to expand or contract the overlay to the desired size. Click OK.

4 Next, right click on the data and click Accept Block to cut the selected section and save the section using a different file name.

5 The selected section, consisting of a specific number of samples will then be resized to the number of samples in the original file.

- For instance, if the vertical length of your rectangular overlay is 300 samples long, and your original data file is a 512-sample file, RADAN will resize the selected section so that it is 512 samples long. The horizontal width of this new file will be determined by the number of scans selected in the rectangular overlay.

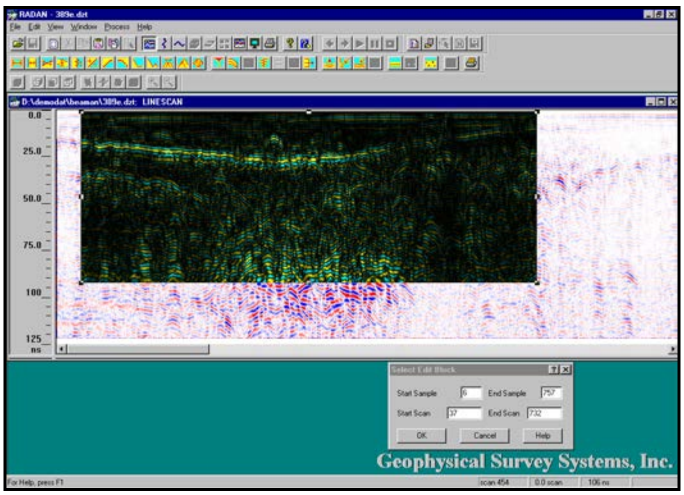


Figure 11: Example1.dzt. Select Edit Block positioned over file segment to be zoomed (1024 samples).

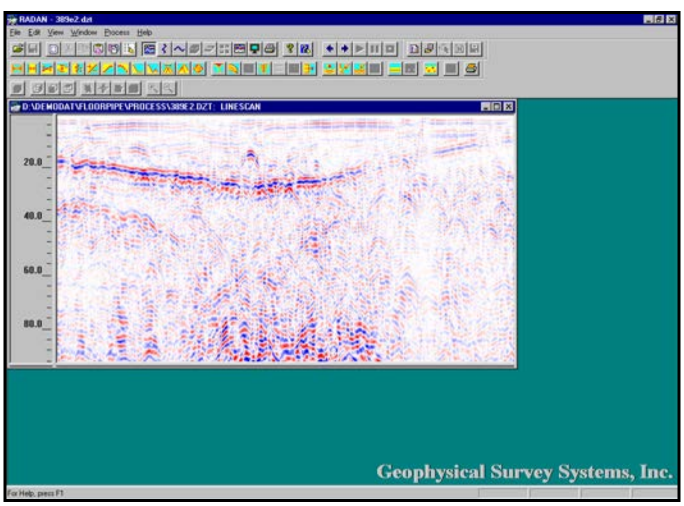


Figure 12: Example1.dzt showing completed edit (Zoomed Section – 1024 samples)

Working with the Database

RADAN now encodes information in a permanent, storable database based on Microsoft Access. This means that the database file associated with each .dzt file can be opened and edited in Microsoft Access. However, Microsoft Access is not required to use the database option in RADAN. The database format is the Microsoft Access .mdb file. A database is automatically created when a file is opened and is only properly saved when a file is closed. This means that if RADAN crashes while you have a file open, that database may be corrupted and RADAN may produce an error the next time that you open that file. That error will say: "Database apparently corrupted, creating new database." RADAN will then create the new .mdb file and you will have lost any changes that you may have made to the old database.

There are two main choices in the database window: Table and Regions. Each discrete 3D dataset may be preserved as a separate region. This allows easy modification of that single dataset's display properties and location information. The Tables sections (3D, GPS, Marker) deal with the overall position information of the entire dataset. Each Region will refer to the master position information contained in the Tables section in order to properly locate the data.

The following sections discuss how to edit a specific database table, the different databases available, and how to relate the regions databases with the tables.

Figure 13 shows the window that pops up after clicking the database icon or going to Edit > Edit Database.

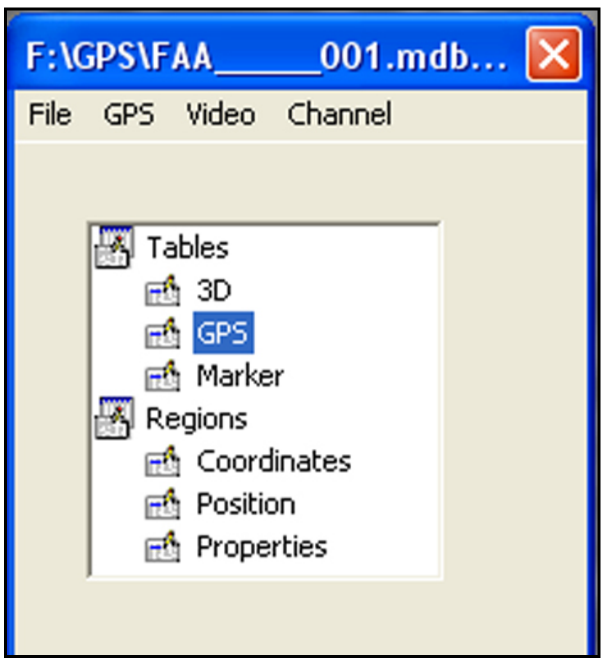


Figure 13: Database Chooser Window.

Each table or region listed in the database chooser window can be accessed by double-clicking on the table name. Double-clicking on the table name opens up a spreadsheet-style window containing the relevant data.

Pull-Down Menus

File: The only option in the File Menu is Merge Regions. Merged regions cannot be broken up, so it is advisable to save a copy of the file under a different name prior to merging.

GPS: There are two options available in the menu: Import GPS and 3D GPS Position.

Import GPS: When you open a DZT file, RADAN typically examines the folder that the DZT file came from to find GPS data that it can apply to the radar file. If it finds a TMF file and a GPS location file (TXT or PLT) with the same root name as the DZT, it is automatically loaded. If not, RADAN will prompt you to specify first the TMF and then the location file. It will then save the necessary information to the GPS table in the database.

3D GPS Position: This dialogue allows you to ascribe GPS coordinates to a 3D dataset. This allows you to correctly position a 3D area by using coordinate values that were recorded separately from the GPR data. Two values are needed and one of them must be the local grid origin.

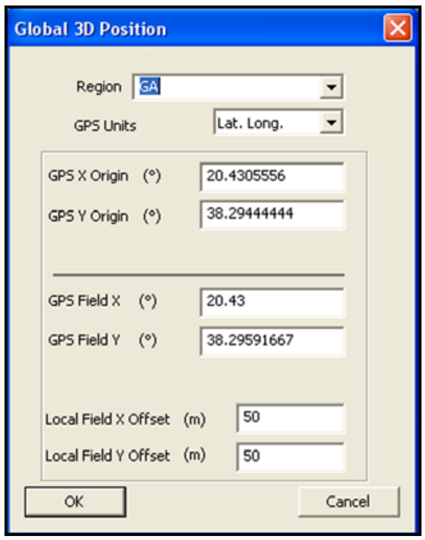


Figure 14: Global GPS Position Dialog

- **Region:** If you have a multi region file, this allows you to specify which region's origin to use.
- **GPS Units:** Either Lat. Long. or UTM.
- **GPS X/Y Origin:** This is the GPS coordinate of the grid's local origin point (0,0).
- **GPS Field X/Y:** This is the GPS coordinate value of another location within the grid. The further away from the origin value, the better.
- **Local Field X/Y Offset:** This is the location of the second GPS point (not the origin) within the grid. The distance units are those set in the View>Customize menu. Think of this as the coordinate within the grid.

Note: All of the GPS coordinate values for Lat/Long are expressed in decimal degrees. To convert degrees.minutes.seconds to decimal degrees, divide the minute value by 60, and the second value by 3600 and add to the degrees. For example: a latitude of 42 deg N 46 min 40.26 seconds becomes 42.7778514 degrees. (42 + 46/60 + 40.265/3600)

Note: This functionality is provided on a trial basis for users of v. 6.6. See page 2 for details.

Video: This menu has one option: Video Sync. This is useful if you are recording digital video at the same time as GPR data. After syncing with the video timeline, you can display that time in the status bar. You will still need to view the video data in a separate player. You can synchronize them by specifying a scan number within the data file, the corresponding time in the video timeline, and the distance offset between the scan location and the location that the camera is recording.

- **File Scan #:** The file scan corresponding to the video synchronization point. Typically this will be zero.
- **Video Time (sec):** The video time corresponding to the File Scan #.
- **Video Pos. Offset (distance):** The distance offset between the field of view of the video camera and the antenna. The distance is positive in the direction of travel. For example: if the video camera is mounted on the front of the data collection vehicle looking forward 10 ft., the vehicle length is 20 ft, and the antenna is mounted 5 ft behind the vehicle, then the offset would be 35 feet.

Note: This functionality is provided on a trial basis for users of v. 6.6. See page 2 for details.

Channel: This menu has one option: Position Reference. This is used to locate the GPR antenna relative to a GPS receiver. The inline offset is the distance forward (positive) or backward (negative) along the collection line from the GPS receiver. The crossline offset is the distance to the right (positive) or left (negative) from the receiver.

The channel position offset is disabled for TerraVision data. TerraVision data is handled in a unique way when it is loaded into RADAN.

Tables

The RADAN database is structured as a series of “tables.” A “table” can be considered to be a simple spreadsheet containing a number of columns and rows. Each row in the table is called a “record.” A record contains a number of properties called “fields.”

As an example of how this all works, consider the marker table associated with a RADAN File. The marker table contains markers associated with different scans. Each marker is a separate record in the marker table. The different marker properties such as its scan number and type (distance mark or user mark) are fields in the marker record. Adding or deleting a marker is simply adding or deleting a record from the markers table.

The RADAN database is a relational database. This means that information from one table may be related to information from other tables. The relationships between different tables are described in the following section.

Each table in the database file can be viewed and edited in the standard spreadsheet format (Figure 15).

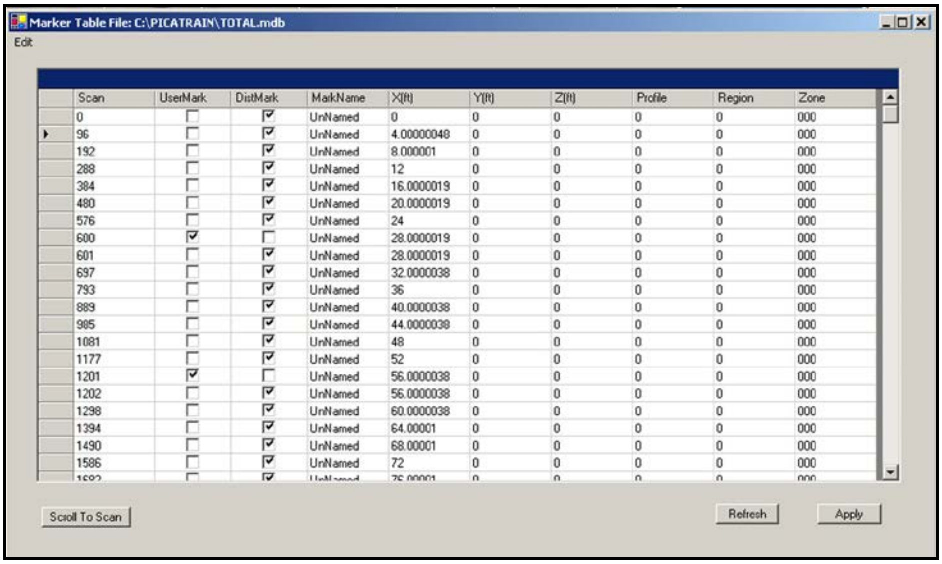


Figure 15: Spreadsheet editing display.

Editing Data

The image above shows the spreadsheet table associated with the markers database table. Different marker properties can be directly modified by clicking on the column and performing the desired action whether typing in a value or clicking on a checkbox. **Note:** None of the edits are saved until the Apply button is pressed.

Deleting Data

Specific rows of the database are deleted by clicking on the left-most column of the table, which highlights the entire row, then selecting Edit > Delete from the Edit menu item. Multiple records can be selected by holding down the “Shift” key while pressing the mouse button on more than one row. These multiple records can then be deleted using the Edit > Delete menu items. **Note:** None of the deletes are saved until the Apply button is pressed.

Adding Data

New records are added to the database table by typing in the desired information in bottom row. **Note:** None of the added records are saved until the Apply button is pressed.

Some tables require unique information in one or more columns. If duplicate information is typed in, an error message will pop up. One example of this is the Marker table. There cannot be any duplicate scan numbers within each region in the Marker Table.

Sorting Data

Clicking a column header sorts the table in an ascending direction based on the values in the column. Clicking on the same column header twice changes the sort direction. The sort capability is a powerful tool for quickly finding certain information in large database tables.

Scroll To Scan Button

The Scroll to Scan button is used to synchronize the linescan data window with the selected scan number in the database. To force the linescan window to scroll to a specific scan number, first select the desired record containing the scan number by pressing the left mouse button on the left-most column of the spreadsheet. This will highlight the entire row. Then, press the Scroll To Scan button. In RADAN version 6.0, this option only works with the markers table.

Refresh Button

The Refresh button is used to reload the data in the spreadsheet from the database file. This button is useful when undesirable edits have been made to the spreadsheet data. Pressing the Refresh button performs the same task as closing and reopening the table.

Apply Button

The apply button saves all changes made to the spreadsheet to the database file.

Database Tables Descriptions

Marker Table

The Marker table can be accessed via double-clicking on “Marker” in the Database Chooser Window or by clicking on the Edit Marks button on the main tool bar  or by selecting Edit > Edit Markers from the RADAN Main menu items. Using any one of the three methods opens up a spreadsheet containing all of the marker information.

The Marker table shown contains a number of new properties in addition to the properties of markers in previous versions of RADAN. Each marker property is briefly described below.

Scan: The scan number associated with the marker. This scan number is relative to the scan number associated with the start of the region in which the scan number belongs. All scan numbers belonging to region 0 are referenced relative to the beginning of the file.

UserMark: A marker in the data that has been added by the user either during data collection or from RADAN. This marker may have a name and or position information. User marks appear in line scan mode as dashed lines.

DistMark: A marker in the data that has been added either automatically during data collection or by the user in RADAN. DistMarks (which is short for distance marks) that are added automatically during data collection contain the correct distance values of the corresponding scan. This is a safety feature for GPR systems that may skip scans when the antenna is moved too fast to maintain the specified scans per distance interval. The distance normalization process in RADAN uses the distance mark values to perform interpolation to fill in the missing scans in files.

Distance-based GPR data collected on the SIR-3000 with a GPS receiver attached contains GPS location information at each distance mark in the GPR data file. In RADAN, this GPS information can be loaded into the marker table. See section describing the GPS Table for more details.

MarkName: The user-assigned name of the mark. It can be up to 64 characters in length.

X,**Y**,**Z:** The x-, y-, and z-coordinates of the scan.

Profile: The profile line number for 3-D files.

Region: This is the region number in which the marker belongs. This value is not fully implemented. By default, all scans in all files have the region number "0." In RADAN the only case where the region number will be non-zero is where the user has used the Append option in RADAN to create an appended file.

Zone: This is the UTM zone for markers containing GPS position coordinates.

GPS Table

The GPS table stores GPS data imported from GPS log files. GPS data logged on the SIR-3000 and TerraVision systems is stored in two files**:** a TXT or PLT file and a TMF file. GPS data collected with the SIR-20 is stored in a POS file. See GSSI Technical Note 0101 for details regarding GPS integration with the SIR-3000. See the SIR-20 manual for GPS integration with that instrument.

The GPS data collected by each system is loaded into the database file from the database table viewing window. If RADAN detects a TMF and a TXT or a PLT file with the same root name as the DZT file in the same folder, then it will automatically load GPS information. Otherwise you can load it manually by accessing the database table window by going to Edit>Edit Database and selecting "GPS" as shown in Figure 16.

RADAN will also accept NMEA GGA files which are output by most GPS instruments.

It is your responsibility to get the GPS output into the NMEA GGA string. GSSI does not support GPS instruments. Contact your GPS manufacturer if you are having trouble getting your GPS to output data in this format.

Once you have a NMEA GGA file with the extension .log or .txt, click import GPS. RADAN will ask you to select the correct file. Change the Files of Type to "NMEA GGA File (*.Log; *.Txt)" and select the correct file. RADAN will then parse out the information that it needs.

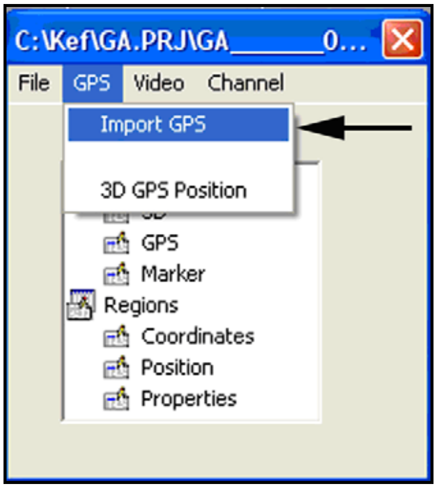


Figure 16: Procedure for importing GPS data into GPS table.

The GPS table contains the GPS coordinates in UTM coordinate system with respect to the global origin. The coordinates of the first scan are identical to the global coordinate origin stored in the Regions Table. All subsequent GPS values are relative to the first scan. The horizontal and vertical units of the UTM coordinates are specified using the View > Customize > Linear Units option in RADAN. A brief description of each field in the GPS table is presented below.

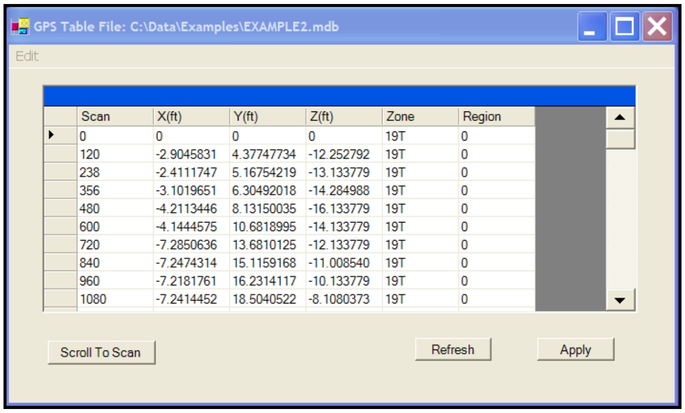


Figure 17: GPS table.

Scan: This is the scan number with respect to the first scan number of the specified region.

X,Y,Z: The x, y, and z coordinates with respect to the global x-, y-, and z- coordinates that are saved in the Regions Table.

Zone: The UTM zone to which the data are referenced.

Region: This is the local region number in which the scan belongs.

3D Table

The 3D Table contains local 3D coordinates of the scans in each region. The local coordinates of all 3D files created in RADAN version 6 are stored in this table.

Note: The information in this table is for viewing purposes only in RADAN. Therefore, the contents of this table should not be modified. In future versions of RADAN, the information from this table will be extensively utilized.

The concept behind the fields in the 3D table is to assign coordinates to each scan in the data file. To accomplish this, the data file is divided into the smallest possible piece, the segment. A segment (Seg in the table) contains a starting scan number, total number of scans, starting (X,Y,Z) coordinates, and vector X, Y, and Z lengths. Each segment belongs to a profile. In turn, each profile belongs to a region. A segment may have a radius of curvature (ROC in the table).

A brief description of each field in the 3D table is presented in Figure 18.

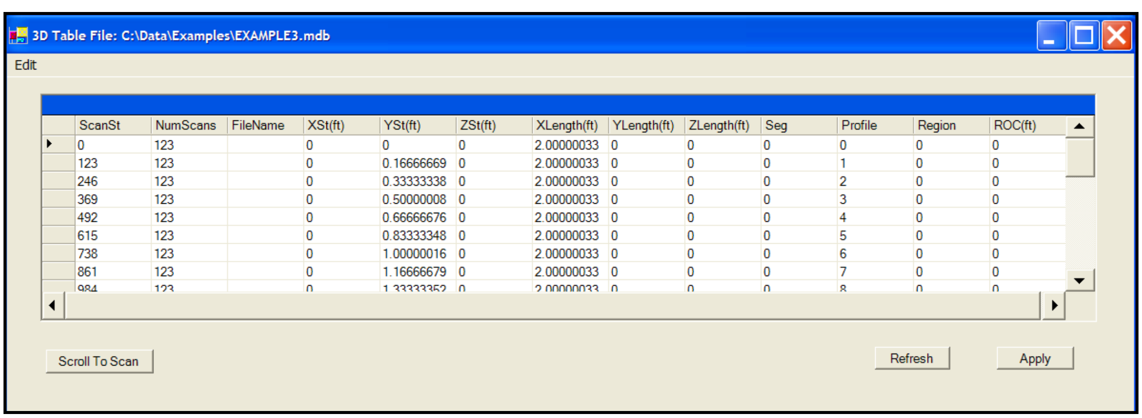


Figure 18: 3D Table.

ScanSt: This is the scan number with respect to the first scan number of the specified region to which the indicated segment of the profile belongs.

NumScans: Total number of scans comprising the segment.

FileName: Filename from which data comprising the segment originated.

XSt, YSt, ZSt: Starting x-, y- and z- coordinates of the segment.

XLength,YLength,ZLength: Vector lengths in x-, y-, and z-directions from starting scan to ending scan in segment.

Seg: Segment number of profile. For profiles that only have one segment this number is always zero.

Profile: Profile number within a region.

Region: Region number.

ROC: Radius of curvature of segment. This function is reserved for future versions.

Special Case: Editing the Markers Database

RADAN provides a way to edit markers entered by the user or survey wheel during the field survey. Before beginning, please make sure that you read the previous section on the database. There are three different markers used by RADAN:

User Marks: Manually entered during the data collection.

Distance Marks: Written into the data file using a survey wheel or another distance-measuring device.

Combo Marks: Overlays of distance and user marks.

Marks that are created on older analog systems by pressing the marker button on either the antenna or SIR-3 or SIR-8, have to be manually entered.

Note: Distance (or Combo) markers are needed to perform Distance and Surface Normalization. If you are converting User marks (from clicking Mark in the field during data collection) to Combo marks, make sure that the DistMark box next to the appropriate mark is checked. Click Apply to save any changes.

Microsoft Access Database creates a database that can be accessed from one RADAN session to another, and saved in Microsoft Access format.

1 To edit markers, choose Edit > Edit Markers or click on the Edit Markers button.

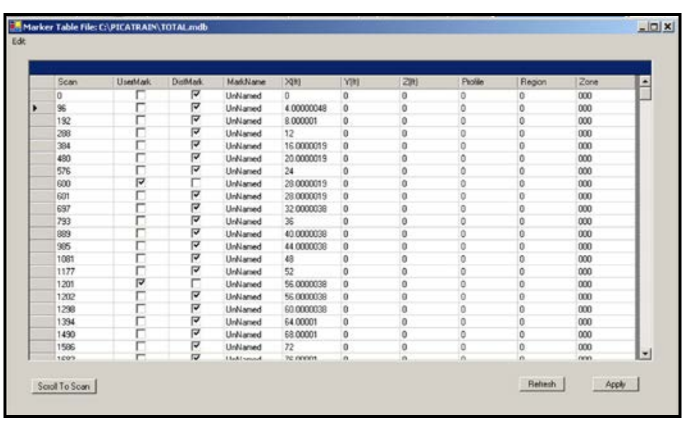


Figure 19: Edit Markers Setup Dialog Box.

2 Next, you will want to find all the markers you wish to keep (i.e., those that correspond to station locations which will help orient the data to your survey line or grid). Set the Horizontal Scale on your linescan data window to scans. You can do this by right-clicking on the vertical scale bar at left and finding Scans under the Horizontal Scale section. Next, find the scan number of the mark you are interested in by left clicking on that mark. The scan number will be displayed in the Status Bar at the bottom of the screen.

- If you know the mark location, you can click on it in the Database window and click Scroll to Scan to have the data window advance to the appropriate mark.

To Delete A Marker

1 Select the marker by left-clicking on the gray box at the far left column of the database window. This will cause the whole row to be highlighted.

2 Find the Edit pull-down menu at the top left of the database window (not the main set of pull-down menus at the top of the RADAN screen).

3 Select Delete. Be sure that you are deleting the correct mark, because there is no undo delete option.

To Add A Marker

To manually add a marker, follow these steps:

1 Scroll to the bottom of the marker database window and find the empty row with an * next to it.

2 Click on the Scan window and type in the scan number where you want the marker to go.

3 Type in any additional position information in the appropriate window.

4 Make sure that the correct marker type box (UserMark or DistMark) is checked.

5 Click Apply.

To Manually Change Marker Type

To manually change the type of marker, follow these steps:

1 Find the scan number of the mark that you want to change and find that mark in the database display.

2 Place a check in the mark type box to change the mark to the desired type. If you want a Combo mark (a mark that encodes Distance, but still remembers that it is a User-defined mark), make sure both UserMark and DistMark are checked.

Regions Table Descriptions

Figure 20 shows the three Regions items in the database: Coordinates, Position, Properties. These can be accessed by double-clicking on them. Additionally, if you would like to merge all of the regions together, select Edit>Merge Regions. This process cannot be undone.

Coordinates

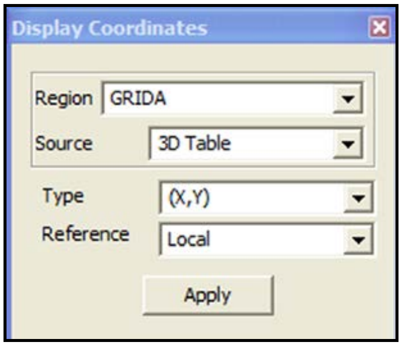


Figure 20: Display Coordinates

It is possible to collect data with no positioning device or with multiple positioning devices. The Display Coordinates control allows you the option of drawing location information from different databases.

Region: Selects which region you will apply changes to.

Source: Selects which type of location information you are using.

- **Survey wheel:** This data is drawn from the Marker Table and typically contains only linear distance information.
- **3D Table:** This data is drawn from the 3D Database and allows X,Y positioning of data points. The 3D database is only populated if the file is a 3D file.
- **Imported GPS :** This data is drawn from the GPS data and allows X,Y positioning of data points. This allows a single profile of GPS collected data to be displayed in 3D.

Type: Selects which display type you would like location information displayed as. It is only possible to display data in the 3D QuickDraw module if you select X,Y or GPS.

- Scan: Location is scan number from the beginning of the region. This display type is available with all collection methods, including time-based continuous mode and point data collection.
- Linear Dist.: Distance offset as a straight line from the beginning of the region in units selected under View>Customize. This is only possible with survey wheel or GPS collected data. This will also disregard any data in the 3D database with the result that the region will show as a single profile in the 3D display mode. This display type is useful for single profiles of data.
- (X,Y): If you have 3D or GPS data, then each point has both an X and a Y coordinate used to locate it in space. This choice will display that information and make it possible to view the data as a 3D area in the 3D display mode.
- Ratio: This type will display a ratio of your current location to the whole data file length.

Reference: This sets the zero point that your data is offset from.

- Local will establish an arbitrary zero position that your data coordinates will be referenced to. Usually this is either the start of your profile line or the 0,0 origin of the 3D grid.
- Global is used mainly when you have a GPS. This sets a GPS coordinate at the reference point and all data points are offset from that spot.

Position

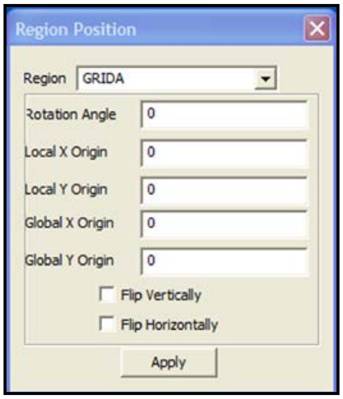


Figure 21: Region Position

The Region Position item allows you to manipulate the position of each region.

Region: Selects the region to apply changes to.

Rotation Angle: This will rotate the region around the local X,Y origin. Values entered here are degrees in a counter-clockwise direction.

Local X/Y Origin: This is the coordinate within the single region that will be considered its origin for the purposes of rotation and concatenation with other regions.

Global X/Y Origin: This origin is typically used only with GPS data to place the region against a Lat/Long coordinate system.

Flip Vertically/Horizontally: Checking these boxes will flip the region in the desired direction.

Properties

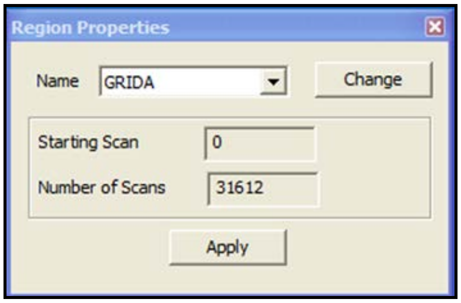


Figure 22: Region Properties

The Region Properties item allows you to change region name. It will also display the starting scan number or the currently selected region and the total number of scans in that region.

Generating Displays for Reports

GPR data displays can be simplified so that significant features stand out. Changing or customizing Color Tables and/or Color Transforms can be used to emphasize the amplitude ranges of specific features. For example, if you are trying to image weak reflections like fine soil layering, you might choose Color Table 1, Color Transform 3. This shows a lot of color variation around zero amplitude and can help to make weak reflections more visible.

In addition, the size of files can be tailored to fit onto a report page using RADAN's file editing feature found under the Edit menu.

1. Select the desired portion of the file.
2. Use the Cut command (or select the Scissors button from the toolbar) to remove the desired section.
3. You will then be prompted for the new file name under which the new data will be stored.

Note: It is easy to export data using RADAN via the Windows clipboard to annotate using other drawing programs. You may copy a selected section, paste it to the clipboard and export it to other programs, such as CorelDraw, Adobe Photoshop, or Microsoft Word. Simply click the clipboard icon  on the toolbar, open the target application, and paste it into that program. You can also use the Print Screen key to save the active window of the screen. This can now be viewed and edited in MS Paint.

Printing a File

Once a file has been edited and processed, you may choose to print this file for publication. The Print command, found under the File menu is used to print a file as well as all the header and processing information that goes with it. The Printer  button can also be used. The print format (Linescan, Wiggle or O-scope) will be the same as that of the active window.

1. Choose File > Print Setup to select or establish the default printer.
2. Select the printer port (usually LPT1). The Setup option will also allow you to select the paper size, source and orientation (portrait or landscape).
3. Preview your print file by using the Print Preview command (found under the File menu), which will display the active file as it would appear when printed.
   - Print Preview allows you to view either one or two pages at a time, move back and forth through the document, zoom in, zoom out and initiate printing. The next page and previous page commands may also be used to scroll through the pages in the print preview.

   Note: In the Print Preview, your file may appear too stretched or too compressed horizontally. To adjust scans per inch for printing purposes go to Display Parameters option under View, or on the main tool bar. Scroll to and select the print option on right side of the display box. Set the desired number of scans per inch. Check on final print resolution through Print Preview.
4. When satisfied with what you see on the screen, click Print or select Print from the File menu.

Note: Some printers have different dots per inch resolution. Select Printer Zoom found in the View menu under Display Options, and enter a number between 1 and 5, depending upon whether your printer is a laser or an ink jet.

- In some cases, the size of the RADAN file to be printed will exceed the internal memory capacity of the printer spooled for use. You should be aware of the memory size of the printer you are using and the size of the file they are trying to print. If the file size exceeds the printer memory size, Windows will return a printer error message. You should then cut the file into smaller sections and print them individually.

Saving Your Data

We recommend storing your output files in a separate output directory to assure that the raw field data and processed data are not stored in the same folder and risk being over-written or otherwise corrupted.

Saving to Hard Drive

Saving data in C:\...\RADANOUT or some other exclusive folder will help prevent accidental deletions. Along the way, as data are edited, filtered, and processed, RADAN will automatically ask you for a new file name so it may store the updates without overwriting old (raw) data.

RADAN will also ask you if you intentionally want to overwrite a data file. You may save your data in RADAN data format as a *.dzt file by going to the File menu and selecting the Save As function. You may choose to save your data using another file name, or on a different drive.

To save FILE1.DZT on Drive A, for instance, go to the File menu and select the Save As function. A dialog box will appear and you may enter either the file name or drive under which you want your data stored. In this case, you will either type in A:\file1.dzt or select the drive using the mouse.

Data may also be saved using the SEG-Y format. From the Save As dialog box, select SEGY File under Save as Type. Data will be saved under the SEG-Y format (*.SGY) so that it may be imported into another processing package. Regardless of which format you choose to save your data, we recommend that you save all active files before closing them and exiting RADAN.

Note: You may use WinZIP or other archiving programs to compress data files and minimize disk space. Compressed files must first be decompressed to run in RADAN.

Chapter 3: Processing

Specific Processing Objectives

You may choose to apply further processing as appropriate, from the Process menu to clarify the GPR data presentation:

Horizontal and Vertical Filters

Spatial 2D Filtering

Range Gain

Restore Gain

Surface Position Adjustment

Distance Normalization

Horizontal Scaling

Horizontal Distance Adjustment

Deconvolution and Migration

Hilbert Transform

Surface Normalization

Velocity Analysis

These processing functions are described in detail below. Initially, single files are processed step by step. Once processing parameters have been established for a specified function, you may start processing by selecting OK in the menu corresponding to the processing function of interest. Use the Stop Processing  button (located in the toolbar) to stop processing at any point.

Once you are satisfied with the processing steps necessary to produce a good-looking data file, a macro program may also be created to automatically process a data file. Large data sets may be automatically processed by using RADAN Project Mode. The user assigns numerous data files, all of which are processed using the steps outlined in the specified macro program. Chapter 6 will discuss in detail how to create macro programs and process large data sets.

Listed below are specific radar data processing objectives and the methods that will accomplish each of them. Also included are the critical processing parameters that must be established.

OBJECTIVE	METHODS
Remove flat-lying ringing system noise	• Horizontal High Pass Filter • Vertical High Pass Filter • Spatial Filter • Background Removal
High frequency noise (i.e., snow)	• Vertical Low Pass Filter • Horizontal Low Pass Filter • Spatial Filter
Ringing Multiples	• Deconvolution
Remove diffraction (compress hyperbolas) and correct dipping layers	• Migration
Increasing visibility of low amplitude features	• Arithmetic Functions • Display and Range Gain
Detect subtle features	• Hilbert Magnitude Transform • Spatial Filter
Generate clearer data displays for reports	• Arithmetic Functions • Local peaks • Static corrections

Table 1: Processing objectives and corresponding methods.

Horizontal Scale Adjustments

Distance Normalization

Distance Normalization allows you to establish a constant horizontal scale between marks. This function performs rubber-sheeting so that there is an equal distance, or equal number of scans per unit distance, between markers.

This is generally required when data is collected in continuous mode without a survey wheel and is due to unavoidable inconsistencies in antenna towing speed. When Combo or Distance Marks are set and verified (see Editing the Markers in Chapter 2), Distance Normalization will correct the number of scans between markers by stretching and skipping, thereby correcting for variations in survey speed.

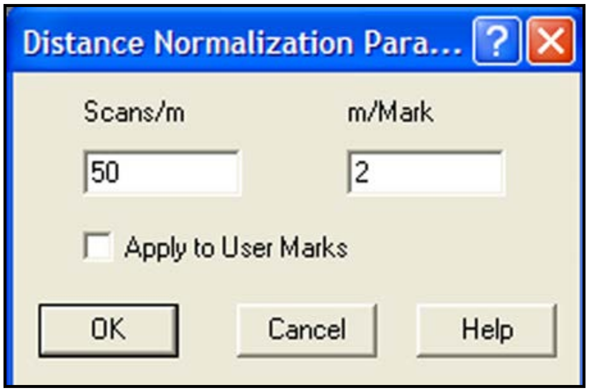


Figure 23: Distance Normalization Parameters Setup (with meters selected as linear units).

Note: Distance Normalization requires that marker information be stored in the Microsoft Access Database; otherwise it will be inactive.

Note: Distance Normalization will be "grayed out" and inactive if the file is a 3D file or has GPS information.

- Distance Normalization requires a minimum of TWO markers to work.
- Make sure that the markers are correct (no double or missing markers, first and last markers are present, all User markers are converted to Distance or Combo) before running Distance Normalization.
- The Scans per Unit and the Units per Mark must be assigned a value in the input file header in order for Distance Normalization to work.
- Units per Mark are determined at the time of the survey.
- Scans per Unit may be estimated by using the mouse cursor to count the number of scans between markers or by taking the Scans/Sec value in the header and estimating the number of seconds it took to traverse the distance between marker stations.
- Both Scans per Unit and Units per Mark parameters can be changed for the output file.
- Horizontal and vertical units (meters, feet, etc.) must be set before opening the file. Use the Linear Units tab under the Customize command in View menu.

To use, correctly set the scans/unit distance and the distance/mark in the File Header. Then click on the Distance Normalization button, or Process>Distance Norm. Make sure that the correct parameters appear in the Distance Normalization window, check the "Apply to User Marks" box, and click OK. Save the file with a new name when prompted.

Note the correct values for the scans/unit distance and marks/unit distance in both the file header and Distance Normalization dialog box.

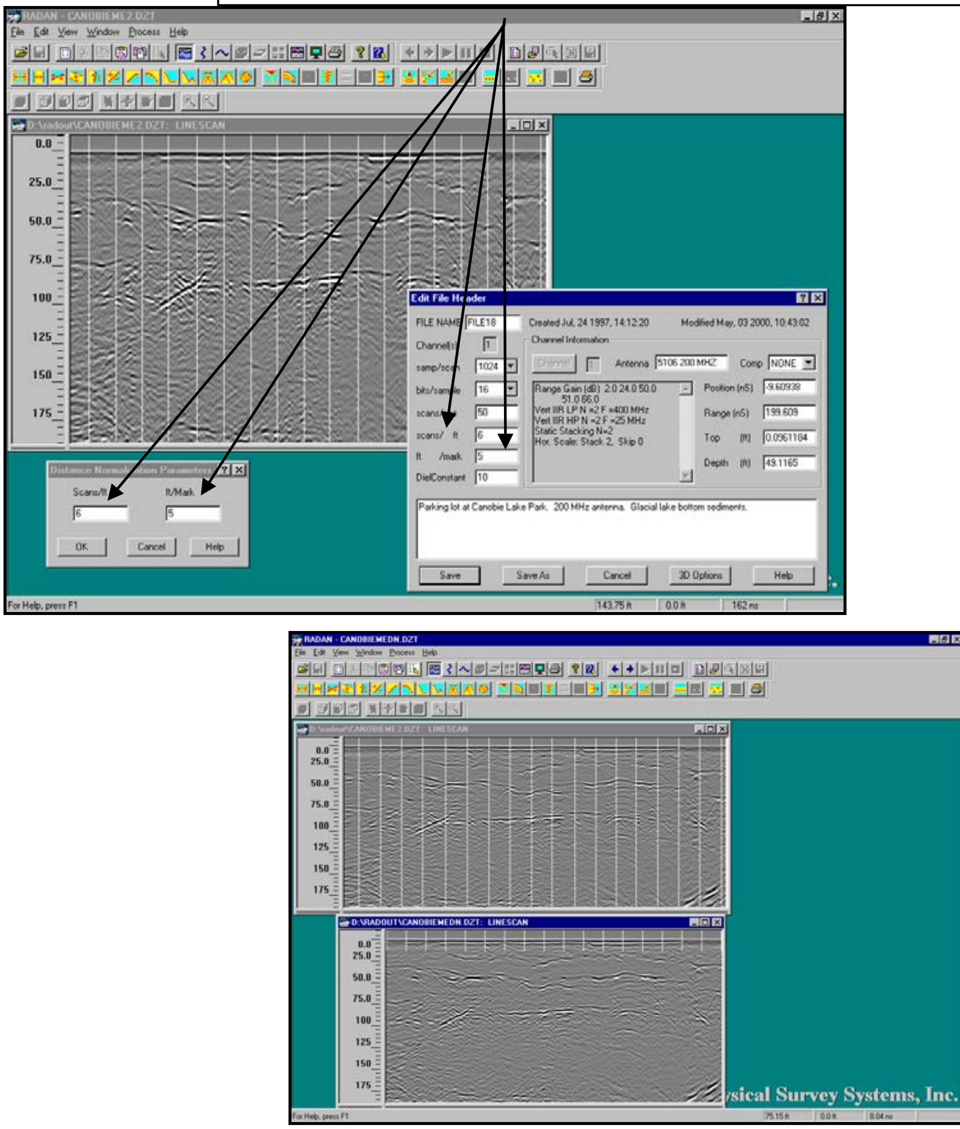


Figure 24: Example2.dzt. Distance normalization complete. Note the slight shift of the markers relative to reflectors in the data. Note also that data up to the first mark (scan 22) has been cut off by the normalization process.

Horizontal Scaling

Data may be modified by adjusting the Horizontal Scale using the Stacking, Skipping and Stretching functions. To do this, use the button or go to the Process menu and select Horizontal Scale.

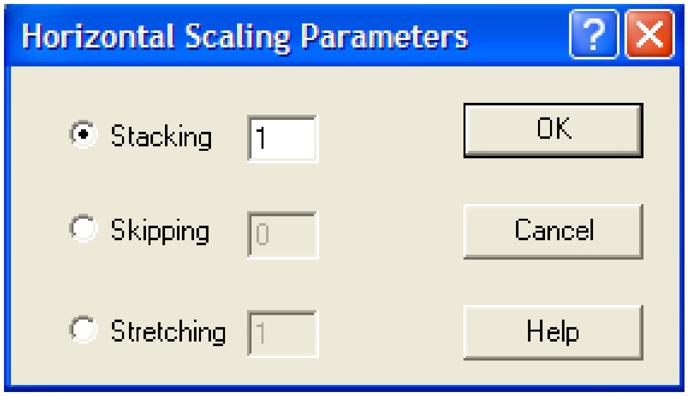


Figure 25: Horizontal Scaling Parameters Dialog Box.

Note that you can only run one of the three choices at a time. You must click on the circle next to your desired choice to select it.

Stacking: Select Stacking to apply a simple running-average to stack the data. Stacking combines the adjacent selected radar scans and outputs a single scan. When stacking values are used in RADAN, the program will retain the marks in the file. However, the scans per unit distance and marks per unit distance will be changed in the header. For example if you had a raw file with 80 scans per meter and 1 meter per mark and you stacked by a factor of two (2) the output file would have 40 scans per meter written into the header (reduced by a factor of 2).

Skipping: Select Skipping to specify the number of scans you wish to skip over from the previous scan. For instance, enter 1 if you wish to omit every other scan from the file (hence compressing it by a factor of 2).

Stretching: Select Stretching to expand the horizontal scale. The Stretching function will calculate the simple average of two adjacent scans (or the specified number of scans) and place the averaged scan in between the existing scans.

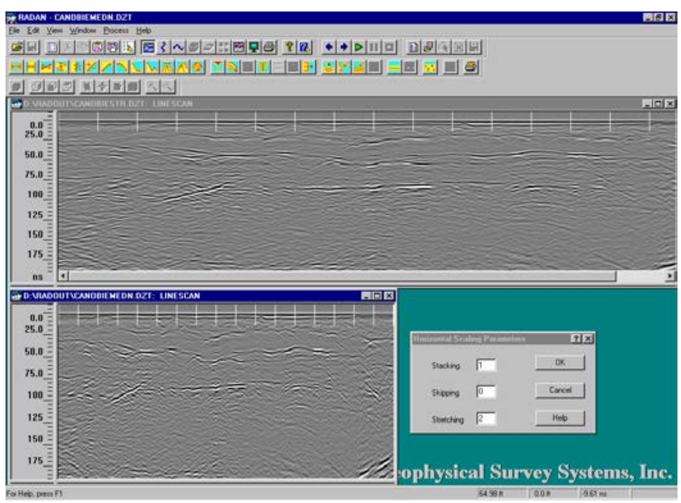


Figure 26: Example2.dzt. Data file STRETCHED by a factor of 2.

Appending Files

In some cases it is necessary to collect profiles in segments due either to logistical or data file size constraints. In order to append two (2) or more segments of the same profile together the user must first determine if any data editing functions (Marks conversion, Horizontal scaling, etc.) need to be performed on the data.

In the example that follows we will:

- Append the file segments,
- Edit the markers and the file,
- Perform a Zero Position correction and then;
- Perform a Surface Normalization.

***In this example we will actually skip a step, as it is generally desirable to perform any signal processing (Filtering, Migration, Gain functions, etc) on the whole file PRIOR to Surface Normalization. We will return to this file later on in the manual.

Appended files will be preserved as different regions. This is especially helpful if the files are 3D files.

1 To append files segments together select File > Append File. This opens the Select Single Channel File dialog box (Figure 27).

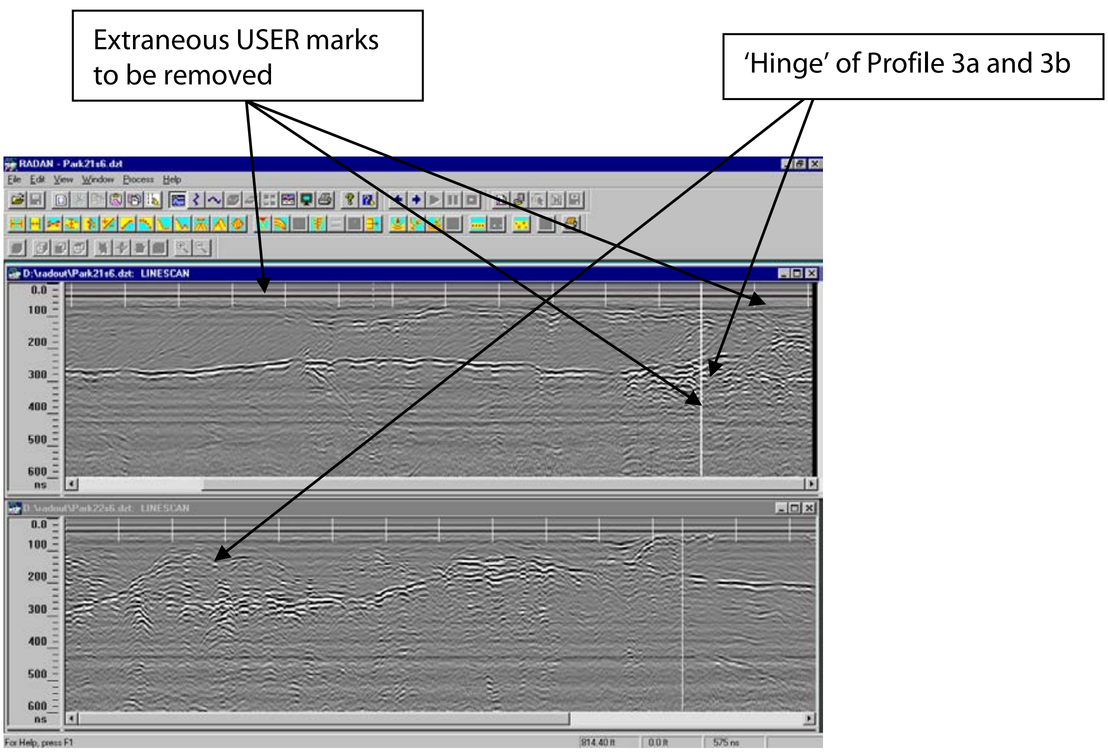


Figure 27: Example3a and 3b. 40 MHz antenna. Top profile (Example 3a.dzt) is the first segment. The bottom profile (Example3b.dzt) is to be appended to Example3a.dzt.

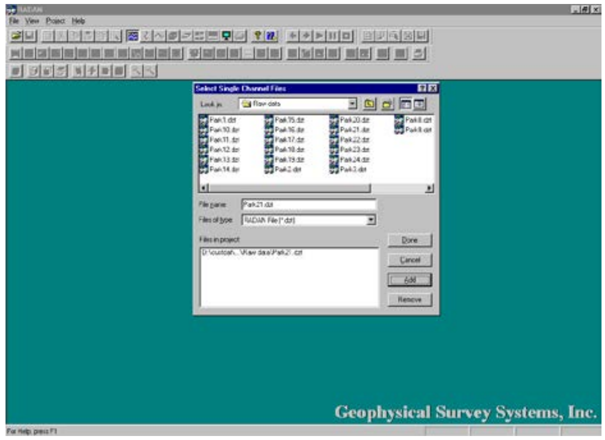


Figure 28: Select Single Channel File dialog box open. First profile segment selected.

2 Select each file segment IN SEQUENCE and select Add from the dialog box. In Figure 28 the first file segment has been selected.

3 When both file segments have been selected and Added to the Files In Project box, click Done.

4 The files will then be appended. Save the file with a new file name.

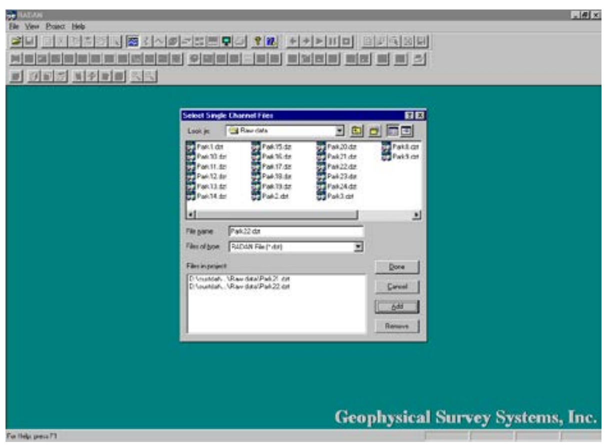


Figure 29: All file segments to be appended are Selected.

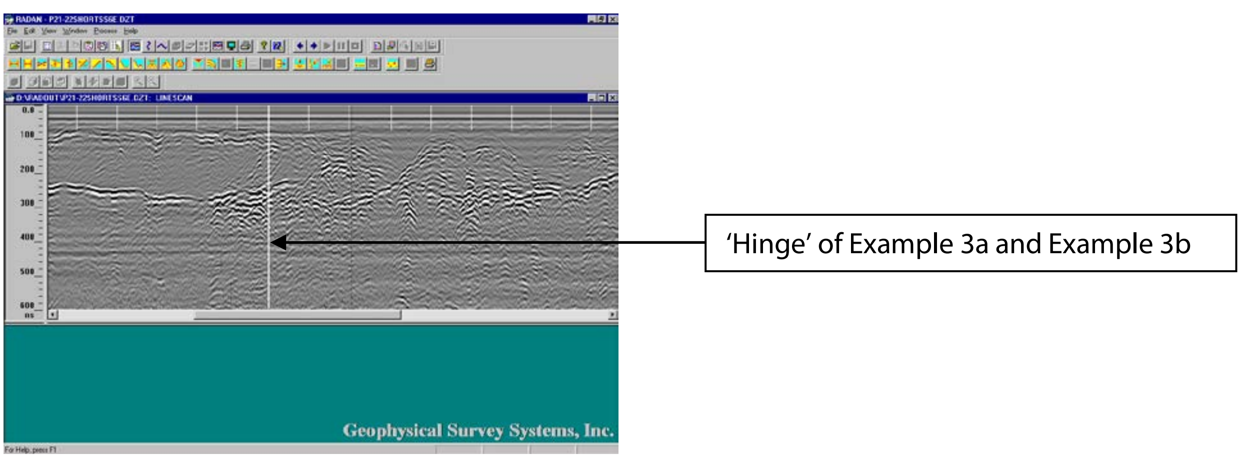
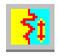


Figure 30: Example3a & 3b. File append is complete.

Vertical Scale Adjustments

Surface Position Adjustments 

Sometimes it is necessary to vertically adjust the position of the whole profile in the data window (adjust time-zero). You may want the first positive peak of the direct wave from a ground coupled, bistatic antenna to be centered at the top edge of the screen so that you can consider ground surface to be at the top of the window (at Time Zero). This can be done using the Correct Position command in the Process menu or by selecting the  button. A corrected 0-position will give you a more accurate depth calculation because it sets the top of the scan to a close approximation of the ground surface.

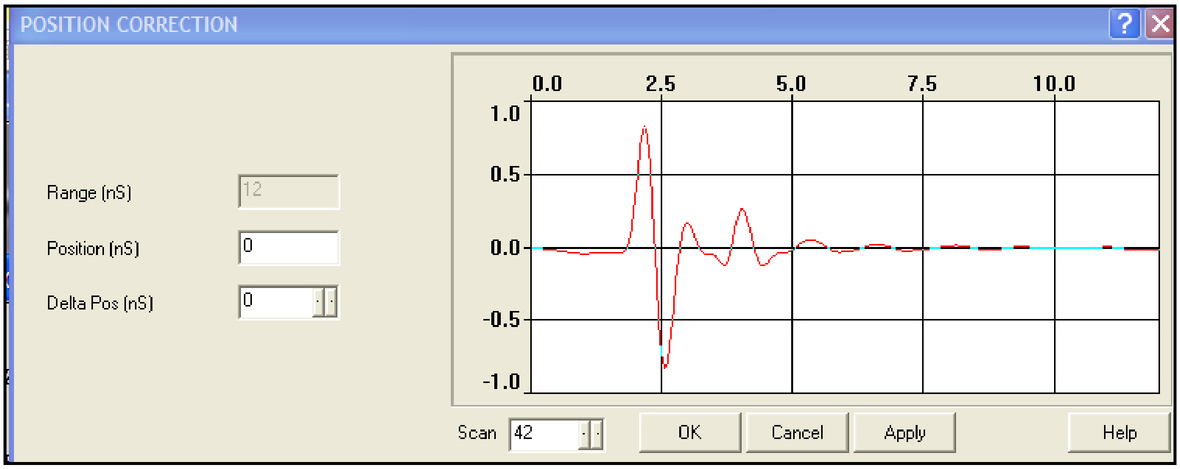


Figure 31: Position Setup Dialog Box.

In the dialog box, the position of the beginning of the trace on the time scale can be entered.

- The trace can also be shifted in small increments using the Delta Pos (nS) arrows.
- The scan to be displayed is selected in the Scan box and can be changed by placing the mouse cursor on the Display (Linescan, Wiggle, O-scope) and scrolling through the file.
- When you are satisfied with the correction select OK. The position correction will then be applied to the entire file. The correct 0-position is usually about 90% of the way to the first positive peak.
- If you wish to reset the top of the vertical scale to zero, then go to Edit>File Header and replace the value in Position(nS) with a zero.

Note: To shift the vertical scale without shifting scans in the display, modify the Position parameter in the file header.

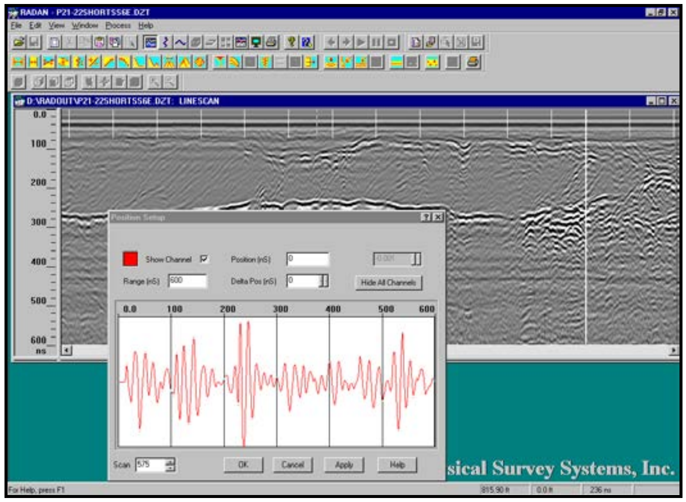


Figure 32: Example3a&b.dzt. Position Setup dialog box open.
Trace location corresponds to the dashed User mark in the middle of the profile.

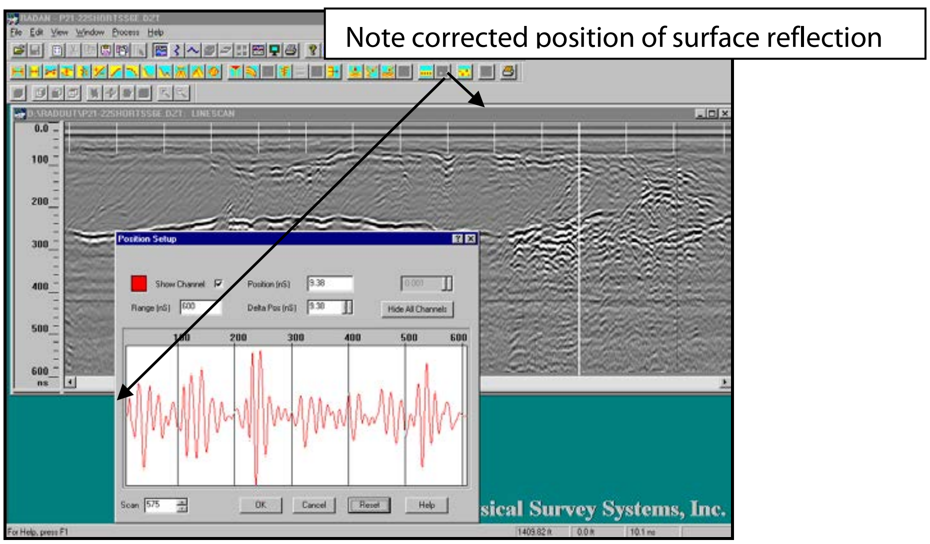


Figure 33: Example3a&3b.dzt. Zero position corrected.

Surface Normalization (Adjusting for Elevation Changes)

Surface Normalization allows you to assign an elevation to the markers in the database and correct for elevation changes. In other words, Surface Normalization adjusts the vertical scale to remove topographic effects, which results in horizontal or near horizontal reflectors appearing as they are in reality. For instance, the water table may appear to have significantly greater relief in radar data than in actuality. Surface Normalization corrects for the topography and displays the water table as a flat reflector.

Vertical Scale: The Vertical Scale may be set to 1:1 (normal view), 1:2, or 1:4. Using the latter two scales compresses the vertical axis (and adjusts the vertical scale accordingly) by factors of 2 and 4, respectively.

This compression of the vertical scale may be necessary if the relative change in elevation for the file is greater than the display range of the monitor being used. If data is not compressed, the file may 'run-off' the top or the bottom of the display window.

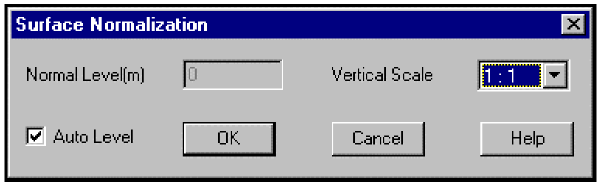


Figure 34: Surface Normalization Parameters Setup.

Normal Level: Normal Level can be manually input if the Auto Level option is deactivated. Surface Normalization requires that Combo (or Distance) Markers be used.

Note: Elevation values have to be manually assigned to the markers using Edit Markers (see Chapter 2, Editing Markers.)

When entered, elevation data will be stored in the Microsoft Access Database file.

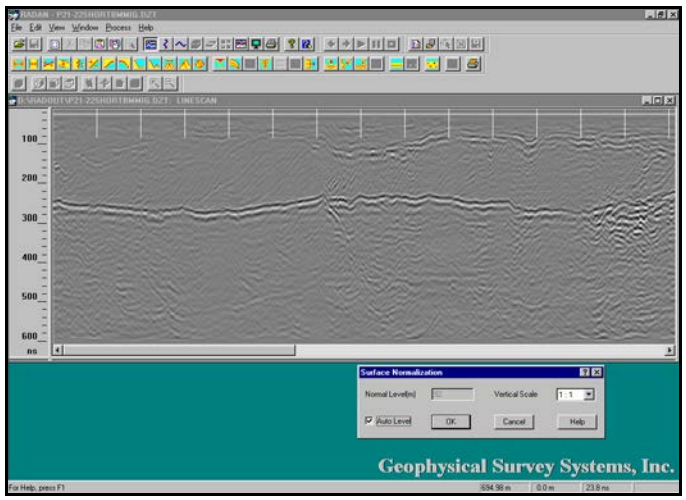


Figure 35: Example3ab.dzt. All DISTANCE markers converted to COMBO marks and Elevations entered. (See Table 3 for elevations.)

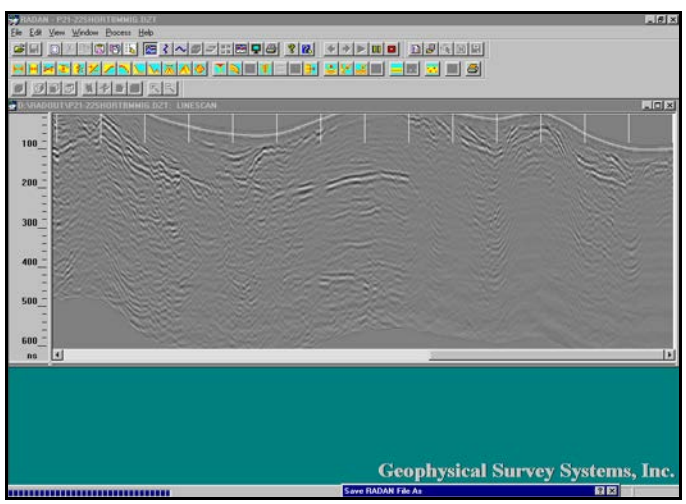


Figure 36: Example3a&b.dzt. Data has been normalized with Auto Level ON, Vertical Scale is 1:1.
Note that part of the file has ‘run-off’ the display window. You must either set a greater Vertical Compression or change the Auto Level.

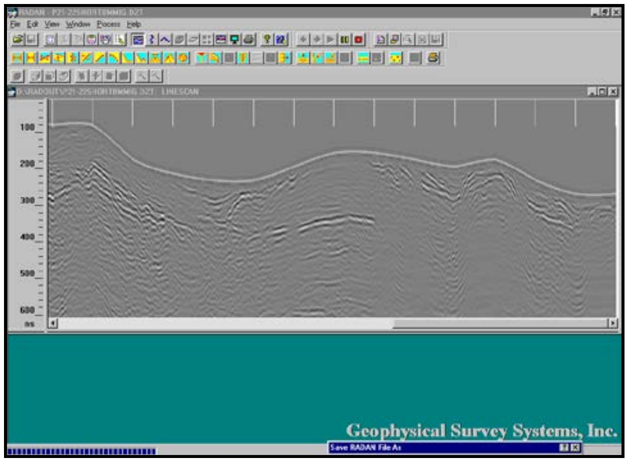


Figure 37: Example 3a&b.dzt. File has been normalized with Auto level set to 92. Vertical Scale is 1:1. Note that by using an Auto Level value of 92 (top of display window is 92 M) , the highest point (91m msl) in the data will appear on the screen. Please note that the Vertical scale is set in TIME, not depth (or elevation)

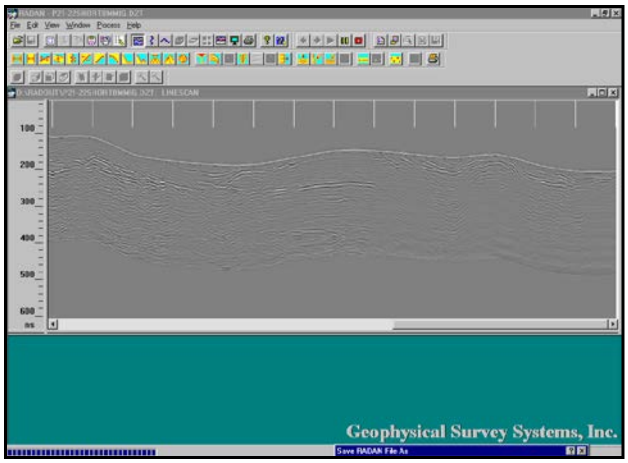


Figure 38: Example3ab.dzt. Auto Level selected. Vertical Scale 1:2. Due to the long time range of this file a 1:2 compression is probably not suitable for display or printing purposes.

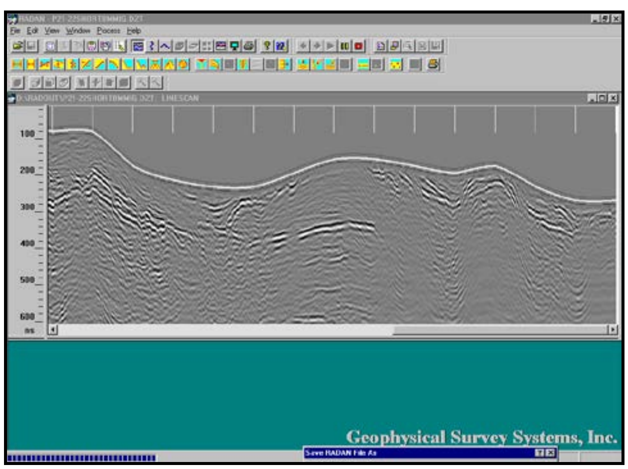
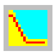


Figure 39: Example 3ab.dzt. Auto Level = 92, Vertical Scale 1:1. While the bottom of this file is missing (at the lowest surface elevations) .

About Filters

There are three types of filters available in RADAN to process radar data:

- Infinite Impulse Response (IIR) filters
- Finite Impulse Response (FIR) filters
- 2-D spatial FFT filters (F-K filters).

IIR Filters 

IIR filters were introduced before the advent of computers, when simple LRC circuits were used as analog filters. When an IIR filter encounters a feature in the radar data, it produces an output that decays exponentially towards zero but never reaches it, hence the name "infinite." IIR filters are not necessarily symmetrical and while they achieve excellent amplitude response, their phase response is non-linear and so they can cause slight phase shifts in the data.

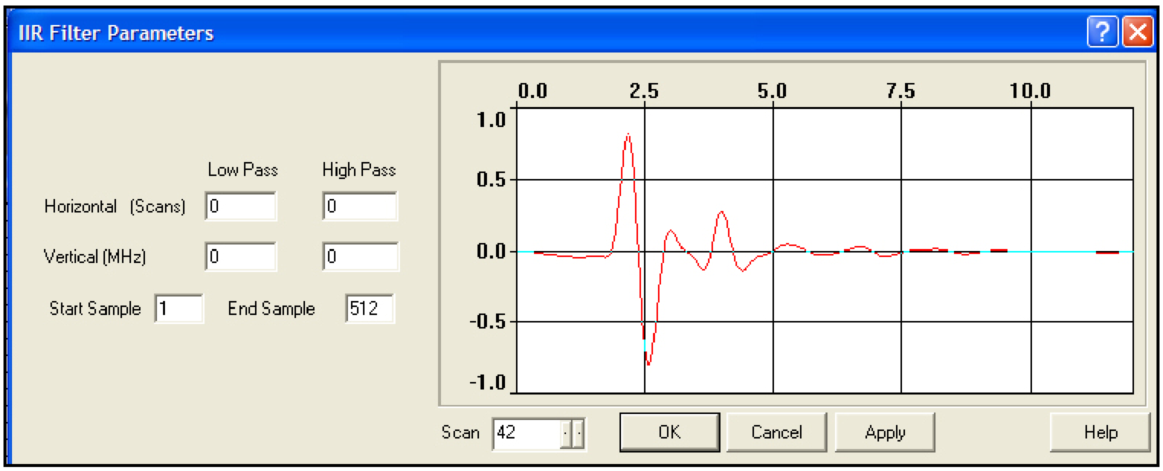


Figure 40: IIR Filter Parameters Setup.

- The IIR Filter Parameters Box lets you define the high and low pass horizontal and vertical filters as well as the time interval that will be processed, defined by the start and end sample number (RADAN automatically defaults to the whole time window).
- The cutoff frequencies are defined in number of scans horizontally and in MHz vertically.
- You can apply any combination of vertical filters simultaneously and see the result using the Apply button.
- Horizontal filters, due to their implementation, will not work under Apply. Select OK to see the horizontal filter's effect on the file.
- When you're satisfied with the results, Save the processed file.

RADAN uses IIR filters having only one pole so that there is not a sharp break at the cutoff frequency, which may provide limited noise reduction. As a consequence of this, it may be beneficial to run the same filter more than once. Or, another approach is to modify the Color Transform (under the Display Parameters Dialog Box) to hide what little noise remains in your data.

FIR Filters

RADAN contains Vertical and Horizontal FIR filters as well as Spatial 2-D filters. FIR filters have a finite-duration impulse response. FIR filters, when encountering a feature in the data, are guaranteed to output a finite filtered version of that feature. This property makes it possible to design filters that are perfectly symmetrical and have linear phase characteristics.

FIR filters will therefore produce symmetrical results so reflections will not be shifted in time or position. Note, because of the symmetrical nature of FIR filters, FIR filter lengths should always be an odd number. Generally, FIR filters are normally preferred in digital signal post processing; however, users more familiar with IIR filters might choose to use them instead.

There are two types of FIR filters available in RADAN, Boxcar and Triangular Filters.

Boxcar Filter: The Boxcar filter is a rectangular window function that performs a simple running average on the data. A portion of the data, determined by the filter length, is averaged, and the average is output as a single point at the center of the active portion of the filter window. The filter moves on to the next sample and the process is repeated. The Boxcar filter assigns equal weight to the data all along the filter length.

Triangular Filter: The Triangular filter emphasizes the center of the filter more heavily than the ends of the filter. This type of filter is a weighted moving average, with the weighting function shaped like a triangle. A portion of the data, determined by the filter length, is multiplied and summed by this function. The result is output at the center of the triangle. The filter then advances one sample and the process repeats.

Because of the number of calculations involved, Triangular filters are slower than Boxcar filters. Hence, we recommend using the Boxcar filter first because of its speed. If results are not adequate try the Triangular filters.

Data Filtering

Frequency Spectrum of Data

You may wish to determine the predominant frequencies of your data for processing purposes, or to determine the frequency of any noise. In RADAN, you can display the frequency spectrum of your data in any display format. The frequency spectrum can be analyzed in detail on a scan-by-scan basis using the O-Scope display format.

1. Enable the O-Scope display by using the toolbar or View menu. You will see the oscilloscope representation of a scan (amplitude versus time or depth).
   - Use the scroll bar to choose the desired scan. Its number will be displayed beside the cursor position in the bottom of the main window.
2. Place the cursor within the data window and click the right mouse button.
   - In the menu box that appears, choose Transfer > Spectrum. The displayed scan will be replaced with its frequency spectrum plotted in terms of relative amplitude (0 to 1) versus frequency in MHz.
   - It is recommended to create a Split Display first by using the Horizontal Split Bar, and then display the spectrum in one of the windows with the right mouse button (Figure 41). This way, both the waveform and the frequency spectrum for the selected scan will be shown.

3 Move the mouse cursor to determine amplitude or frequency parameters.

- If you click the left mouse button within the time-amplitude plot, the cursor position display at the bottom right of the main window will give you values for amplitude and time (or depth if it is selected as the vertical scale option and a dielectric constant or depth range is input into the file header).
- Frequency (MHz) and relative amplitude will be displayed if you click within the frequency spectrum plot.

4 Use the Scroll bars to view other scans.

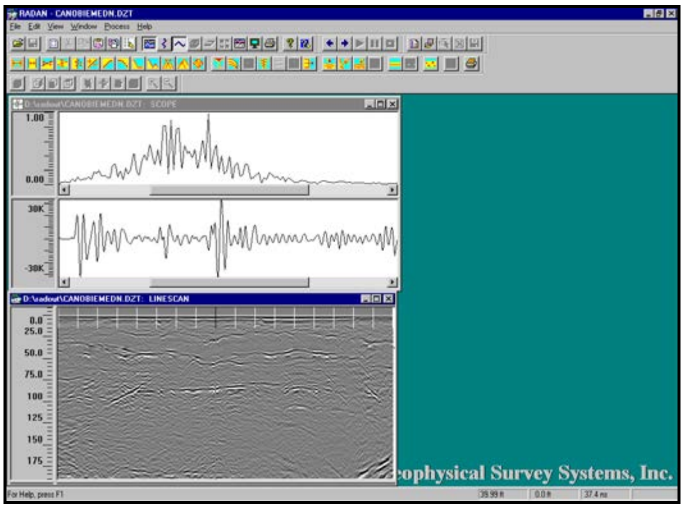


Figure 41: Example 2.dzt. Split Display with Linescan and O-Scope. O-scope display split to show frequency spectrum of scan 201 on top and scan on bottom. Trace location corresponds to black highlighted marker in the middle of linescan display.

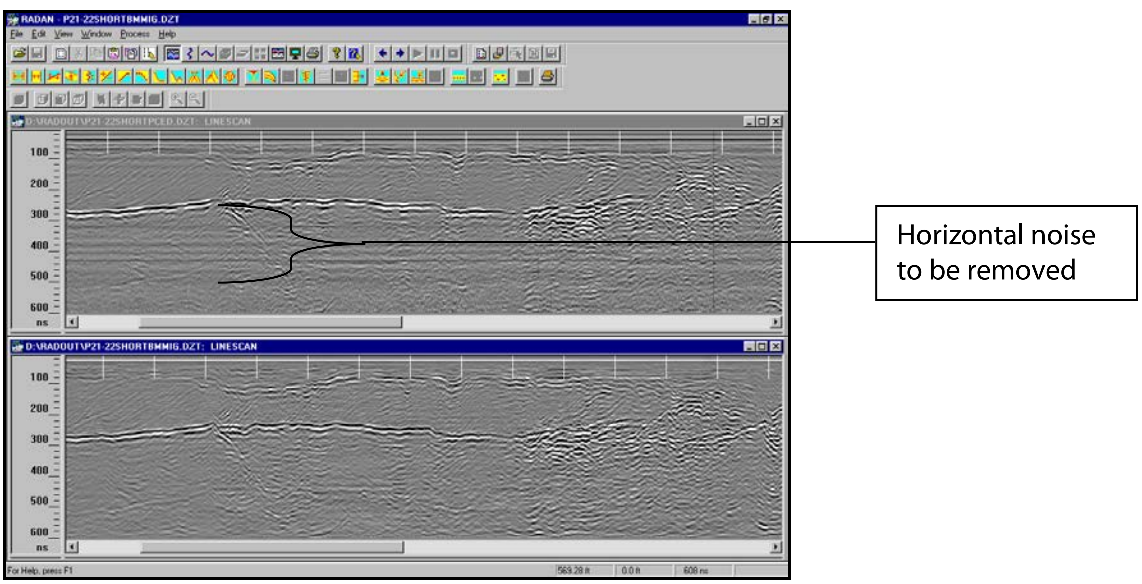


Figure 42: Example3a&b.dzt. Upper profile is raw data. Bottom profile has had FIR Background Removal filter, N =1023 applied from sample 20-512 and was then migrated. A display gain of 2 has been applied to the processed file.

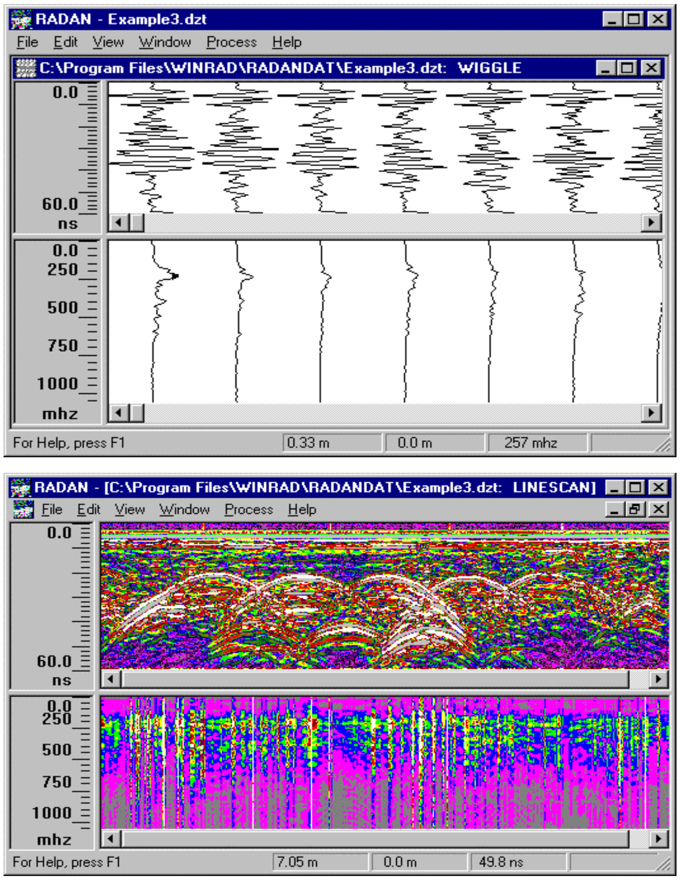


Figure 43: Split Display with a frequency spectrum in Wiggle format (top) and Linescan Format (bottom).

In the split display, if you use the scroll bar associated with the O-Scope plot, the frequency spectrum below will be synched to the current scan. Scrolling is not synchronized if you use the scroll keys from the frequency plot. It is also possible to synchronize to the Linescan plot by clicking on a single scan in the Linescan display window.

In RADAN, the frequency spectrum can be displayed in the Linescan and Wiggle formats as well, using the above procedure in the corresponding data windows. This option allows you to analyze frequency variations along the survey line.

- In the Linescan format, the scans will be replaced with their frequency spectra. The same color table will be used. Right-click on the data window, select Transfer, then Spectrum.
- In the Wiggle format, the wiggle traces (waveforms) will be replaced with their spectral plots (Figure 43).

Some Examples Of Different Filter Applications And Their Effects

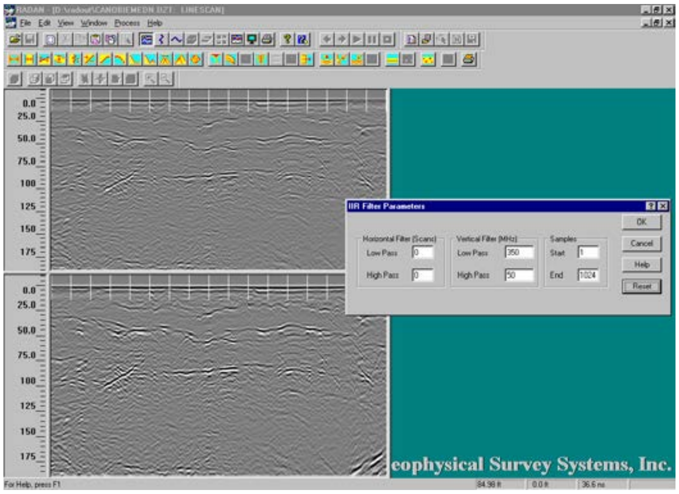


Figure 44: Example2.dzt. A Vertical IIR Low and High Pass Filter combination (band-pass). Upper half of spilt-screen is processed data. Lower half is original (raw) data.

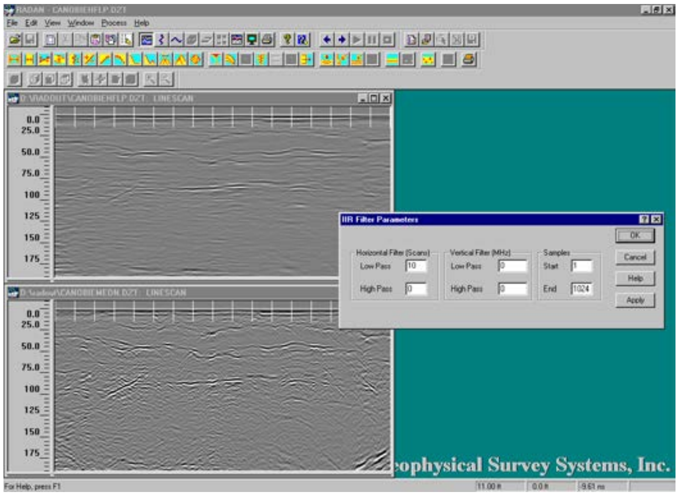


Figure 45: Example2.dzt. A 10 scan IIR Horizontal Low Pass (smoothing) filter applied. Upper half of split-screen is processed data. Lower half is original (raw) data.

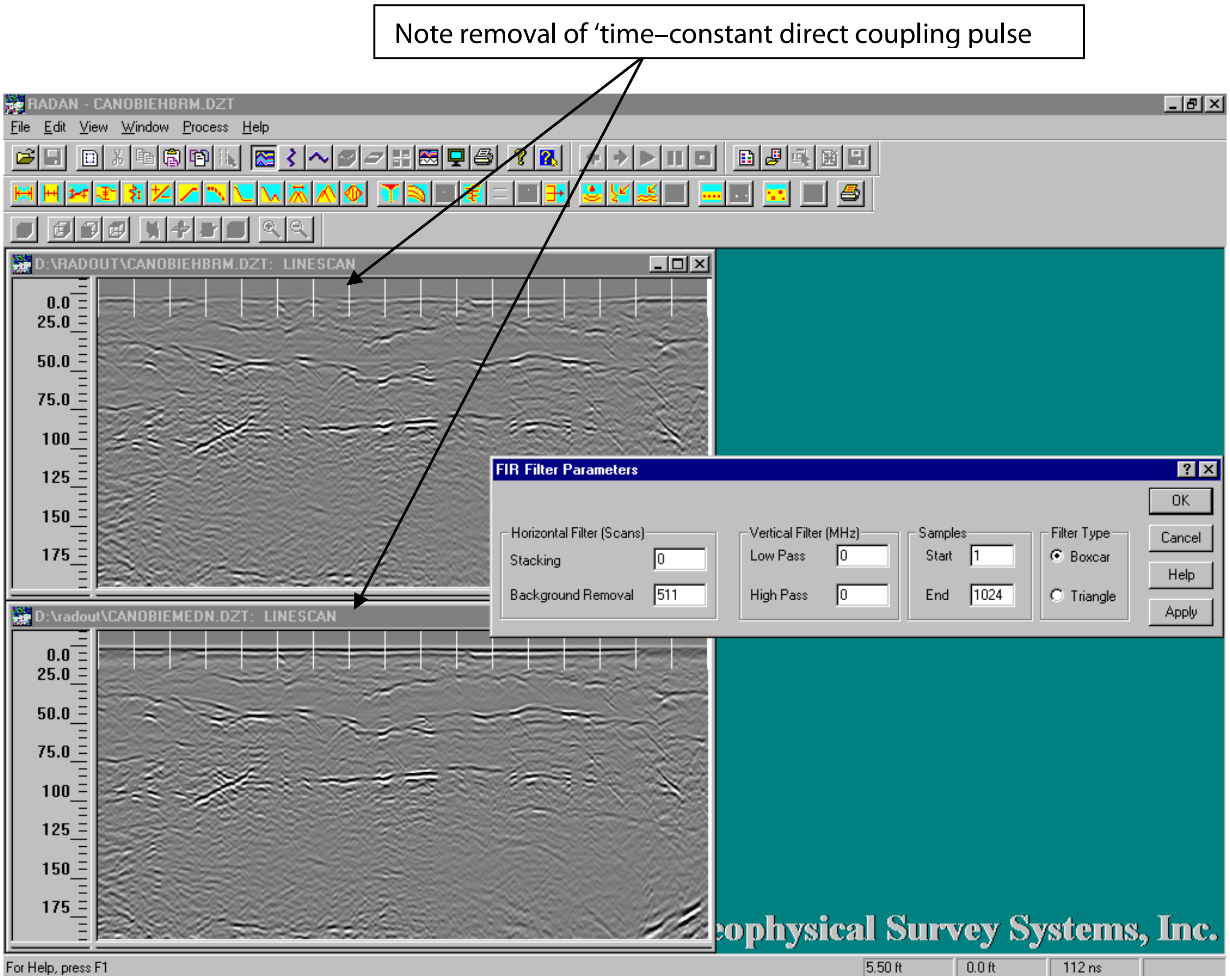


Figure 46: Example2.dzt. 511-Scan FIR Background Removal (Horizontal High Pass) filter applied. Bottom profile is raw data upper profile is processed data

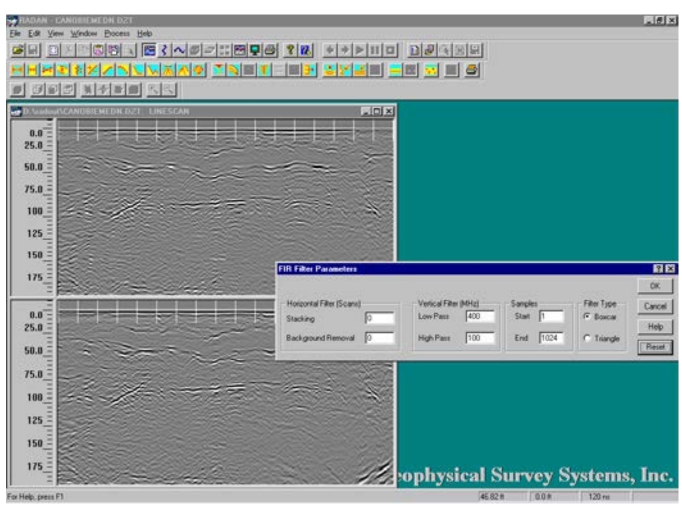


Figure 47: Example2.dzt. A Vertical FIR Low and High Pass filter combination (notch) applied.

Removing Flat-Lying Ringing System Noise

(Vertical HP, FIR Horizontal BM, IIR Horizontal HP)

This type of noise is usually most prevalent when the range is set near the maximum limits for the antenna. It is characterized by flat-lying or horizontal bands usually of a vertical frequency lower (shown by wider bands) than that of the real reflections in the data set. This type of noise can obscure or mask real reflections at greater depths.

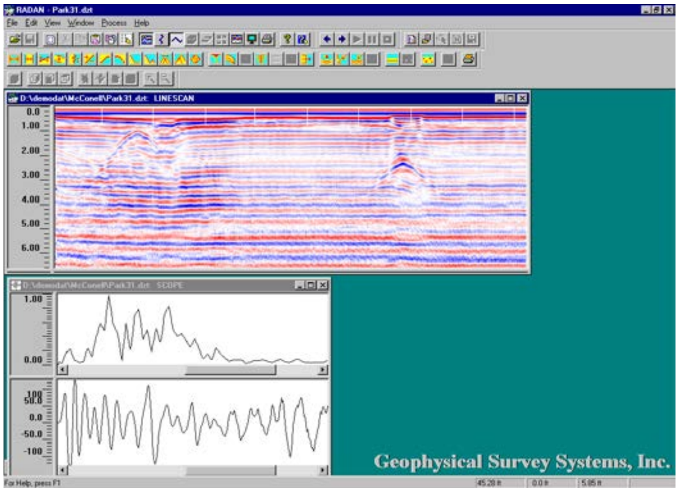


Figure 48: Example3.dzt. 400 MHz antenna. Data is predominated by flat-lying horizontal or ‘ringing.’ The O-scope display and spectrum correspond to a trace centered on the right-hand hyperbolic target.

Two utilities are shown here. The shallower target located in the upper left is a 6 inch metallic pipe buried .8 ft below the surface (ε ~ 24). The target on the right is a gas filled PVC pipe 1.85 ft below the surface. Both targets are buried in clay under a 4-6 inch thick asphalt pavement.

Horizontal High Pass (Background Removal) Filter

Using the Horizontal High Pass (Background Removal) Filter is the best way to remove bands of ringing noise. When a non-zero value is used, high pass filtering will occur in the horizontal direction. This has the same effect as a background removal filter. Low frequency features in the data will be removed, such as antenna ringing.

- The filter length should be set to the number of scans equal to the feature length you want to remove. In some cases this may or may not be realizable, as the file may be longer than the maximum number of scans that can be implemented for a particular filter. In these cases the user will have to accept some filtering of long i.e. ‘real’ horizontal reflectors in the data.
- The maximum value for a Horizontal HP IIR filter is 511 scans.
- The maximum value for a Horizontal Background Removal FIR filter is 1023 scans. In the case of Example3.dzt, the total file length is 719 scans (total distance is 45.4 ft). You may use a filter length of 719. Note that any continuous feature within the data that is on the order of 719 scans in length, such as a water table reflector or a stratigraphic boundary between two soil types, may also be filtered out to some extent. In this case these features are not present. You must be careful not to filter out actual real data.

Horizontal High Pass (Background Removal) Filter Parameter Selection

- The horizontal high pass length parameter should be an odd number.
- For the initial filter test, set this parameter to its maximum value (255 scans for IIR and 1023 for FIR filters) and run a Boxcar filter.
- If this does not remove the noise, decrease the filter length.
- Features that are flat (time constant) for the number of scans equal to the length of the filter or longer will be filtered.
- Features that are flat for and have feature lengths less than the length of the filter will be minimally affected by the filter.

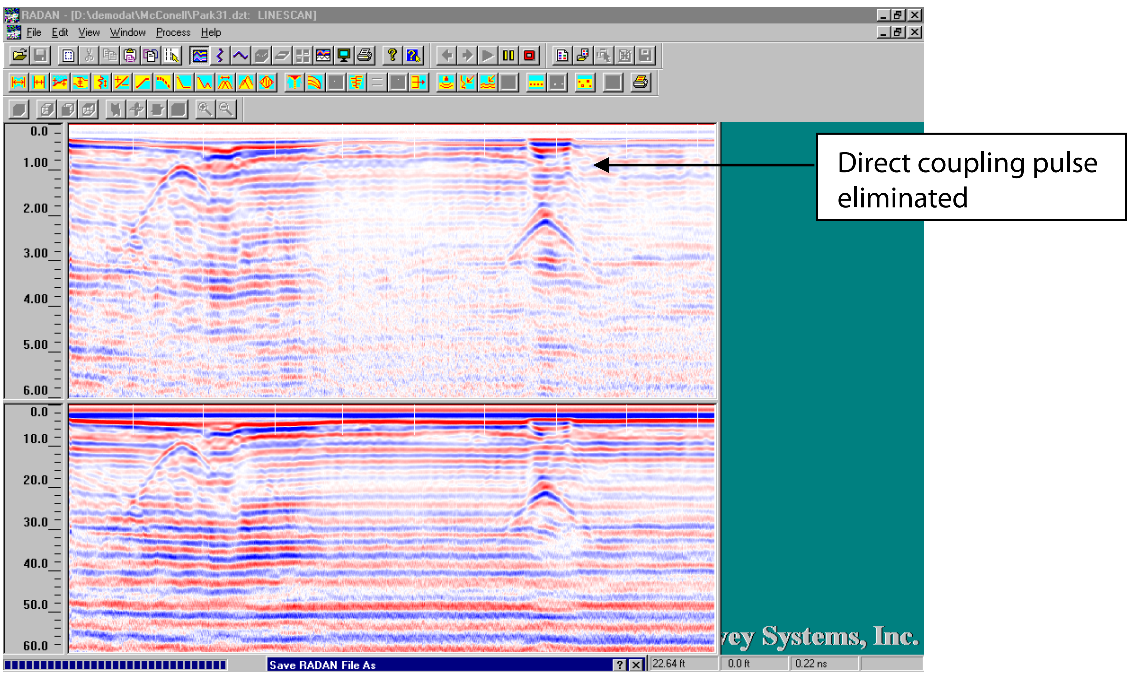


Figure 49: Example3.dzt. FIR Background Removal Filter N=1023 scans.

Note: The length of the filter should always be a greater number of scans than the length in scans of the longest flat "real" event in the data that you want to keep.

This filter will remove the surface reflection (direct coupling) pulse. In many cases, it is important to keep that direct coupling pulse as that is a visual check of your surface. If you want to keep the pulse, change the starting sample number to a value below the surface reflection. This may necessitate overlap filtering later to remove non-linearities created in the data by "window" filtering.

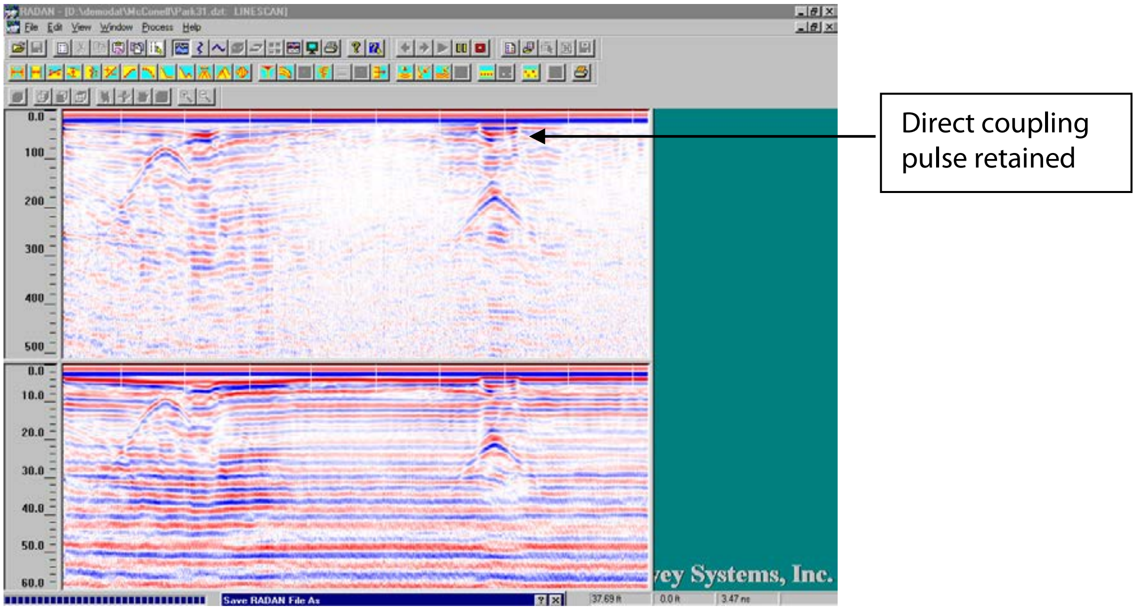


Figure 50: Example 3.dzt. FIR Background Removal Filter, N =127.
Filter started at sample number 28 to retain direct coupling/surface pulse.
Note the removal of additional horizontal and sub-horizontal event as compared to Example 34.

In some cases, the unwanted horizontal information will be lower in frequency than the antenna signal in the ground. In these cases, a Vertical High Pass Filter may be used to remove the lower frequency information.

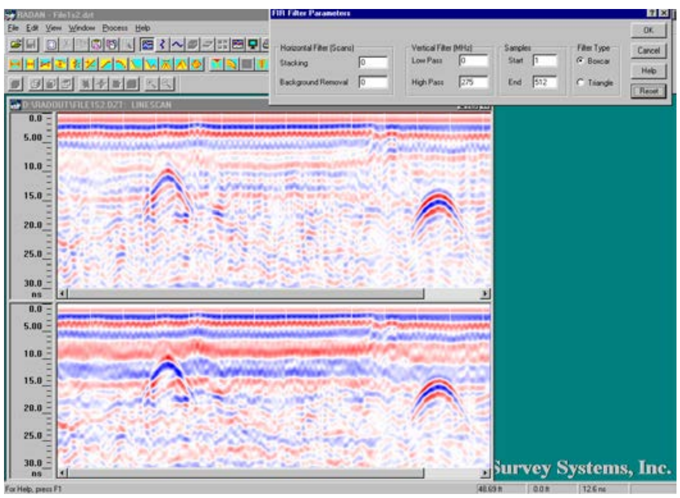


Figure 51: Example4.dzt. 400 MHz antenna. A Vertical High Pass (band-pass) FIR filter, N = 300 MHz is applied.
The bottom half of the split screen is the original 'raw' data. Two metallic utilities are shown in this example.
Total profile length is 43.2 feet. The targets are located under a 4-6 inch concrete slab reinforced with wire mesh.
The target in the upper left is 1.6 ft below the surface.
The target on the right is 2.3 ft below the surface.

If the desired horizontal features are of higher frequency content, use a FIR or IIR Vertical High Pass Filter with a cut-off frequency corresponding to about ¼ the center frequency of the antenna. For example, if you are using a 400 MHz (Model 5103) antenna, set the high pass cut-off to 100 MHz as a starting point, then try changing the frequency of the filter up or down within the antenna bandwidth to find the best fit.

Vertical High Pass Filter Parameter Selection

1. First measure the frequency of the noise bands you want to eliminate. This can be accomplished (as previously discussed In Frequency Spectrum) by using the O-Scope Display mode in the Display Options menu.

2. Click the right mouse button within the data window and choose Transfer > Spectrum.
   - The section describing the O-Scope Display Format in this chapter explains how to obtain and analyze a frequency spectrum of your data. See Figure 45 for example of O-scope/spectrum display with linescan.

3. Set the vertical high pass frequency equal to or slightly lower than the highest frequency you wish to eliminate and run the Boxcar filter.
   - The frequency range that you may choose will depend on the data sampling frequency. You should start at low frequencies first. If this does not adequately filter the noise, slowly increase the high pass cut-off frequency.
   - If the frequency of the noise bands is much lower (i.e., wider bands) than the reflections of interest, this approach will work quite well. However, if the noise bands and the reflections of interest are of the same frequency (width) the effectiveness of this approach is minimal.

Removing High Frequency Noise

This type of noise is usually most prevalent when the range is set near the limits for the antenna in use, and large amounts of gain are used. It is characterized by "snow-like" noise in the data at depth. This type of noise can make it difficult to map real reflections at depth. Both Vertical and Horizontal Low Pass Filters are effective for removing high frequency noise.

Vertical Low Pass Filter Parameter Selection

The Vertical Low Pass Filter will eliminate all the high frequency noise that often is seen in relatively deep radar profiles. You will be asked to input a frequency inside the range, which depends on the data sampling frequency.

- The cutoff frequency may be estimated by looking at the frequency spectrum of the radar data. We suggest using the frequency spectrum feature of RADAN to look at the frequency content of the radar file.
- A Vertical Low Pass Filter will reject frequencies above an established threshold. It is a good idea to reject all frequencies above the range where meaningful data are observed.

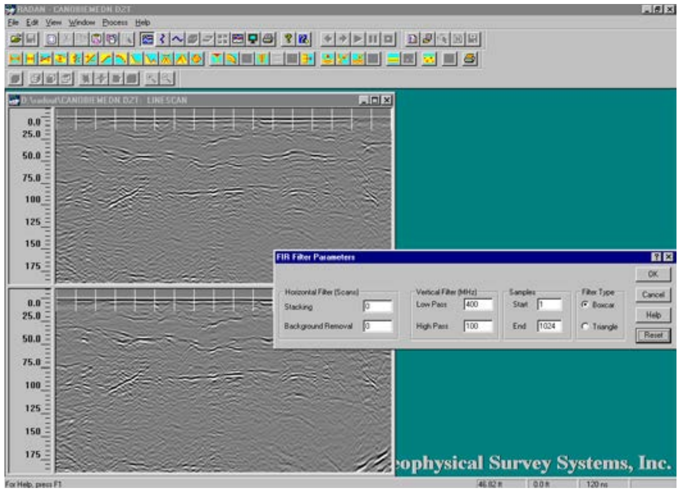


Figure 52: FIR vertical low pass filter selection.

Horizontal Low Pass Filter Parameter Selection

When a nonzero value of the Horizontal Low Pass Filter is used, low pass filtering will occur in the horizontal direction and reduce the “snow” noise and smooth the data. A number of scans on either side of the center scan will be averaged and the results placed in the center scan. The filter then moves on to the next scan and repeats this process until the end of the file is reached.

This type of processing is the same as applying a running average stack. Always input an odd number for symmetry. A Horizontal Low Pass Filter length of 5 will normally greatly reduce the “snow” noise and only slightly smooth the data. Increasing the filter length will remove more “snow” noise but will smooth the data more.

Spatial 2D Filtering 

Spatial FFT Filters (F-K Filters)

The spatial FFT filter , which is a two-dimensional frequency filter, takes place in the time-space domain. It is often called a frequency–wave number, or F-K, domain. This approach generates a two-dimensional matrix, the complex elements of which represent the phase and amplitude of various spatial waves present in the radar data. It allows the user to develop a two-dimensional filter to attenuate the noise.

Performing the inverse Fourier transformation of the product matrix from the transformed data and the filter yields a data with reduced noise. Technically, at this stage the frequency domain data is reconstructed back to the time domain.

The advantage of F-K filtering over successive vertical and horizontal one-dimensional frequency filtering is that it enables a better distinction to be made between the signal and the noise. The signal and noise spectra may overlap in one dimension, which makes their separation impossible, but this is less likely in the F-K domain.

The 2-D filter is defined by four parameters: Radius, Delta Radius (dRadius), Alpha and Delta Alpha (dAlpha). In a two-dimensional F-K domain their analytical expression in polar coordinates is as follows:

F(r,a) = k * Fo(r,a)

RADIUS   r0 = (r1 + r2)/2;   Alpha a0 = (a1 + a2)/2;

dRADIUS dr = r2 - r0;   dAlpha da = a2 - a0;

Four different filters are available in the RADAN Spatial FFT module: High-cut Horizontal, High-cut Vertical and the two corresponding symmetrical filters. They are described in the Spatial FFT section further in this manual.

Each filter can be used with filtering windows of different shapes. This determines the type of function necessary to obtain a finite-length impulse response by truncating an infinite-duration impulse response (frequency domain analog of time domain window functions).

- The linear window parameters, which are the radius parameters, represent fractions of the maximum data frequency. The following selection of filtering windows is available: Rectangle, Bartlett, Hanning, Hamming, and Blackman. The rectangular window cuts off at the specified limits, when the other windows allow for a smoother, more gradual transition. Their analytical expression, based on the parameters defined above, is as follows (assuming rt = r - r0;   at = a - a0, PI=3.14..):

Rectangular	k = 1, for -dr <= rt <= dr and -da <= at <= da;
Bartlett	k = (1 - rt/2dr) * (1 - at/2da), for -2dr <= rt <= 2dr and -2da <= at <= 2da;
Hanning	k =0.5*(1+cos(2*PI*rt/4dr))*0.5(1+cos(2*PI*at/4da)), for -2dr <= rt <= 2dr and -2da <= at <= 2da;
Hamming	k = (0.54 + 0.46 * cos(2*PI*rt/4dr))* (0.54 + 0.46 * cos(2*PI*at/4da)), for -2dr <= rt <= 2dr and -2da <= at <= 2da;
Blackman	k = (0.34 + 0.5 * cos(2*PI*rt/4dr) + 0.16 * (cos(2*PI*rt/4dr) ** 2)) * (0.34 + 0.5 * cos(2*PI*at/4da) + 0.16 * (cos(2*PI*at/4da) ** 2)), for -2dr <= rt <= 2dr and -2da <= at <= 2da; otherwise always k = 0.

Using The 2D Spatial Filter To Enhance Target Reflections In GPR Data

The 2D spatial filter (i.e., frequency/wave-number (F-K)) filtering technique is a robust tool for isolating sloping features with known frequency components in GPR data. This technique was first implemented by the seismic industry to remove ground roll from seismic data. In the case of GPR, many of the important targets contain reflections with characteristic slopes. Figure 53 is an example of noise removal.

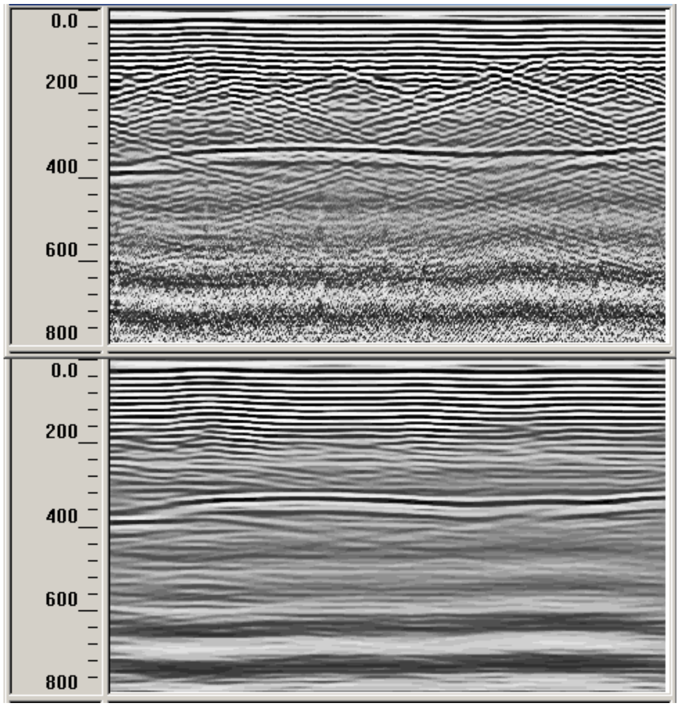


Figure 53: Noise removal using the Spatial filter.

Note the lattice-like noise pattern in the top window of data. A spatial filter can be adjusted to remove features with a specific dip angle, while leaving other features intact (bottom window).

1 To activate the F-K target filter, click the F-K button on the menu bar or choose Spatial Filter from the dropdown menu on the toolbar.

2 Click the box near Target Parameters. Approximate values for the ground propagation velocity, depth, and diameter of the pipe should be entered in the dialog.

3 The F-K spectrum of the highlighted section of the data file is shown on the left side of the dialog with the outline of the F-K target filter super-imposed.

4 When the highlighted section of the data file contains a strong hyperbolic reflection and the user-specified target parameters are accurate, the outline of the F-K target filter should extend around the highest amplitude portion of the spectrum.

5 To activate the F-K target filter, click OK. Features in the data with slopes outside the filter range are removed from the processed data.

This function is entered by selecting Spatial Filter in the Process menu or by using the button. A dialog box appears as shown in Figure 54 below. It shows spectrum display and filter parameters on the right and a 2D FFT diagram on the left. The diagram is a graphical representation of the 2D filter in a time-space domain. Its vertical axis represents signal frequency F (MHz) in the vertical direction (in time); the horizontal axis shows the wave number K (cycle/cm) in the horizontal direction (in space, i.e., along the profile).

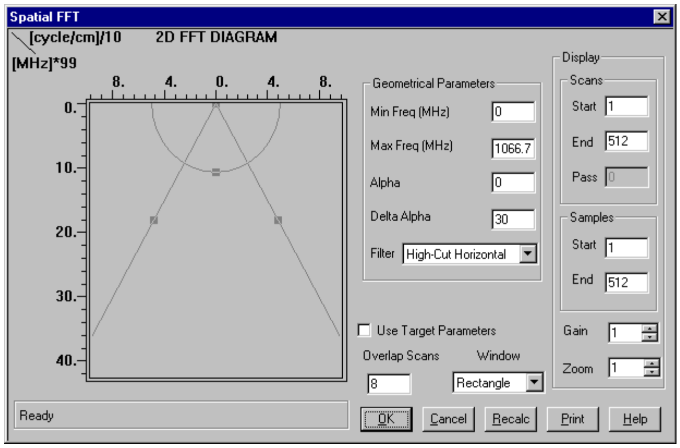


Figure 54: Setup menu for spatial filtering.

The recommended processing sequence starts with a spectrum display. The Recalc button transforms the file into the two dimensional frequency domain and displays the spectrum of the active file in the 2D FFT Diagram (Figure 55).

The Display group of parameters on the right side of the dialog box controls the spectrum display. Once a spectrum is displayed, use the Gain and Zoom parameters to enhance the display as desired. By default, the spectrum of 512 scans by 512 samples data section is calculated. You can select a different block of data by changing the start and end values under Scans and Samples, or you may select a portion of the file using the overlay box which will appear on the data display when the 2D FFT function is selected. Click the Recalc button again to display the spectrum of the selected section.

A 2-D filter for the inverse spatial FFT can now be set up. This can be done either by setting the filter parameters directly or by using target parameters.

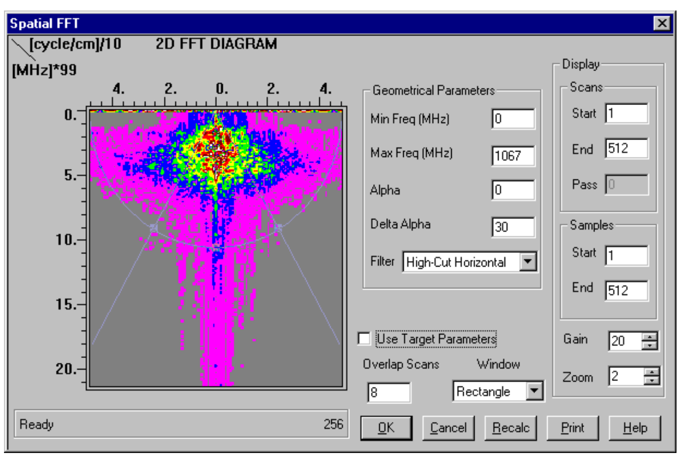


Figure 55: Spatial FFT dialog box with a data frequency spectrum.

Filter Parameters Setup

1 To set filter parameters directly, make sure the Use Target Parameters box is blank (this is the default).

2 Check and adjust the Geometrical Parameters (Min and Max Frequencies, Alpha and Delta Alpha).

- These parameters can be entered in the appropriate boxes or adjusted by dragging the four square boxes in the 2D diagram.
- Minimal and maximal frequencies are represented by the arcs in the diagram.
- Alpha and Delta Alpha that control the horizontal components are represented by two straight lines (radiuses) in the diagram.

Alpha expresses the filter symmetry and remains close to zero whenever the radiuses are placed symmetrically on both sides of the imaginary vertical centerline (zero wave number). In this configuration, horizontal and vertical features will be emphasized.

An asymmetric setting (high Alpha) will emphasize slant reflections. Default is a zero Alpha setting, but it is recommended to experiment with combinations of asymmetric radiuses and symmetric filters (see below) that can, in some cases, make weak reflections clearly visible.

Delta Alpha controls the angle between the radiuses that physically corresponds to the linear dimension of reflections.

3 Once the Geometrical Parameters of the filter have been set, the 2D diagram can be printed out using the Print button. The arc and radius positions will be drawn with the four parameters printed below: Radius, dRadius, Alpha, and dAlpha (see the "About Filters" section for the definitions).

Filter: This parameter determines the part of the 2D diagram that will be processed with inverse spatial FFT. The five possible options are:

None: The FFT file will be reconstructed without any changes.

High-Cut Horizontal: Reconstruction will use only the wide arc domain between the radiuses.

High-Cut Vertical: Reconstruction will use only the wide arc domain between horizontal zero-frequency line and radiuses (outside the radiuses).

High-Cut Vert Symm: Two equal sectors outside the radiuses are used for reconstruction.

High-Cut Horz Symm: Two equal sectors between the radiuses are used.

The symmetrical filters are useful in cases where the radiuses are positioned asymmetrically relative to the imaginary vertical centerline.

Window: Each filter can be used with any of the filtering windows available: Rectangle, Bartlett, Hanning, Hamming, and Blackman. The rectangular window cuts off at the specified limits, whereas the other windows allow for a smoother, more gradual transition. The analytical expression for these windows is given earlier in this manual (see section, About Filters).

Overlap Scans: Determines the overlap between consecutive passes of the filtering window. More overlap produces a smoother result; in most cases, the default value of 8 is adequate.

Using the Target Parameters

The Geometric Parameters setup is replaced with the Point Target Parameters setup, if the Use Target Parameters option is activated (the corresponding box is checked). The following parameters are required:

Diameter (m): Enter the typical size of an expected target.

Depth (m): Enter the expected target depth.

Ground Relative Permittivity: Enter an estimate of the relative dielectric constant of the ground material.

Low K removal number: Cutoff wave number. Wave numbers less than this value are removed by the filter.

1 RADAN will adjust the filter parameters according to the specified target parameters. In the Use Target Parameters mode, no arcs and radiuses are displayed in the 2D diagram, but a spectrum can still be displayed using the Recalc button.

2 When the filter parameter setup is complete, click OK and the result of the F-K filtering will be displayed in the data window.

3 You will be prompted to save the file. Do so if you're satisfied with the result. Otherwise, cancel the Save operation, go back to the Spatial FFT dialog, readjust parameters and try filtering again. A trial and error approach may be necessary due to the complexity of this procedure.

Increasing Visibility Of Low Amplitude Features

Gain may be used to emphasize low amplitude sections of data or accentuate small amplitude differences. GPR data will often exhibit large amplitude variations. The low amplitude regions of the survey data are often difficult to interpret from the raw field data. There are three methods in RADAN to enhance low amplitude sections of data or accentuate small amplitude differences:

1. Change the Color Transform
2. Adjust Range Gains
3. Adjust Display Gain

By changing the Color Transform, low amplitude regions can be enhanced with only minimal effect on the high amplitude events. Range Gains, while increasing the low amplitudes, also amplify the high amplitude reflections. The Display Gain may be thought of as nothing more that screen contrast, and does not apply any permanent processing to the data. It also applies the same value to the entire dataset and as a result, higher amplitude areas may appear over-gained.

Changing The Color Transform

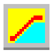
The Color Transform is in the View menu under Display Options (select Linescan). The section on reviewing and changing the Display Parameters earlier in this chapter explains in greater detail how to change the Display Parameters such as Color Transform. The default Color Transform (Transform #1, linear) is made up of 8 positive polarity and 8 negative polarity amplitude color bins. The total amplitude range of all the color bins are equal.

Often, small amplitude differences in GPR data can be an indication of significant changes in the subsurface. For instance, hydrocarbons floating on top of the water table may cause slight amplitude changes. To emphasize lower amplitude events, select Color Transform #2 (square root); for an even stronger lower amplitude emphasis, select Color Transform #3 (logarithm).

Weak, or similar amplitude reflectors, can be highlighted by creating customized transforms that emphasize low amplitudes. The Color Transform can also be used to suppress high amplitude features and highlight only the features of interest, such as metal pipes, drums, and underground storage tanks.

Range Gain Parameters Selection

Often, the signal amplitude is reduced when some filters are executed. RADAN allows you to increase the Gain and compensate for amplitude reduction. Two types of gain modification are present: Range Gain  and Restore Gain . The Range Gain helps the user to interactively modify the gain applied to the data. Restore Gain removes the gain applied to the data during acquisition.

Range Gain 

There are three Range Gain options available in RADAN: Automatic Gain, Linear Gain and Exponential Gain. Linear and Exponential Gain functions are applied in the Manual Mode and allow the user to manipulate the gain between gain points. The gain value can be entered in the Value box or adjusted by dragging the gain points (small squares) up and down.

- When Linear and Exponential Gain functions are selected, gain corrections are applied to the entire data set. These curves will not only amplify the low amplitude signal but also the high amplitude areas.
- The Linear function applies a linear gain between gain nodes.
- The Exponential function applies an exponential gain curve between gain nodes. The vertical scale of the Exponential Gain function is displayed in terms of decibels (dB) so that it is linear. This is designed to compensate for attenuation.

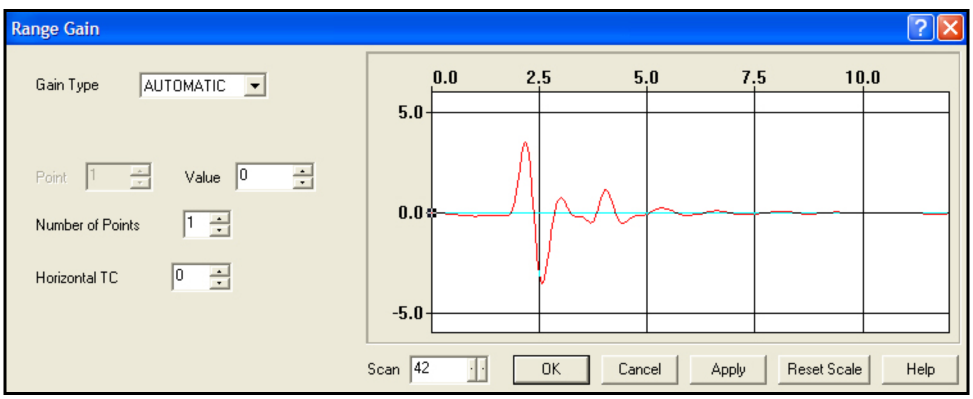


Figure 56: Range Gain Parameters Selection.

- The Automatic Gain feature attempts to balance the gains over each scan.
- A value for the horizontal time constant is required to run the Automatic Gain function. This time constant determines how many scans on the left side of the current scan will be used to shape the automatic gain curve. It applies a weighted filter. A small value giving more weight to scans adjacent to the current scan, a large value giving weight to those further away.
- When using both the Automatic Gain and the Manual Gain we recommend setting the number of breakpoints to between 4 and 8.
- For the Automatic Gain the overall gain factor is normally set between 2 and 5 and the horizontal time constant is normally set between 11 and 21.

Restore Gain

The Restore Gain function removes the gain applied to the data during acquisition. Restoring gain is an important option should you wish to export your data to a forward modeling program, or determine the dielectric permittivity, conductivity, and dispersion (approximate attenuation) of layers. The Restore Gain function uses gain information found in the file header to remove the gain function and normalize the gains.

Note: Gain differences exceeding 30 dB may result in a significant loss in data resolution. Saturated data will result in distorted wavelets after Gain Restoration.

Display Gain

To change the Display Gain, simply right click on the data window and select Display Gain. You can either then select from a preset list of multiples ranging from .0625 up to 16, or input a Custom value. This will change all samples, no matter where they are in the pulse, by the same amount. Altering the display gain does not change data values like Range Gain. Trying different values in the Display Gain may make it easier to spot lower amplitude targets.

Deconvolution: Removing Ringing Multiples

Multiples or "ringing" occur when the radar signal bounces back and forth between an object (such as a piece of metal or layer of wet clay) and the antenna, causing repetitive reflection patterns throughout the data and obscuring information at lower depths. Multiple reflections may also be observed when mapping water bottom, bedrock (or till), or voids. Deconvolution is the filtering method used to remove this type of noise.

RADAN uses a method called Predictive Deconvolution. It is a general technique that includes "spiking" deconvolution as a special case. Predictive deconvolution is aptly named because the method tries to approximate the shape of the transmitted pulse as the antenna is coupled to the ground. Assuming a source wavelet of a specified length, called the operator length, this filter will predict what the data will look like a certain distance away, called the prediction lag, when the source wavelet is subtracted (or deconvolved) from it. This results in the compression of the reflected wavelet. Predictable phenomena, such as antenna ringing and multiples, are moved to distances greater than the prediction lag and are effectively removed from the data.

Deconvolution Parameter Selection

In order for Deconvolution to work properly, certain parameters, such as operator length, prediction lag, prewhitening, gain, start sample, and end sample, must be supplied as input.

Operator Length: The operator length specifies the size of the filter used in terms of the number of samples making up 1 pulse length.

- Longer filters give a better approximation of the radar wavelet and generally give better results, but take longer to process.
- A good rule to start with is that the operator length should be about one full cycle of the radar antenna wavelet. A value less than this gives poor results.
- To remove reverberation, first measure the width of a reverb packet in number of samples. Then set the operator length to that value. Increase the operator length slightly for more effect.

- Tutorial two in the "Advanced Processing Tutorials" section will detail how to measure the width of a feature and input an appropriate operator length.

Prediction Lag: The Prediction Lag should be set to the desired length of the output pulses (about one-half cycle of the antenna wavelet). Smaller values than this will produce more noise.

- When using Deconvolution to remove multiple reflections, the lag should be equal to or less than the spacing between multiples.
- A prediction lag between 5 and 1 is used to approximate “spiking deconvolution.” However, this introduces significantly more noise into the data.

Prewhitening: Prewhitening modifies the autocorrelation function by boosting the white noise (zero delay) component. Mathematically, prewhitening stabilizes the filter, thereby smoothing the output and reducing noise. Values between 0.1 and 1 percent are common, 0.8 is a good value to start with.

Additional Gain: Additional Gain may be needed because the deconvolution process attenuates the signal, especially when the prediction lag is short. Gain values of 3 to 5 are common, but use whatever achieves an amplitude level equal to the original data.

Start/End Sample: The starting sample and ending sample should be set to establish the “time gate," specified in terms of sample number, in which the Deconvolution filter is active. For instance, a start sample and end sample of 256 and 1024 respectively may be used to remove multiples beneath a reflector located at sample number 240 in a 1024 Samples/Scan data set.

Migration: Removing Diffractions And Correcting Dipping Layers

The radar antenna radiates energy with a wide beamwidth pattern such that objects several feet away may be detected. As a consequence of this, objects of finite dimensions may appear as hyperbolic reflectors on the radar record as the antenna detects the object from far off and is moved over and past it.

Deeper objects may be obscured by numerous shallower objects that appear as constructively interfering hyperbolic reflectors. Steeply dipping surfaces will also cause diffracted reflections of radar energy. This diffracted energy can mask other reflections of interest and cause misinterpretation of the size and geometry of subsurface objects. The apparent geometry of steeply dipping layers are an illusion and need to be corrected in many cases. Migration is a technique that moves dipping reflectors to their true subsurface positions and collapses hyperbolic diffractions.

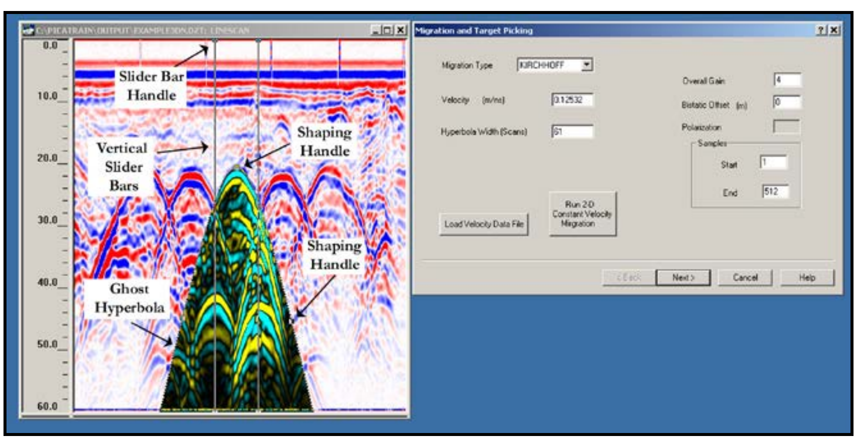


Figure 57: Migration Window explained.

Migration Parameter Selection

There are two Migration methods available in RADAN: Kirchhoff and Hyperbolic Summation. The Hyperbolic Summation method is faster but less accurate than the Kirchhoff method.

Hyperbolic Summation: Hyperbolic Summation works by summing along a hyperbola placed on the data, and placing the resulting average at the apex of the hyperbola. This process is repeated with the apex on every point of the data.

Kirchhoff (default): The Kirchhoff method is more accurate than the Hyperbolic Summation. An average value is still derived by summing along a hyperbola placed on the data and placed at the apex. However, Kirchhoff Migration also applies a correction factor to this averaged value, based upon the angle of incidence and distance to the feature. It also applies a filter to compensate for the summation process. This filter improves resolution by emphasizing the higher frequencies and applying a phase correction. Generally, because of speed considerations, the Hyperbolic method is used if it provides adequate results. If the Hyperbolic Summation method does not provide good results, the Kirchhoff Migration method should be tried.

- Both the Hyperbolic Summation and Kirchhoff Migration require that the hyperbolic width and relative velocity are specified.
- The following file header parameters must also be assigned a value before the data can be migrated:

    Samples/scan

    Range (ns)

    Scans/meter

Helpful Hint: You should use a survey wheel during the data collection process in order to migrate the data accurately.

Velocity is the speed at which the radar pulses travel through the material. The relative velocity is the ratio between the length of an object in the distance axis (in number of scans/meter) to its length in the time axis on the screen (number of samples/meter).

- You should adjust the shape of the Ghost Hyperbola to match a real hyperbola in the data. Notice that as you change the shape of the hyperbola, the velocity changes. The Ghost Hyperbola is nothing more than a tool to help you identify the correct velocity of your material.

Width (in number of scans) is used to sum across the data file. This value should be set to about the same number of scans as the diffraction hyperbolas in the data. Larger values tend to give more accurate results, but if the value is too large, deterioration will occur.

Gain function is used to increase the data amplitudes after migration, since migration usually reduces the amplitude of the radar signal. The Gain is usually set to a value between 1.5 and 5.

Follow these steps to Migrate:

1 Left-click and hold the mouse button when the cursor is over the center of the Ghost Hyperbola. This will allow you to drag the Ghost Hyperbola to center it over a real hyperbola in the data.

2 Now use the Shaping Handles to match the shape of the Ghost Hyperbola to a real one. You will have to left-click on and hold to drag those around. Be sure to cover up the entire real hyperbola and remember to use to tails of the real hyperbola to help your shaping. This sets Migration velocity.

3 Adjust the Width by left-clicking and holding on the Slider Bar Handle at the top or the bottom of the profile window. You want the slider bars to be wide enough to encompass the real hyperbola that you are matching, but not so wide as to include adjacent hyperbolas. This sets the hyperbola search width.

4 If your material is homogenous, click on **Run 2-D Constant Velocity Migration.** If your material is not homogenous, click Next to go to 2-D Variable Velocity Migration.

2-D Variable Velocity Migration

After matching the hyperbola, click the Next button to go to the next dialog, Variable Velocity Migration. This allows you to enter different velocity values for different depths. This method is most often used when the survey material changes with depth, like dirt. Soil chemistry, porosity, and moisture can all change with depth and using a simple 2-D constant velocity migration may produce tremendous error. In an area of changing conditions, hyperbolas are collapsed more accurately using variable velocity migration, which leads to accurate depth calculations.

Note: This type of migration will not produce a single dielectric value and will not replace the dielectric constant in the File Header.

1 Using the mouse, click on the peaks of several hyperbolas in the data window.

- They will appear as colored circles and the hyperbolas originated at them will be used to automatically calculate the velocity at each of these targets.
- Try to pick targets at different depths, as the velocity of the survey area material may vary not only laterally, but also with depth (IMPORTANT).

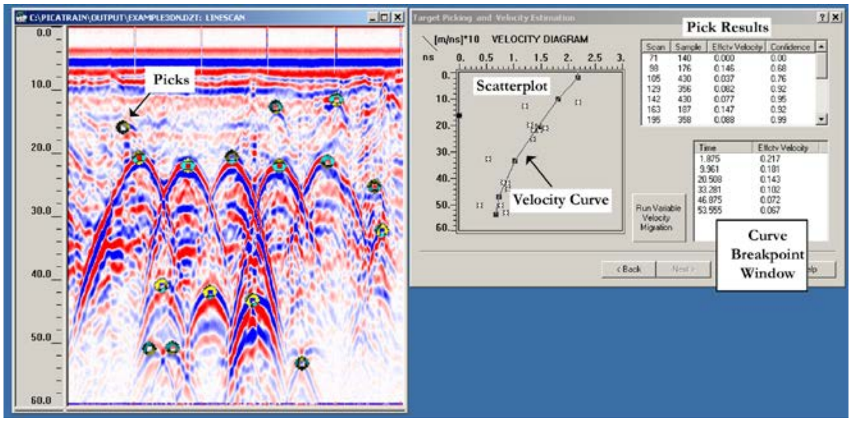


Figure 58: 2-D Variable Velocity Migration.

2 The results are plotted in the left pane of the dialog box and shown in tabular form in the right pane.

- Each target position and velocity are determined with a confidence level. The levels of confidence are displayed in the left pane of the dialog box with three different colors: White – high; Black – low; gray – medium.
- The spreadsheet in the right pane of the dialog box provides numerical information on selected targets: target position (scan and sample #), estimated velocity and its confidence level.

Velocity Profile

1 Double-click in the velocity diagram scatterplot to create a velocity curve. The curve is constructed by selecting a point in the upper level of clustered plotted points (with high confidence, i.e. white), double-clicking, then proceeding down defining the curve as a function of point-velocity cluster.

2 Using the selected points as reference, you may drag breakpoints left or right to define an optimal velocity profile.

- The resulting profile is used by the migration function when the Run Variable Velocity Migration button is clicked. Point targets at different levels will now collapse more accurately than using constant velocity migration.
- If, after initial migration, the data is over-migrated, decrease the relative velocity. Over-migrated reflectors appear as “smiles” or inverted hyperbolic reflectors on the radar record.
- If the data is under-migrated, increase the relative velocity. Under-migrated data appear as “frowns” or partially collapsed hyperbola.

Some general observations about migration:

1. Reflections move updip
2. Anticlinal features become more narrow
3. Anticlinal features have less or the same vertical closure
4. The crest does not move
5. Synclinal features become broader
6. Low point does not move
7. Synclines have more or the same vertical closure
8. Crossing reflections **may** produce sharp syncline image
9. Diffractions become points
10. Crests do not move

Arithmetic Functions

Simple arithmetic functions may be performed on the data by using the Arithmetic Functions feature of RADAN. It allows you to add or subtract another file, add or multiply by a constant, or express data in terms of its absolute value, square root, or integrate the data. When the arithmetic functions log and square root are applied to GPR data, they will emphasize the low amplitude data relative to the high amplitude data.

Note: When using Log or Square Root functions, data amplitudes must be expressed as positive numbers (i.e., data cannot be zero or negative). Otherwise, an error will occur resulting from an improper mathematical procedure. Therefore, you must first take the absolute value of your data.

Using the Exponential or Squared function, you can emphasize strong (high amplitude) signals and reduce or remove weak (low amplitude) signals or noise. All operations are performed on the binary 16-bit data, therefore the constants used will always be in the 32767 to -32767 range and have an integer value.

These operations are performed in the following order:

Add Constant
Multiply Constant
Function
Multiply 2nd Constant
Add 2nd Constant
Truncate to Range (-32768 to 32767)

It is possible to Add and Multiply by a constant before and/or after a nonlinear function.

Note: When designing an operation, be aware that if the original data is only 8 bits it will range from -128 to 127 before the math operation. After the operation, the output file will still be 8-bits, any overflows as a result of the operation will be clipped.

Some operations, such as square root or log, will not operate on zero or negative numbers. However, they can operate on data by first taking the absolute value of the amplitude. Therefore, the Log, Exponent, Square, or Square Root functions may need to be combined with constant multiplication and addition in order to obtain output within the proper range. This is why multiplication and addition are allowed before (1st add constant and 1st multiply constant, respectively) and after (2nd add constant and 2nd multiply constant, respectively) a function. The Arithmetic Function option allows you to select from a number of linear and nonlinear functions as follows:

Negate:	$y(t) = -x(t)$
Absolute Value:	$y(t) = \| x(t) \|$
Differentiate:	$y(t) = x(t) - x(t-1)$
Integrate:	$y(t) = x(t) + x(t-1) + x(t-2) + ...$
Square:	$y(t) = (x(t))^2$
Square Root:	$y(t) = (x(t))^{1/2}$
Log:	$y(t) = \ln [x(t)]$, where ln is the natural logarithm
Exponent (Exp):	$y(t) = \text{Exp}[x(t)]$ or $e^{[x(t)]}$

Hilbert Transform: Detecting Subtle Features 

Reflector amplitude and geometry are the primary types of information in GPR data used to make interpretations. The time domain radar data is defined as time and amplitude of the reflected pulses. Another way of defining the data is to transform it into frequency and phase information. The phase information is sometimes more sensitive to important subsurface (dielectric) changes than the amplitude or geometric information (e.g., contaminants).

A Hilbert Transform, accessed by clicking on the Hilbert icon  on the tool bar or by the Processing menu, will change a radar signal represented as a time series into its magnitude (via envelope detection), instantaneous phase, or instantaneous frequency components (the derivative of phase). The Hilbert Transform expresses the relationship between the magnitude and phase of a signal, or between its real and imaginary parts. It allows the phase of a signal to be reconstructed from its amplitude.

The Hilbert Transform is used to display subtle properties of the earth. The magnitude display is useful for indicating the raw energy reflected from an object or layer. The radar wavelet itself may not always be a clear indicator of energy levels because it consists of several cycles. The instantaneous frequency indicates how the earth is filtering the radar signal.

Hilbert Transform Parameters Selection

1 Certain input parameters are required to use the Hilbert Transform. They include:

- Starting sample number
- Ending sample number
- Transform to
- Frequency scale

2 The Transform To function allows the user to process the data in the indicated format: magnitude, phase, or frequency.

- The frequency scale requires an input in cycles/scan. When Frequency mode is chosen, this sets the maximum frequency that will be output. This value becomes the full scale, and if higher frequencies are present they will be set to this full scale value.

Static Corrections

Static Corrections compensates for variations in elevation, phase shifts, and high frequency noise observed in the horizontal direction and is generally one of the last processing steps undertaken.

Static Corrections assume that near-horizontal layering should be continuous, and only appears discontinuous due to poor antenna coupling, time-zero tracking problems, or some localized changes in velocity. Sometimes after a lot of processing, once horizontal (or near-horizontal) and continuous layers appear discontinuous and slightly shifted in time, making the reflector difficult to trace from scan to scan. Static Corrections can correct for this.

Static Corrections compensates for noise that is introduced by shifting the reflector within a specified time window (specified by the number of samples) so that it is realigned.

Another function of Static Corrections is that it allows you to filter horizontally without influencing the vertical frequency of the data, unlike Horizontal High and Low Pass Filtering. Static Corrections proves the horizontal traceability of layers using cross correlation.

1 To apply Static Corrections, choose Process menu > Correct Static.

- A rectangular overlay will appear superimposed upon your data. You can use the mouse to shape the rectangle to the desired width and move it so it is superimposed upon the reflector of interest.

2 After adjusting the first segment on the reflector, move the cursor with the mouse to the next segment, and click on it.

- In this way, create a multi-segmented window that the Static function will use to trace a reflector.

3 A dialog box will appear in which you will be able to choose the window height (in number of samples), the filter length, and the type of model (Boxcar or Triangle) you wish to use to filter.

- RADAN correlates this model scan of a specified filter length and performs a horizontal boxcar or triangle filter size of filter length on the number of samples in the window and compares it to the highlighted layer.

- The correlation threshold is the value used to cross-correlate the model data with the actual data. It is this parameter that tells you how well a layer can be traced from scan to scan. The correlation threshold is usually from 0.5 to 1.0.

Local Peaks

Local Peak extraction function (Local Peaks) can be accessed from the Process menu or by selecting the button on the Process bar. It will automatically trace continuous reflections in the data window of the active file according to the user-specified selection parameters.

The Local Peaks Extraction Parameters dialog box has the following entries:

Select: Defines if the function will trace ALL, only the POSITIVE or only the NEGATIVE reflections.

Max # of Points: Defines the number of peaks to trace. The indicated number of strongest reflections will be displayed. The reflections may vary along the profile, but their total number in any trace will not exceed the Max #.

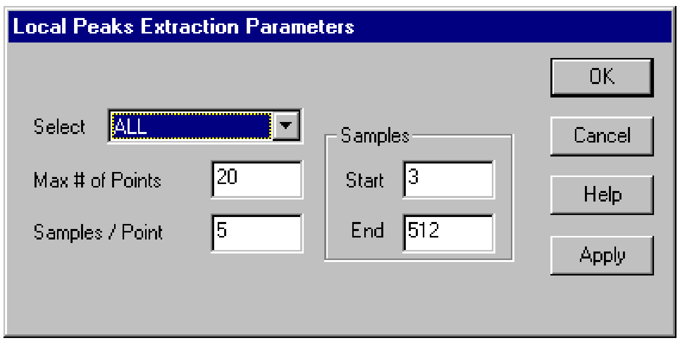


Figure 59: The Local Peaks dialog box.

Samples/Point: Defines the width of the peaks in the vertical direction. The peaks are displayed as bands of the indicated width, with the amplitude values preserved within these bands. The rest of the data is zeroed.

Start and End Samples: By default the entire trace is processed, but the user may choose any horizontal layer, expressed in sample numbers. Only the selected interval will be processed, the rest of the file being left unchanged.

- The Apply button enables the user to see the results of the extraction without being prompted to save the file.
- The button label changes to Reset; pressing it without changing parameters will redisplay the original data.
- If different parameters are selected, pressing Reset will display the results of the new extraction.
- When you’re satisfied with the results, click OK to save the processed file.

Multi Component Combo Function

The MC Combo function creates combinations of channels and assigns them to a selected channel in a multi-channel file. A selection of arithmetic operations is available for this operation. The Multi Component Combo dialog box for a 4-channel file is as follows:

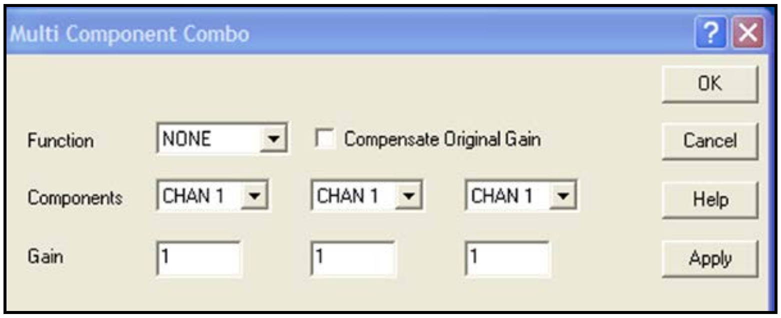


Figure 60: Multi-component combo dialog box.

For a single-channel file, Combo function means an arithmetic operation performed on that channel. The Compensate Original Gain option allows you to restore the range gain.

The following list of functions is available:

NONE - no transformation

ADD - adds the channel

SUB - subtracts the channel

ADD3 - add 3 numbers

SQADD - square root of the absolute value of the sum of the channels

SQSUB - square root of the absolute value of the difference of the channels

SQDIV - square root of the absolute value of the division of the channels

SQMUL - square root of the absolute value of the product of the channels

VSUMM - square root of the sum of the squares of the two channels

VSUMM3 - square root of the sum of the squares of the three channels

- The Apply button enables the user to see the results of the Combo operation without being prompted to save the file.
- The button label changes to Reset; clicking it without changing parameters will redisplay the original data.
- If different parameters are selected, clicking Reset will display the results of the new extraction.
- Click Reset again, and the original data will be redisplayed.
- When you’re satisfied with the results, click OK to save the processed file.

Velocity Analysis

Data Preparation

To use the velocity analysis program in the RADAN Velocity Analysis module, you must first have a data set recorded at multiple offsets using a bistatic antenna configuration using the common-midpoint (CMP) method (described below) or wide angle refraction reflection (WARR) method.

GSSI makes two bistatic antenna models, which can be used for CMP acquisition: the Model 3207 (100 MHz), and the Model 3200 MLF (16-80 MHz). Using a radar system with a multi-channel capability (e.g., the SIR 20, 10A, 10A+, 10B, or 10H systems), any combination of antennas can be used to gather CMP data. Additionally, a dual-antenna adapter is available for bistatic operation with a single-channel system, such as GSSI's SIR-2, 2000, or 3000.

To estimate velocity from a CMP "gather," you will need to collect GPR data using a bistatic antenna configuration in the Static Stack mode. Initially, transmitting and receiving antennas start off adjacent to one another at the "zero offset" position. (Actually, because of the size of the antennas' housings, transmitting and receiving antennas are never at the true zero offset position. Rather, the initial offset is the distance from the symmetrical reference - i.e., the zero offset position- to the antenna's centerline.) Data are then collected at multiple offsets, as the antennas are moved symmetrically apart from the zero offset position. The output data quality improves significantly using a large number of offsets and stacks. However, by using a lot of offsets and stacking, acquiring data may be very time consuming. The operator will have to decide the best utilization of time when establishing the best offset interval, the number of stacks per measurement, and number of offsets, versus the desired quality of data output.

With estimated velocities acquired in this way, we can more accurately estimate the depth to certain targets or stratigraphic features. Also, using a DOS subroutine supplied by GSSI with the Velocity Analysis module, estimated velocities can be used to construct a CMP "stack." Using derived velocities, offset traces are corrected for nonzero offset, and then stacked to form a single trace at the zero offset position. Many CMP gathers can be likewise compressed to a single trace, resulting in a corrected stacked section with a significantly enhanced signal-to-noise ratio.

Theoretical Overview

For a single constant-velocity horizontal layer, the travel time curve as a function of offset is a hyperbola. The time difference between travel time at a given offset and at zero offset is called normal moveout (NMO). The velocity required to correct for normal moveout is called the normal moveout velocity. For a single horizontal reflector, the NMO velocity is equal to the velocity of the medium above the reflector. For a dipping reflector, the NMO velocity is equal to the medium velocity divided by the cosine of the dip angle:

$$(0), \text{ or } V_{nmo} = V / \text{Cos } 0$$

Travel time, as a function of offset from a series of planar horizontal layers, is approximated by a hyperbola. This approximation is better at small offsets than large offsets. For short offsets, the NMO velocity for a horizontally layered earth is equal to the root mean square (rms) velocity down to the layer boundary under consideration. In media composed of layers with arbitrary dips, the travel time equation gets complicated. However, in practice, as long as dips are gentle and the spread (offset interval) is small (less than the reflector depth), the hyperbolic assumption can be made. Conventional velocity analysis is based on the hyperbolic assumption. For a detailed discussion of velocity analysis, see Seismic Data

Processing, by Ozdogan Yilmaz, published by the Society of Exploration Geophysicists in 1987, an excellent reference from which this brief description has been extracted and adapted.

The velocity analysis method used in this module is based on computing the velocity spectrum. The principle is to display some measure of signal coherency on a graph of velocity versus two-way zero-offset time. Signal coherency is computed on the CMP gather in small time gates that follow a hyperbolic trajectory. Stacking velocities are interpreted from velocity spectra by choosing the velocity function that produces the highest coherency at times with significant event amplitudes.

Using the Velocity Analysis Function

Once you have gathered some CMP data sets,

1. Transfer them to your computer (into a separate directory for Velocity Analysis).

2. Next, run RADAN and choose File > Open.

3. Select the desired CMP file having the extension (*.dzt). Note that GSSI has provided a sample CMP data set for your use, should you not have one available to you.

4. Next, check the file headers of the CMP gathers and make sure that the Scans/Unit parameter is entered (Figure 61).

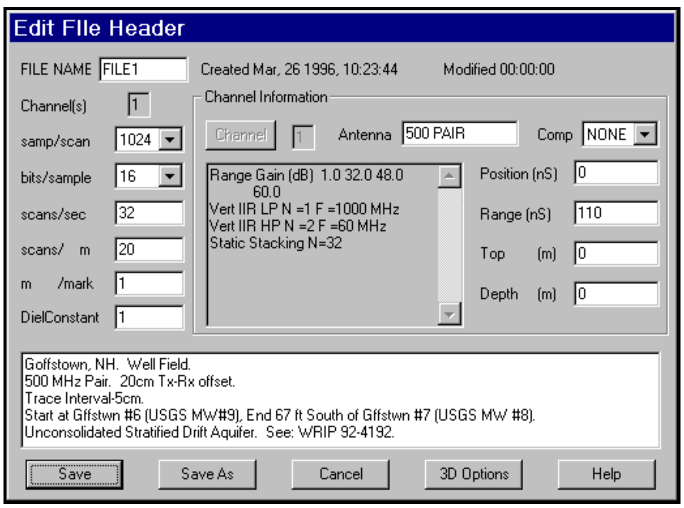


Figure 61: Check file header information for velocity analysis.

Note: The Scans/Unit parameter must have a non-zero value before the velocity analysis can begin.

5. With a CMP file open, initiate the Velocity Analysis module by clicking on the appropriate icon  on the toolbar, or choosing Process > Velocity Analysis.

6. An Open Velocity File Message Box will appear and prompt you to input a *.vlc file.
   - A *.vlc file is a velocity data file created and saved from a previous Velocity Analysis session.
   - If this is the first time activating the Velocity Analysis, click Cancel to continue to the Velocity Diagram screen.

7 Upon activating the Velocity Analysis function, you will see the following window on your screen (Figure 62):

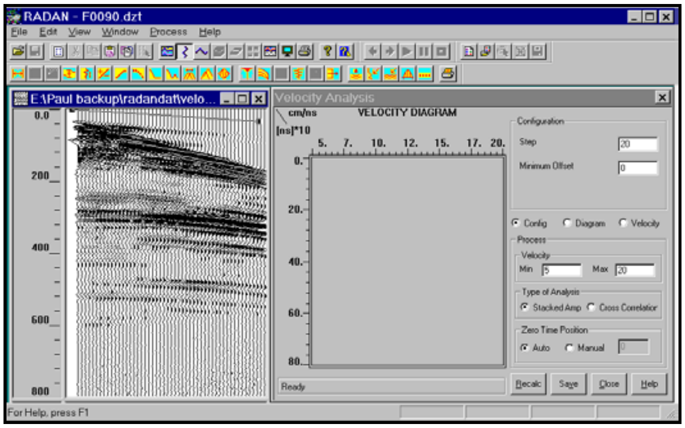


Figure 62: Velocity analysis processing window.

8 The program will default to the Configuration menu, as indicated when the Configuration button at the right center portion of the screen is selected. In order for the Velocity Analysis program to operate properly, the following information MUST be input:

- In the Configuration section of the menu, select the proper Distance Unit (cm, inch, or foot).
- Next, set the Input Step. This refers to the step interval distance the antennas are moved apart each time data is stacked during the CMP gather.
- Input the Minimum Offset. This is the distance between the antennas center to center when they are at their closest during the CMP gather. Note that because of the antenna housing, this value should always be a non-zero number.
- In the Process section of the menu, input the minimum and maximum velocity values you expect at the site you are surveying in cm/ns.
- Next, choose the type of analysis you want the program to use: Stacked Amplitude or Cross Correlation. As the name implies, the latter method relies on a cross-correlation of traces in a gather, and not on the lateral continuity of traces. Hence, the Cross Correlation method produces less scatter in the data, but at the cost of using up significantly more processing time. The Stacked Amplitude method generally produces adequate results, but requires much less time for processing. For a detailed description of these analytical methods, see Yilmaz, (1987).

9 Last, select whether you want the Zero Time Position derived automatically, or if you want to input a value manually.

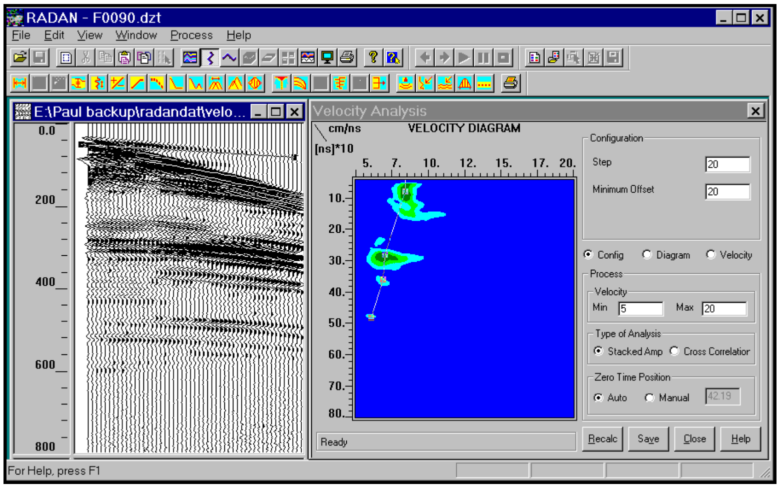


Figure 63: Velocity Analysis window showing results of computation.

10 Once you have entered the required information, click the Recalc button and the program will calculate the estimated velocities of the layers present in the data. The resulting velocity spectrum will look like Figure 63.

The velocity spectrum shown clearly exhibits three layers. The bold elliptical to circular areas in each layer represent the most probable velocity of that layer, based on the correlation or lateral continuity of data.

The Diagram Parameters menu allows the user to locate the maximum velocity within the data set and establish the velocity within other layers. The program can also display isolines, or contours having the same velocity.

To access the Diagram Parameters window, click the Diagram button. The Diagram Parameters window is shown on Figure 64. The following features will allow you to modify the display in ways described below:

Mouse Cursor Function: When the cursor is placed on the left side of the window, the program shows the user the velocity, two-way travel time, and amplitude at that point.

MAX Function: The Max function returns the cursor to the maximum velocity of the dataset. By clicking Max, the program will automatically pick the maximum velocity layer, place crosshairs at the maximum point, and display the velocity of the layer and the time in nanoseconds (ns) at which it occurs.

Amplitude %: Amplitude % is displayed in another window. The Amplitude % value can be used as an indication of the “coherency” of the layer. The closer to 100%, the greater the correlation (or lateral continuity) of that value with adjacent values.

Isolines Function: The Isolines function enables the user to see contours of areas having the same velocity. This function is active when the Isolines box is selected with the mouse. When selected, a check mark will show next to the word isolines and the display will show velocity contours, as in Figure 65.

Left/Right Arrow: Clicking on the left or right arrow buttons will cause the program to select other layers to display their velocities, times and amplitudes.

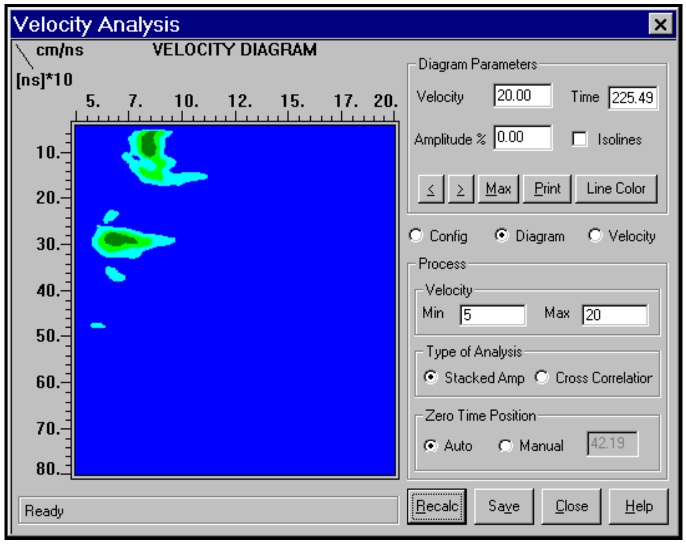


Figure 64: Velocity Analysis window showing Diagram Parameters menu.

The Velocity menu is accessed by selecting the Velocity button. This function allows the user to make a velocity log of significant layers in the data by clicking on the Velocity button. The velocity log consists of the velocity from each layer, the two-way travel time to the maximum velocity, the effective layer velocity, and the true layer velocity. To set up a velocity log:

1 Starting at the upper-most layer, move the mouse cursor to the maximum % Amplitude value.

2 Double-click the left mouse button, and the layer information will appear at the top right of the screen in the Velocity Dialogue box.

3 Move the mouse cursor to the next velocity layer and repeat the steps above.

Velocity log information will be displayed in the Velocity window to the right, as shown on Figure 65. A line will also be plotted from layer to layer, showing the best correlation of velocity.

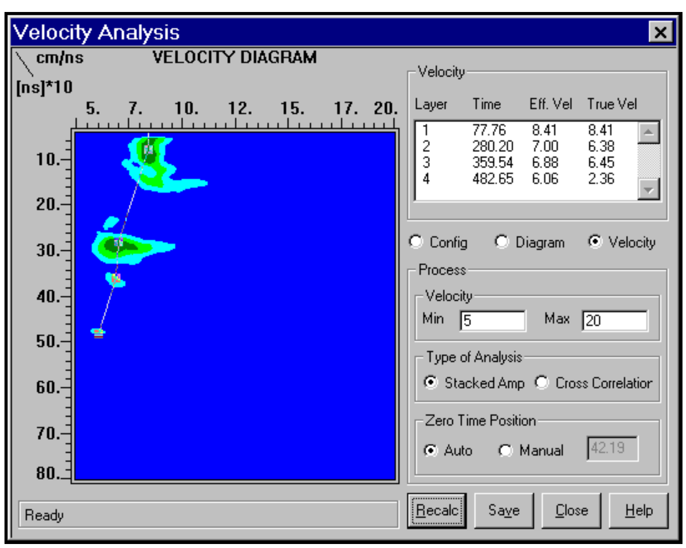


Figure 65: Velocity Analysis window showing Velocity menu.

Results of the velocity analysis can be saved in a file, or printed. To save these results in a velocity file (*.vlc), select the Save button at the bottom of the screen. To print the velocity log:

1. Select the Diagram button.
2. Click the Print button. A Print Dialogue box will appear.
3. Select Setup to make sure that the printer is setup properly, having the appropriate page quality and orientation.
4. OR, to save the velocity log to a file, using the mouse, select the Print to File box at the bottom left of the Printer Dialogue box.
5. Click OK to Print to the printer (or file).

Comparison of Stacked Amplitude vs. Cross Correlation Methods

As mentioned previously, the cross-correlation method derives velocity estimation from the cross-correlation of traces in a gather. The Stacked Amplitude method correlates reflections (and hence velocities) by determining if the reflections are laterally continuous from trace to trace (Yilmaz, 1987).

Of the two methods used in the Velocity Analysis program, the Stacked Amplitude method runs the fastest. It provides acceptable results when the reflecting horizons are easy to pick and reasonably regular and horizontal. For more complex situations, or when the layers vary more, use the Cross Correlation method. It takes longer to run (about 6.5 times), but gives more coherent results. The following is a comparison of results of the two methods on a 50-scan CMP gather acquired in river flood-plain sediments exhibiting two prominent layers in Goffstown, NH:

Method	Max. Vel. Layer	Time	Run time	Amplitude %
Stacked Ampl.	10.17 cm/ns	130.5 ns	1.8s	100
Cross Correl.	10.27 cm/ns	138.22 ns	12.1s	100
% difference	< 1	< 6	647	0
	Slower Vel.Layer	Time	Run time	Amplitude %
Stacked Ampl.	7.26 cm/ns	282.42 ns	1.8s	68.7
Cross Correl.	7.26 cm/ns	287.57 ns	12.1s	49.15
% difference	0	< 2	647	28.5

Table 2: Comparison of Velocity Analysis: Stacked Amplitude versus Cross Correlation.

Max Depth Estimator

This function analyzes the noise and signal loss (attenuation) from scan to scan and gives you an estimate of your effective depth penetration The output of this function is shown as a red line on the screen and saved as an ASCII .shp file for review later.

To use this function, follow these steps.

1. Open the data profile.
2. Click on the Max Depth Estimator button. The output will be saved in a .shp file with the same root name as the .dzt file.

Helpful Hint: You may want to have the Command Toolbar (View > Toolbars > Command Bar) open so that you can pause this function as it is running. If you wait till the end of the function, that red line will disappear.

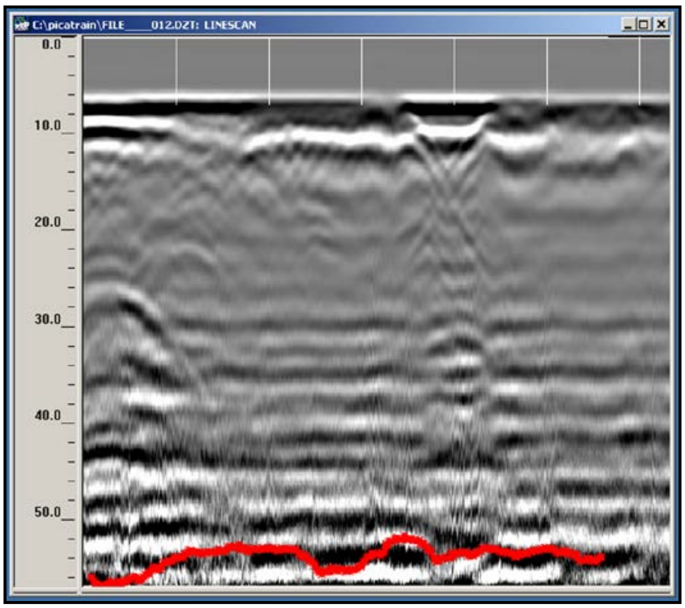
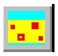


Figure 66: Max Depth Estimator analysis.

Running the Automatic Portion of the SI Module 

1 After opening the data file that will be processed, click the Structure Identification icon located on the RADAN tool bar. (It is also possible to run the process by selecting Process > Infrastructure, then selecting Structure Identification). The dialog shown in Figure 67 will appear. Each item in the dialog is described in detail below.

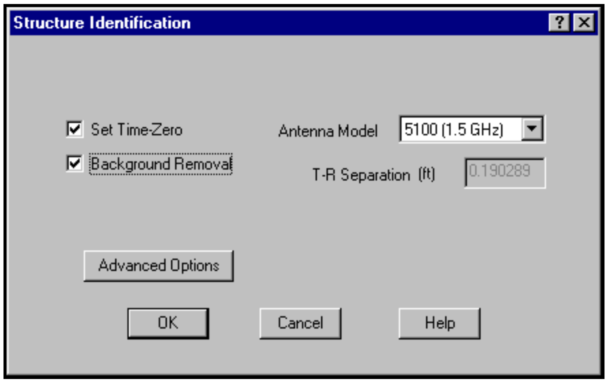


Figure 67: Dialog containing the various settings used to process the data.

Set Time-Zero (Position): When checked, this function will shift the vertical scale so time zero is aligned with the surface reflection in each scan. Should always be enabled unless there is a specific reason not to use it.

Antenna Model: Select the antenna used for data collection. Factory-defined antenna parameters (Transmitter-Receiver, or T-R separation) will be used in depth calculations. The T-R Separation box will display the distance between transmitter and receiver of the selected antenna. User input of this parameter will only be enabled if Other antenna model is selected.

Background Removal: When checked, a filter useful for removing horizontal banding will be applied to the data before further processing. Two options are available under Advanced Options:

- **Average of All Scans** calculates the average scan by averaging all of the scans in the file and subtracts it from each scan starting at time-zero. This is the default option used in most cases.
- **Specified Scan** option allows the user to subtract a single scan of his choice by specifying the Background Scan number. Figure 68 shows data obtained over a concrete floor with and without the background removal option used, respectively. If an airwave or other single scan is to be removed from the data, this option would be used.

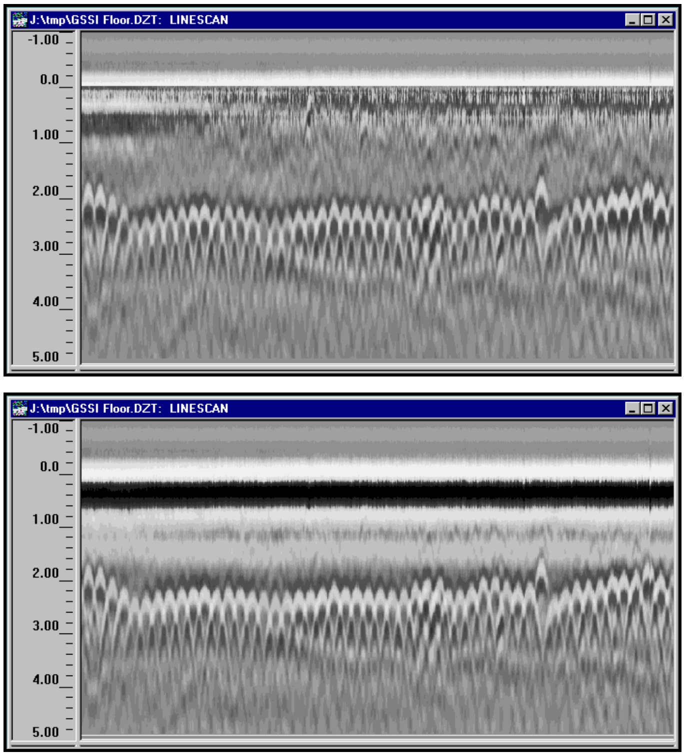


Figure 68: Data processed with (top) without (bottom) background removal.

Advanced Options

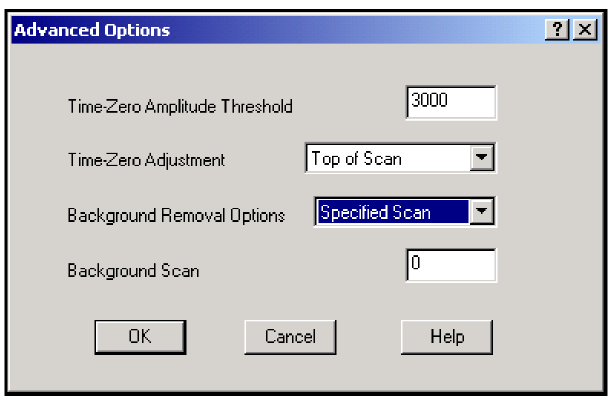


Figure 69: Advanced Options dialog.

Time Zero Amplitude Threshold: The amplitude value used by the system to locate the surface in a data file. If the threshold value is positive, the first positive peak exceeding that value is assumed to be the surface. If it is negative, the first negative peak exceeding the threshold is assumed to be the surface.

Amplitude Threshold can be adjusted if the surface detection is incorrect (data appear broken after SI processing). The default setting will normally work, but if problems occur, use the O-scope display of data in RADAN to estimate the minimum amplitude value of the first peak throughout all scans in the data file. Set the threshold just below this amplitude, but high enough to avoid picking minor noise peaks before the surface.

Time-Zero Adjustment: Gives the choice of shifting the surface to the top of the data window (Top of Scan) or leaving it at the current Average Position (default). The Top of Scan option should be selected if the data file will later be migrated.

1 Click OK to begin data processing. There may be a delay (depending on the computer speed) before any action appears on the screen.

2 After processing is completed, a Save RADAN File As dialog will appear on the computer screen asking the user whether to save the processed data to an output file. This dialog allows the user to select the directory in which to save the output file and the option of changing the output filename.

Interactive Interpretation 

The Interactive Interpretation module in RADAN is similar to the SSI module in RADAN for Windows 95 and of RadPick in some older NT versions.

Interactive Interpretation allows the user to semi-automatically locate and analyze features in radar data by placing "picks" on the data. A "pick" is a peak of amplitude identified in a scan that can correspond to a **layer** or a point **target**. Each pick is identified by a small circle on top of the data in the top Interactive window pane and by a small circle located at the proper depth in the bottom window pane. Numeric information on their position, depth and amplitude is automatically extracted into a spreadsheet. Both horizontal and vertical velocity variations can be taken into account in the depth calculations.

When picking layers, the program looks for amplitude peaks in each scan. Up to 7 layers can be defined for each file. All picks assigned to a layer have the same name, color and size. Target picks are single dots not associated with a layer. They can be assigned individual properties (name, color) by placing the cursor on them and pressing the right mouse button. A scan can contain any number of target picks, but only one pick of each layer in the right order (layer 1 above layer 2, etc.).

The pick locations, depths, and reflection amplitudes are stored in an ASCII file (*.lay) when the user selects the "Save Changes" option. An ASCII file can be opened and edited many times.

Note: If you are running Interactive Interpretation on structural concrete data (StructureScan or single profiles collected with the 1.5 GHz antenna) you should migrate the data first. If you are using Interactive Interpretation for utility or any soil application, you should work with un-migrated data.

Note: If you purchased Interactive^{3D}, then this button will open the I^{3D} split screen.

Opening the Interactive Option

Open the desired file (or click on the data window if already open), then click the button in the RADAN tool bar. The Get ASCII File dialog shown in Figure 70 will appear on the screen.

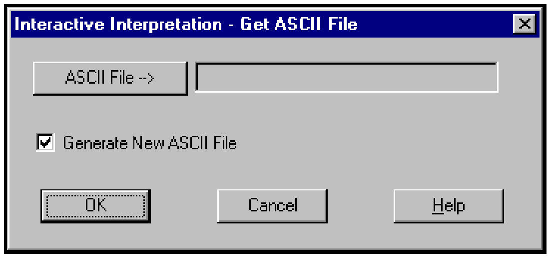


Figure 70: Dialog appearing after pressing the Interactive button.

If this is the first time you'll be working on this file after it was processed in SI, there is no result (ASCII) file associated with it. Make sure the Generate New ASCII File option is checked and click OK.

A split data window will appear (Figure 71). The top half contains the radar data. This window is similar to a standard RADAN data window, except the vertical scale is in time units only. Depth scale cannot be displayed here. A horizontal scale in units of distance or scan numbers can be shown as usual (right-click on the vertical scale). Picking the important features within the data window (i.e., labeling them with colored dots) is the first step in interactive interpretation.

The bottom half is reserved for display of the results. Layer and target picks, for which depth can be determined, will appear in the bottom pane against a depth scale. The depth of each pick is calculated using the information provided by the operator. This information is entered as user later-specified layer velocity or core data and can be modified (see Other Options below). The entire depth range of the bottom window is defined by the Depth parameter in the file header.

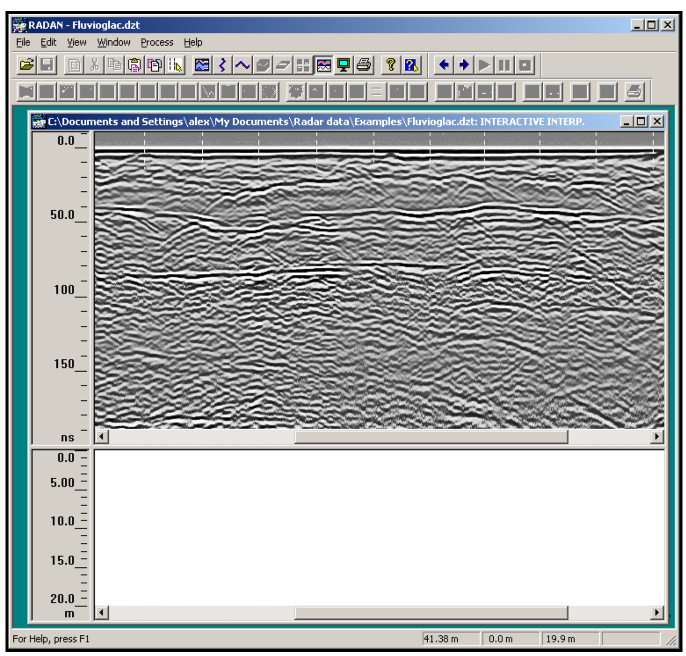


Figure 71: Interactive Interpretation window. The upper window shows the GPR data and the lower is reserved for the picked feature depths relative to the surface. Since no picking has been performed, the lower window is blank.

Interactive Interpretation Main Menu

All of the user options available in Interactive Interpretation are accessed first by moving the mouse cursor so that it is within the Interactive Interpretation data window (upper pane), then pressing the right mouse button. The menu shown in Figure 72 will appear. A detailed explanation of each of the available options is presented below.

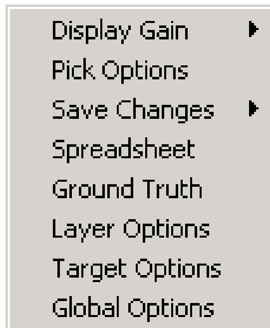


Figure 72: Main menu accessed by clicking on the right mouse button when the mouse is positioned anywhere within the Interactive Interpretation data window.

Display Gain

The multiplication factor applied to the data to increase or decrease their display amplitude. It is called Display Gain because this multiplication factor will not change the data values in the file.

Clicking the left mouse button when the cursor is positioned over one of the gain values changes the display gain. A gain of 1 is set by default. Clicking on Custom allows the user to specify a different multiplier than those listed.

Pick Options

Selecting Pick Options from the Main menu opens a dialog box containing the available options for adding and deleting picks. This process is useful for editing poor reflection picks and adding new picks.

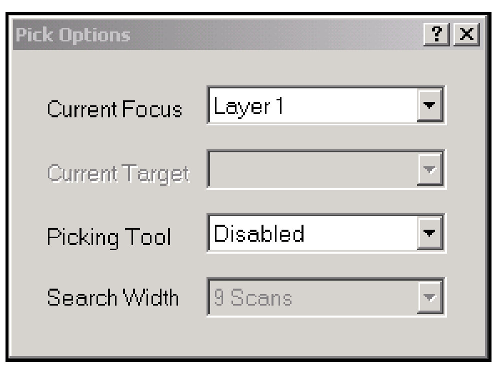


Figure 73: Pick Options dialog.

Current Focus

The layer or target to which all edit operations currently apply. The choice is any of the layers defined in the *.lay file (1, 2, etc.), All, Targets, or Filtered.

- When a layer number is selected, picks in that layer can be added or deleted.
- The All and Filtered options only allow the user to delete picks.
- The Targets option allows the user to add single independent picks to mark objects such as pipes, culverts, voids, or events such as road intersections, starting and ending points of new pavement, etc.
- Filtered appears as an option when the filtering option is enabled (See section on Layer Options).

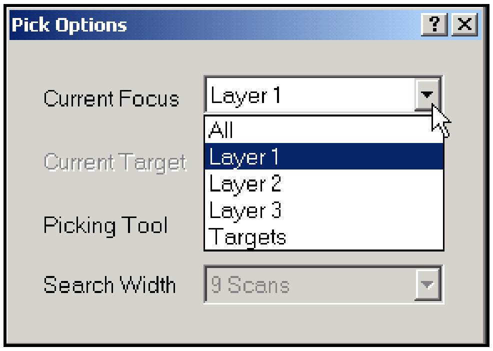


Figure 74: Options available for the Current Focus.

Current Target

The user has the option of adding target picks. These picks can be used to denote specific features in the data, such as culverts, bridge locations, etc. The user can add specific target picks by specifying "Target" as the current focus, then selecting the desired current target. The default target name is "Rebar." Specific targets can be named using the Target Options menu item in the Main Menu.

Picking Tool

The mode in which the picks are selected. Figure 75 shows the different types of picking tools.

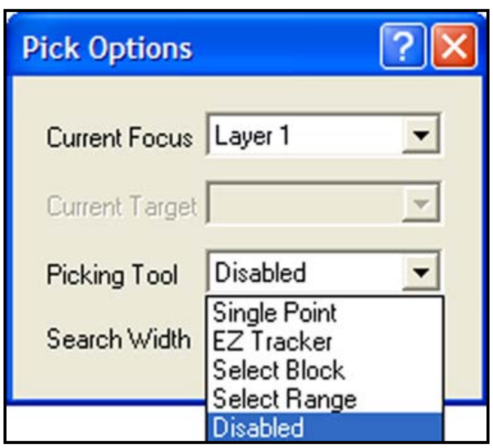


Figure 75: Different layer picking tools available.

Single Point: Layer picks are added each time the user presses the left mouse button and deleted each time the user presses the right mouse button. Only one pick can be added at a time with this option, but multiple picks can be deleted depending on the Search Width.

Search Width

The effective width of the mouse cursor when the selected picking tool is Single Point. The search width is only applicable to the Single Point mode. Figure 76 shows the different search widths available.

Figure 76: Different Search Widths indicated by the cursor size that can be used to add and delete picks in single point mode in Interactive Interpretation. The cursors correspond, from left to right, to 1 scan, 3 scans, 5 scans, 9 scans, and 17 scans.

Adding Picks in Single Point Mode

1 Position the mouse cursor over the area where you would like a pick to be added.

2 Click the left mouse button. A search will be performed on all of the scans between the left and right inside edges of the mouse cursor to locate the maximum amplitude. If the search is successful, a pick will appear on the data (Figure 77). The type of search used to locate the new pick can be customized in the Layer Options menu choice (see section on Layer Options).

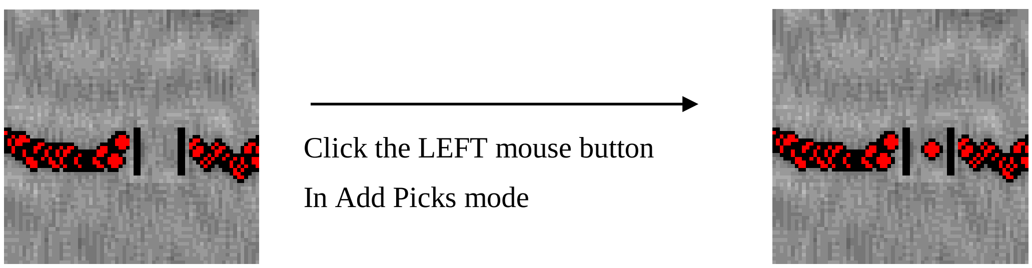


Figure 77: Example of correct mouse cursor position prior to adding a pick.

- A pick will only be successfully added if a reflection can be located over the cursor search width.
- If no pick is added after pressing the left mouse button, reposition the mouse cursor and click the left mouse button again.
- For cases where the reflection peak is reversed polarity, the user would first need to select Neg. Peak for the Layer Properties under Layer Options in the Interactive Interpretation main menu, then place the mouse cursor over a negative polarity reflection.

Deleting Picks in Single Point Mode

1 To delete poor picks, a procedure similar to adding picks is followed. Position the mouse cursor so that the poor pick is located within the search area of the cursor as shown in Figure 78.

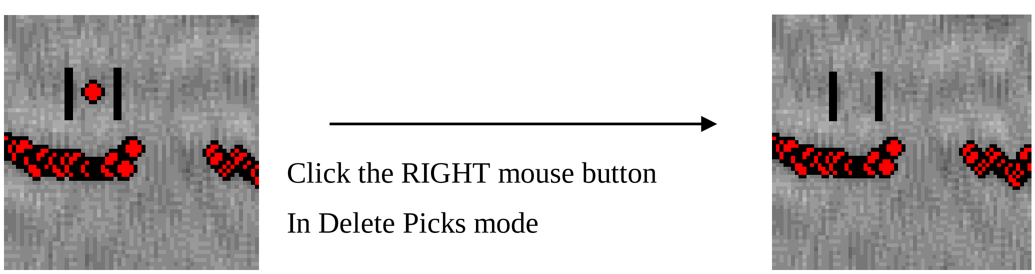


Figure 78: Example of correct mouse cursor position prior to deleting a poor pick.

2 Then, click the right mouse button. If a portion of the pick circle bisects the vertical midpoint of the cursor, then the pick will be deleted from the database and from the screen.

Select Block and Select Range

The Select Block and Select Range picking tools are designed to operate over a large number of scans.

Select Block

When Select Block is activated, a multi-colored, translucent square will appear over the data when the user clicks the left mouse button. The select block contains tiny squares on each face and corner. These squares act as handles that can be used to resize the select block. Select Block is only available if you have purchased the Structure Identification module for RADAN.

To Resize Select Block

1 Position the mouse cursor over one of the handles and press the left mouse button.

2 Move the mouse cursor to the desired location with the left mouse button still pressed down.

3 When the desired size is reached, simply release the left mouse button.

To Move Select Block

1 Place the mouse cursor within the select block and press the left mouse button down.

2 Move the mouse cursor with the left button still pressed down until the block is in the desired position. Finally, release the left mouse button.

Select Range

When Select Range is activated, a multicolored translucent overlay appears over the data, extending from the beginning to the end of the file. It operates similarly to the Select Block, except that all operations performed using the Select Range picking tool are performed within the time interval (slice width) of the selected area on *all* of the scans in the file.

The slice width can be changed by clicking the left mouse button on one of the handles (located at the top and bottom at the horizontal midpoint of the slice) and with the left mouse button still pressed, dragging the handle to the desired location.

Adding and deleting points are performed within the Select Block and Select Range areas. These options are activated by pressing the right mouse button down while the mouse cursor is positioned within the multicolored Select Block or Select Range area. This action activates a pop-up menu shown in Figure 79.

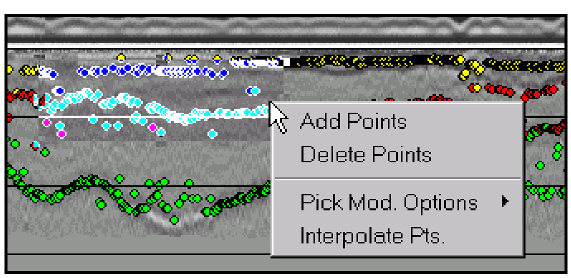


Figure 79: Options available for the Select Block and Select Range picking tools.

Add Points: Clicking on Add Points will activate the program to begin a smart search for reflection peaks within the selected region. Circles will overlay the data where reflection peaks are identified by the search algorithm

Delete Points: Clicking on Delete Points will activate the program to start deleting the picks of the Current Layer located within the selected region.

Layer Modification Options:

- **Change Velocity** changes the velocity of the currently selected layer points located in the selected region. Clicking on Change Velocity opens a dialog box for entering the desired velocity. The new velocity is used for all of the currently selected layer picks in the selected region.
- **Change Pick ID** allows the user to change the layer number assigned to the picks located within the selected region. For example, the user desires to change the layer # of a group of layer 3 picks to layer 2. The user must select layer 3 as the Current Layer, position the Select Block (or Select Range) over the group of points and click the right mouse button to access the pick modification options shown in Figure 80. Clicking on Change Pick ID will open a dialog box for entering the desired layer number. After changing the layer number, the color of the selected picks will change to the color of the new layer.

Note: A selected point is not changed to the new layer if a pick from the new layer is already present in the scan, or if the new layer overlaps another layer pick (i.e., changing a layer 3 pick to a layer 1 pick with a layer 2 pick present in the scan).

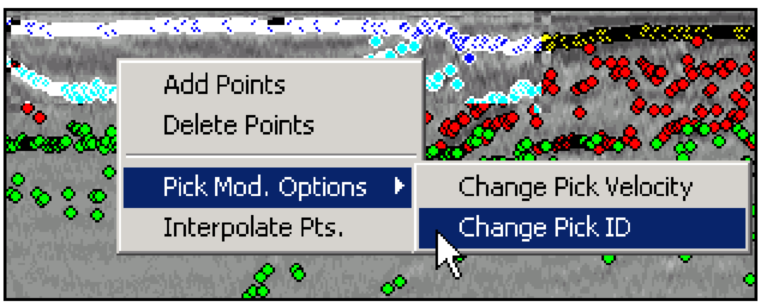


Figure 80: Layer Modification Options submenu.

Interpolate Points: Will interpolate layer picks (add new picks between existing ones) using the interpolation method (Linear or Nearest Neighbor) specified in the Properties dialog under Layer Options.

EZ Tracker

EZ Tracker will attempt to trace a layer by following similar conditions in successive scans. You should note the desired layer's phase information and select Positive, Negative, or Both under layer options.

To use EZ Tracker, make sure that the current focus is set to the layer that you want to track and click Start. Then click on the layer. Move the cursor further down the layer and click again. EZ Tracker will attempt to trace that layer between the two points. A closer click spacing will produce better results. If you make a mistake, you can right click to undo the previous section. You should click Save every few picks to save changes. If you come to a gap in the layer, click Stop and then Start to restart the layer at the other side of the gap.

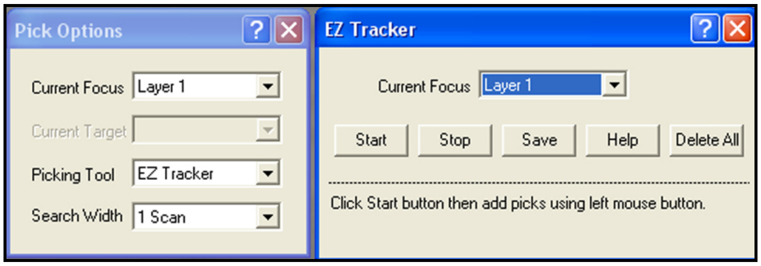


Figure 81: EZ Tracker Control Dialog.

Save Changes

The picks are stored to an ASCII *.LAY file or binary *.BII file when Save Changes is selected from the main menu. See Layer Interpretation section for the detailed description of the *.LAY files format. The user has an option of saving the changes to the currently open file or to a new file.

When New Filename is selected, two options are offered:

- Save As Is will prompt for a new filename;
- Save Options, if selected, displays the dialog box shown in Figure 82.
- Export will allow you to export the layer data as a KML file for use in Google Earth. See the Export to Google Earth section later in this chapter for more details.

Save Options allows the user flexibility in saving the layer information. Different data units, depth references and distance intervals can be selected. The user also has the option of saving only picks associated with scans containing user marks.

Output Interval Data: This option allows the user to output data at specific distance intervals rather than writing all of the data to the output file. The Output Interval Data box must be checked to activate the available save options.

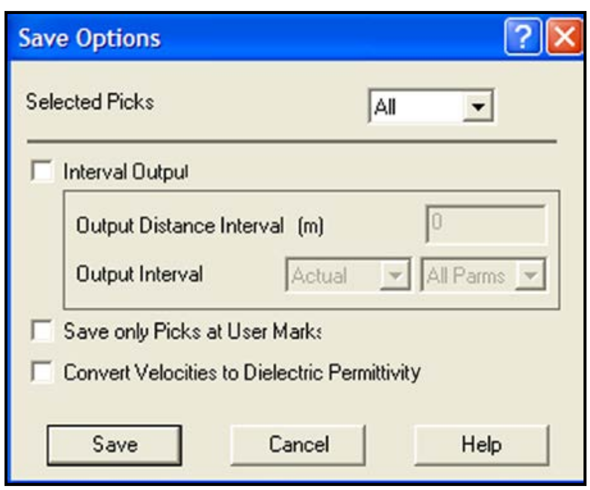


Figure 82: Save Options dialog box.

Output Distance Interval: The spacing between reflection picks output to the data file. For example, if the user selects the output interval to be 1.0 ft. and the data were obtained at a distance increment of 25 scans/ft, then the pick from only 1 of the 25 total scans will be output per 1 foot increment to the ASCII file. The depth, amplitude, velocity and time values associated with the output pick are determined by the Interval Options (Actual, Average, Minimum or Maximum) specified next to each respective category.

Selected Picks: The desired output picks. Only the selected picks will be output to the ASCII file.

Output Interval Options: Only specific picks meeting the criteria specified on this line are output to the ASCII file.

- For example, if Minimum and Time are chosen as the options and Layer 1 is the selected picks, and the output distance interval is 1 ft, for the pick at 3 ft, the minimum depth value corresponding to a distance between 2.5 ft and 3.5 ft is output to the ASCII file.
- When Actual is selected for the criteria, the depth value associated with the scan at 3 ft is output to the ASCII file.
- The other Output Interval Options are average, minimum, maximum. These options apply to All parameters, Depth, Amplitude, Velocity, or Time. For certain combinations of Selected Picks, Output and interval options the Output parameters box will be disabled, as shown in Figure 82.

One more Output Option example: Suppose the pavement engineer needed to know the average pavement thickness over 10 meter intervals. The options in Figure 82 should be set to:

Output Distance Interval (m) = 10

Selected Picks = All

Output Interval Options = Average and All Parms.

The output ASCII file will contain the averages of all parameters (depth, time, velocity, and amplitude) for each layer. The user can then extract the average depth values for the desired pavement layer.

Save only Picks at User Marks: Only the picks located at scans containing user marks are saved to the output ASCII file.

Convert Velocities to Dielectric Permittivity: This will replace the velocity column in the spreadsheet with dielectric for the picks.

Editing Picks Using Spreadsheet

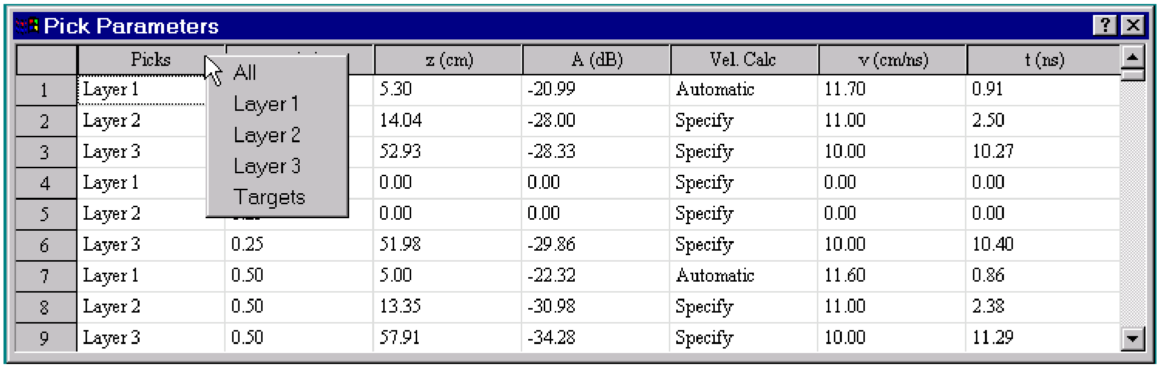
Selecting the Spreadsheet option from the Interactive Interpretation main menu shown in Figure 72 brings up an Excel-style spreadsheet containing the current pick information. Figure 83 shows spreadsheet data from a single channel file. The spreadsheet from a multi-channel file will have a separate column to denote channel number. Additional columns are also added if the filter option is enabled (see section on Layer Options) Each row in the spreadsheet shows data from a single pick. Subsequent rows represent subsequent picks. All layers and target picks are displayed by default.

Pick Parameters

	Picks	x (m)	z (cm)	A (dB)	Vel. Calc	v (cm/ns)	t (ns)
1	Layer 1	0.00	5.30	-20.99	Automatic	11.70	0.91
2	Layer 2	0.00	14.04	-28.00	Specify	11.00	2.50
3	Layer 3	0.00	52.93	-28.33	Specify	10.00	10.27
4	Layer 1	0.25	0.00	0.00	Specify	0.00	0.00
5	Layer 2	0.25	0.00	0.00	Specify	0.00	0.00
6	Layer 3	0.25	51.98	-29.86	Specify	10.00	10.40
7	Layer 1	0.50	5.00	-22.32	Automatic	11.60	0.86
8	Layer 2	0.50	13.35	-30.98	Specify	11.00	2.38
9	Layer 3	0.50	57.91	-34.28	Specify	10.00	11.29

Figure 83: Pop-up spreadsheet containing layer pick information.

By clicking the right mouse button on the Picks column header, a small pop-up menu is invoked (Figure 84). You will be able to select a single layer or targets or all picks to be displayed.

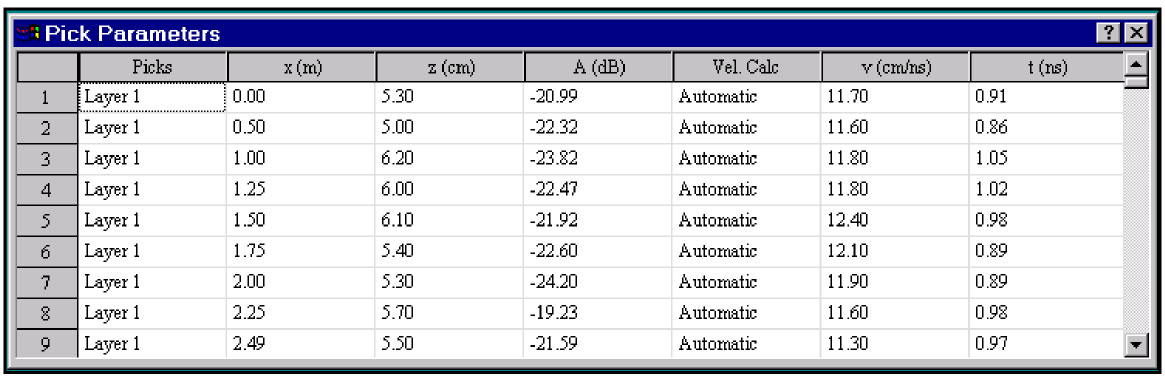


	Picks		z (cm)	A (dB)	Vel. Calc	v (cm/ns)	t (ns)
1	Layer 1		5.30	-20.99	Automatic	11.70	0.91
2	Layer 2		14.04	-28.00	Specify	11.00	2.50
3	Layer 3		52.93	-28.33	Specify	10.00	10.27
4	Layer 1		0.00	0.00	Specify	0.00	0.00
5	Layer 2		0.00	0.00	Specify	0.00	0.00
6	Layer 3	0.25	51.98	-29.86	Specify	10.00	10.40
7	Layer 1	0.50	5.00	-22.32	Automatic	11.60	0.86
8	Layer 2	0.50	13.35	-30.98	Specify	11.00	2.38
9	Layer 3	0.50	57.91	-34.28	Specify	10.00	11.29

Figure 84: Layer selection menu.

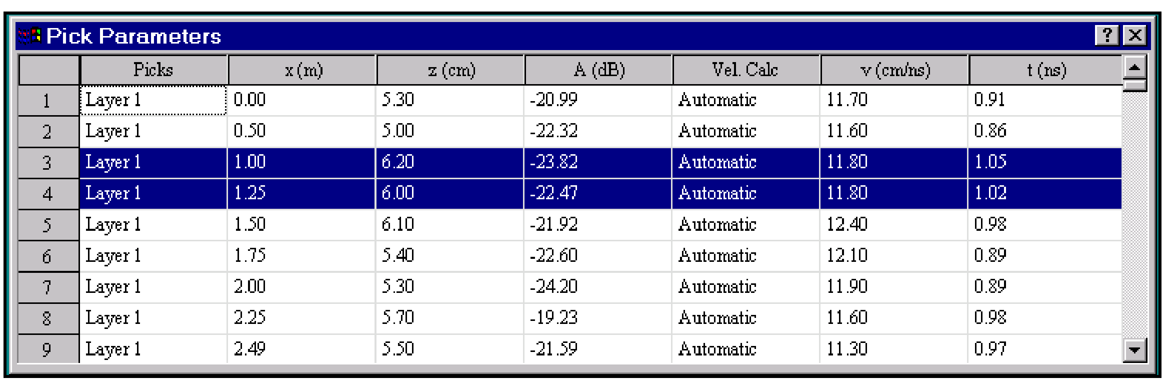
Figure 85 shows the same spreadsheet with only Layer 1 displayed. Picks can also be filtered based on depth by clicking on the z column header with the right mouse button.

Single picks can be deleted from the spreadsheet and database by clicking on the row numbers to highlight a row (Figure 86), then pressing the delete (Del) key on the computer keyboard.



	Picks	x (m)	z (cm)	A (dB)	Vel. Calc	v (cm/ns)	t (ns)
1	Layer 1	0.00	5.30	-20.99	Automatic	11.70	0.91
2	Layer 1	0.50	5.00	-22.32	Automatic	11.60	0.86
3	Layer 1	1.00	6.20	-23.82	Automatic	11.80	1.05
4	Layer 1	1.25	6.00	-22.47	Automatic	11.80	1.02
5	Layer 1	1.50	6.10	-21.92	Automatic	12.40	0.98
6	Layer 1	1.75	5.40	-22.60	Automatic	12.10	0.89
7	Layer 1	2.00	5.30	-24.20	Automatic	11.90	0.89
8	Layer 1	2.25	5.70	-19.23	Automatic	11.60	0.98
9	Layer 1	2.49	5.50	-21.59	Automatic	11.30	0.97

Figure 85: Single layer display in a spreadsheet.



	Picks	x (m)	z (cm)	A (dB)	Vel. Calc	v (cm/ns)	t (ns)
1	Layer 1	0.00	5.30	-20.99	Automatic	11.70	0.91
2	Layer 1	0.50	5.00	-22.32	Automatic	11.60	0.86
3	Layer 1	1.00	6.20	-23.82	Automatic	11.80	1.05
4	Layer 1	1.25	6.00	-22.47	Automatic	11.80	1.02
5	Layer 1	1.50	6.10	-21.92	Automatic	12.40	0.98
6	Layer 1	1.75	5.40	-22.60	Automatic	12.10	0.89
7	Layer 1	2.00	5.30	-24.20	Automatic	11.90	0.89
8	Layer 1	2.25	5.70	-19.23	Automatic	11.60	0.98
9	Layer 1	2.49	5.50	-21.59	Automatic	11.30	0.97

Figure 86: Spreadsheet rows (picks) selected by clicking on the row number.
They can be deleted using the delete key on the keyboard.

Ground Truth

Selecting the Ground Truth menu item from the Interactive Interpretation main menu (see next section) opens a spreadsheet that allows the user to enter ground truth data that can automatically be used to calculate layer velocities as shown in Figure 87.

Ground Truth Points

	X (m)	Y (m)	Z (cm)	Boundary	Data X (m)	Data Y (m)	Time (ns)	v (cm/ns)
1	0.00	0.00	0.00	Layer 1	0.00	0.00	1.49	0.000

Figure 87: Spreadsheet showing options for ground truth points.

Ground truth data can be entered on the left half of the spreadsheet and the calculated velocity and nearest scan location are automatically updated and shown in the right side of the spreadsheet.

For example, let's say a core was drilled 104.5 m from the starting location of the file and the measured depths of the layer interfaces were 12 cm, 22 cm, and 33 cm. Each of the first three columns in the Ground Truth spreadsheet should be filled with this information as shown in Figure 88.

Ground Truth Points

	X (m)	Y (m)	Z (cm)	Boundary	Data X (m)	Data Y (m)	Time (ns)	v (cm/ns)
1	104.50	0.00	12.00	Layer 1	104.50	0.00	1.69	14.222
2	104.50	0.00	22.00	Layer 2	104.50	0.00	3.76	9.660
3	104.50	0.00	33.00	Layer 3	104.50	0.00	6.38	8.406
4	0.00	0.00	0.00	Layer 1	0.00	0.00	1.49	0.000

Figure 88: Spreadsheet showing options for ground truth points.

The 5th, 6th and 7th columns of the spreadsheet shown in Figure 88 were automatically calculated by RADAN. The Data X shows the location of the nearest scan containing the layer pick, Time is its arrival time, and V is the calculated velocity for the layer. If no picks are located within 20 scans of the core location, then zeros will appear in the last 3 columns.

Once core data have been entered, the spreadsheet can be closed or left open. When the user saves the data as an ASCII *.lay file, the core data are stored in a separate ASCII file with the same name as the *.dzt file and the extension .gtr. Once this file has been created it will automatically open and its contents read by RADAN the next time the user opens the ASCII file providing it is located in the same directory as the ASCII file. Alternatively, if the user saves the pick data in a *.bii file, all of the ground truth information will be stored with the picks in the *.bii file.

The velocities calculated from core data can be used to calculate layer depths. To change the velocities of existing picks, use the select block or select range picking tool and move the selected region over the picks that need to be changed. Then, click the right mouse button to bring up the pick options as shown in Figure 73 and select the Change Pick Velocity option. Proceed to change the selected pick velocities as directed in the dialog.

To specify all new layer picks to have velocities calculated from the ground truth data, the velocity option must be changed from the Layer Properties Dialog page accessed through the Layer Options menu item.

When ground truth data from more than one core are entered in the Ground Truth spreadsheet and the user selects core data as the velocity option for picks, the velocity used for each pick is obtained from the nearest core.

Any changes in core data are automatically updated in the picks that have core data calculated velocities.

Layer Options

This tabbed dialog box is accessed by selecting the Layer Options item from the Interactive Interpretation main menu. You can select one of the 6 pages: Filters, Display, Properties, Layer Names, and Other options... by clicking on the corresponding tab.

Filters

Data can be filtered according to several statistical parameters. By default, filtering is disabled and the parameter boxes are inactive. The user has to uncheck the Disable Filters box in order to enable filtering and adjust the desired filter parameters. The filter items are statistics calculated for each layer. The data can be filtered according to the normalized reflection amplitude or another amplitude criteria (see Global page) using column 1. The -40 appearing in column 1 (Figure 89) indicates that all reflections associated with each layer that have normalized amplitudes less than –40 dB will appear as a different, user-defined, color in the window panes.

The second column in Figure 89 is the filter option for the deviation of picks from a least-squares fit line through a segment of the data defined by the Statistics Layer Length. Figure 89 shows that all layer picks with deviations greater than 0.03 m will be filtered out (shown as a different color in the window). Filtering points using their deviation from a least-squares fit line is effective in eliminating spurious reflections from the database.

The third column in Figure 89 is the Minimum Percent Scans filter option. The percent scans containing the layer surrounding each reflection point is calculated for each reflection. This calculation is performed using the Statistics Layer Length entered in the bottom of the page. Very discontinuous layers can be filtered out (shown as a different color in the window) using this option.

The Statistics Layer Length shown on the bottom of the page is used in the calculation of Maximum Deviation and Percent Scans statistics.

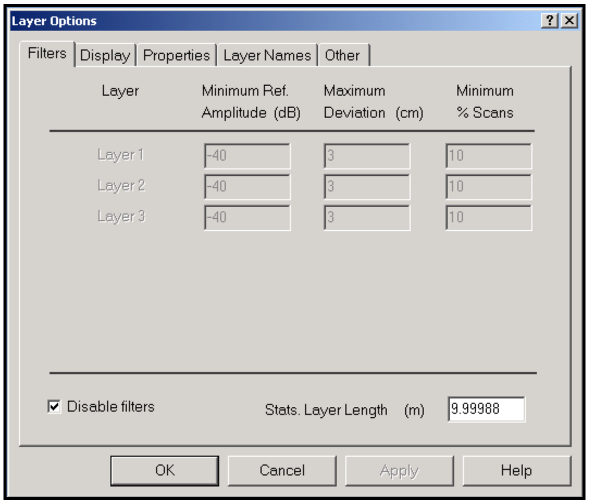


Figure 89: Filters page of the Layer Options dialog box.

Display

This dialog (Figure 90) controls the appearance of picks representing each layer.

Color: The different layer pick colors available include: yellow, red, green, blue, brown, gray, and black. Filtered Points Color selection will display the filtered points in a distinct color.

Size: The size of the picks shown on the screen can be varied using this option. The number shown is the diameter of the pick in pixels. Pick sizes can be varied from 0 to 10 pixels. Setting the pick size to 0 will prevent the picks for the specified layer from being drawn on the computer screen.

Add Black Outline around Points: This option is used to add or delete a black outline around each pick. Normally the black outline enhances individual picks. However the black outline may be undesirable if multiple picks are placed very close together because the black outline will prevent the user from observing the color of the pick.

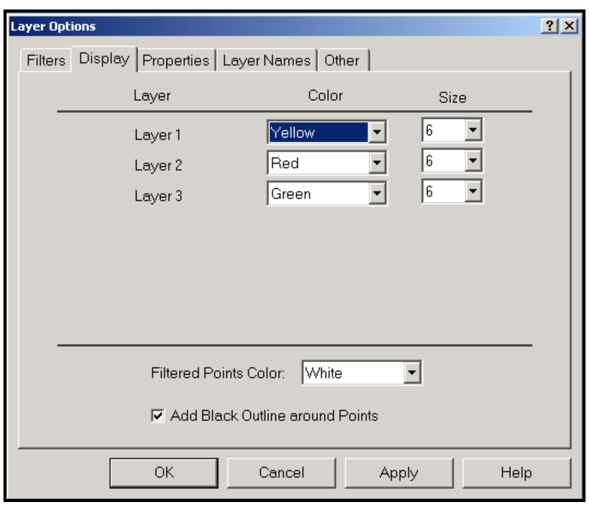


Figure 90: Display page of the Layer Options dialog box.

Properties

The layer properties dialog page allows the user to specify the criteria used to pick the layer reflections and the velocity used to calculate the layer depth (thickness). Figure 91 shows the layer property options.

Bottom Picking Criteria: These criteria are used when the user adds reflection picks using the picking tool. Each time the user adds a pick, a search is performed to locate the corresponding feature of the reflection that will be used to identify the reflection arrival time and amplitude. The different criteria include: Positive Peak, Negative Peak, Absolute Amplitude Peak and None. When the picking tool is the Single Point and the None criteria is selected, the location and amplitude of the reflection is determined by the exact position of the mouse cursor over the data. Otherwise the nearest reflection peak meeting the chosen criteria is selected. Positive Peak is the default for all road subsurface layers.

Layer Velocity: Sets the propagation velocity used to calculate the thickness of each layer. If the Auto box is checked, the velocity will be automatically calculated for each radar scan. The other options are: (1) User-specified, (2) Core Data, and (3) Velocity Analysis File. The Velocity analysis option is most commonly used for geological investigations where a common-midpoint file has been collected and processed using the Velocity Analysis Option in RADAN. The output file from the Velocity Analysis must be entered in the Global page before this option is activated here.

Interpolation Type: Selects Linear or Nearest Peak as the method used to interpolate points within the selected data block or range (see Interpolate Points in the Select Block and Select Range section). The nearest neighbor method involves a search for the nearest peak between existing picks. The linear interpolation method does not perform any peak searching and simply picks points in scans based on a straight line drawn between the nearest 2 picks. The Nearest Peak interpolation is recommended because it preserves reflection amplitude information.

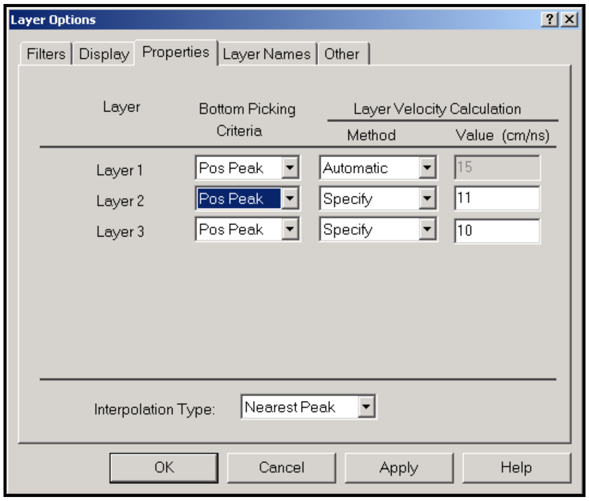


Figure 91: Properties page of the Layer Options dialog box.

Note: Changes made to the items in the Properties page will only be applied to new picks. For existing picks the user must use the Select Block or Select Range to modify pick velocities.

Layer Names

The Layer Names page permits the user to specify a name for each layer. For example, for a typical road structure, the user may want to rename Layer 1 as Asphalt, Layer 2 as Base and Layer 3 as Subbase. Layer name changes are shown in all dialogs and will be output to the ASCII file when the user performs the next ASCII file save (see the Save Changes section).

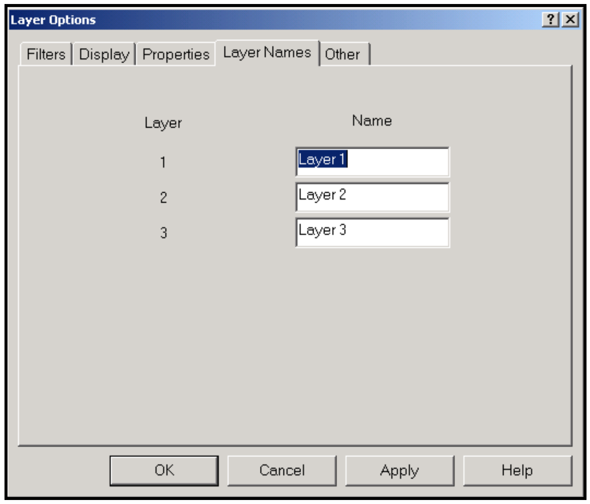


Figure 92: Layer Names page of the Layer Options dialog box.

Other

The Other page contains two separate options.

Maximum Number of Layers: Maximum number of layers that can be traced in the current data file. It is recommended that the user select the minimum # of layers required for the project. Additional layers require more memory allocation and decrease program performance. A maximum of 7 layers is permitted.

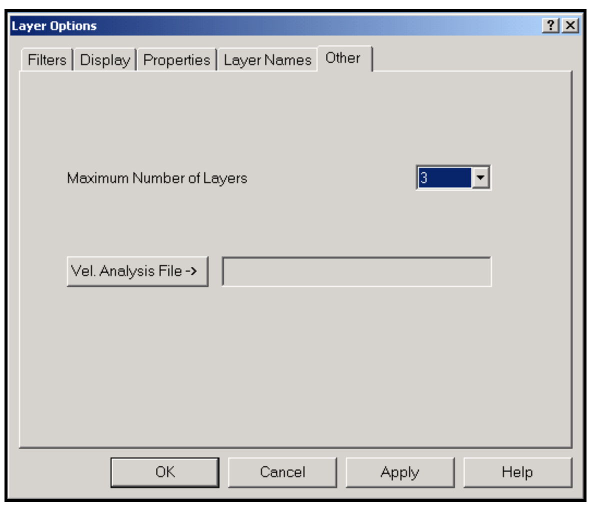


Figure 93: Global options page of the Layer Options dialog box.

Vel. Analysis File: The Velocity analysis option is most commonly used for geological investigations where a common-midpoint file has been collected and processed using the Velocity Analysis process in RADAN. Enter output file from the Velocity Analysis process here to make these velocities available for picked layers. After the velocity analysis file is entered here, these velocities can be specified for new picks using the Properties Page or on existing picks by using the select block/select range option and selecting Pick Mod. Options from the drop-down menu.

Target Options

Clicking on the Target Options menu item from the Main Menu opens up a list box containing the names and properties of all of the targets as shown in Figure 94.

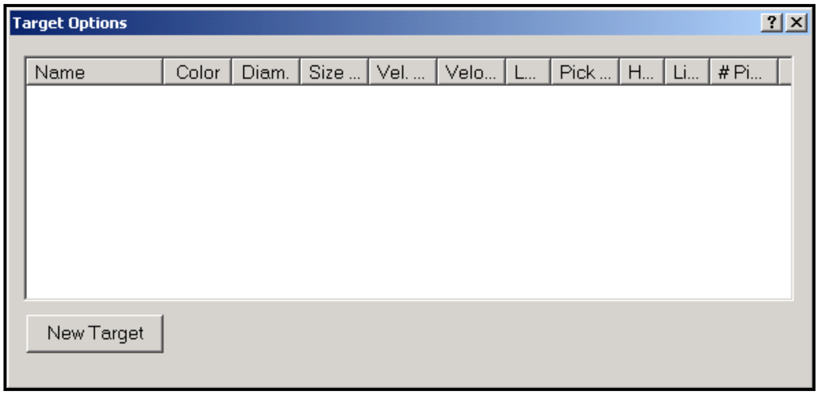


Figure 94: Target Options list accessed by selecting Target Options from the Main Menu.

Initially, the target list will be empty. Targets are added by clicking New Target. Each time the user clicks New Target, a new target name and its properties are added to the list. Figure 95 shows the target rebar that has just been added by clicking New Target.

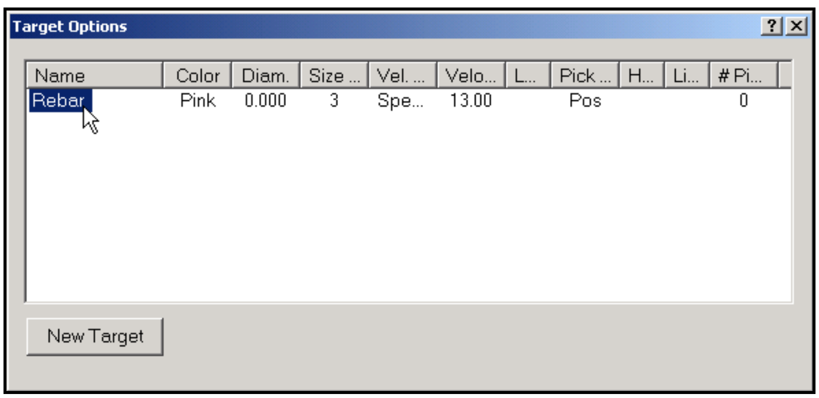


Figure 95: Default target showing up following clicking New Target. Target properties are edited by placing the mouse cursor over the target name, as shown, and double-clicking.

The new target properties are edited by placing the mouse cursor over the target name as shown in Figure 95 and double-clicking. This procedure opens up the dialog shown Figure 96.

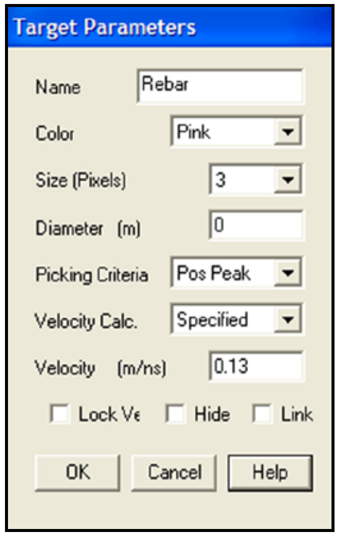


Figure 96: Target Parameters dialog accessed by double-clicking on the target name.

Description Of Each Target Parameter:

Name: The name of the target. This name will appear in the spreadsheet and in the output ASCII file.

Color: The color of the circle drawn at the target location in the data pane and corresponding target depth in the depth pane.

Size: The size, in pixels, of the circle drawn at the target location in the data pane.

Diameter: The diameter of the target. The width of the circle drawn in the depth pane is directly proportional to the target diameter when this value is greater than zero. When this value is zero, the size of the target circle drawn in the depth pane corresponds to the specified pixel size.

Picking Criteria: The criteria used to pick targets in the data. The options are: (1) Positive Peak, (2) Negative Peak, (3) Absolute peak, and (4) None. When options 1-3 are used, the location of the target will correspond to a reflection peak. For option (4), the location of the target will directly correspond to the location of the mouse cursor or select block.

Velocity Calc.: Sets the propagation velocity used to calculate the depth of each target. The options are: (1) User-specified, and (2) Core Data. To enter a user-specified option, select Specify and enter the value in the box next to Default Velocity.

Velocity: This is the user-specified velocity.

Lock Vel: Checking this box prevents the user from selecting a different velocity method or user-specified velocity for individual targets within the group of targets possessing the same target name.

Hide: Checking this box hides all the target picks from view and prevents them from being selected using the select block or select range picking tools.

Link: Checking this box connects the target picks together to form pipes and other linear objects that can be viewed in RADAN QuickDraw This option is only available for users who have purchased the I^{3D} and QuickDraw modules.

Global Options

The Global Options dialog is accessed from the Global Options menu item in the Main menu. This dialog, shown in Figure 97, contains two adjustable options.

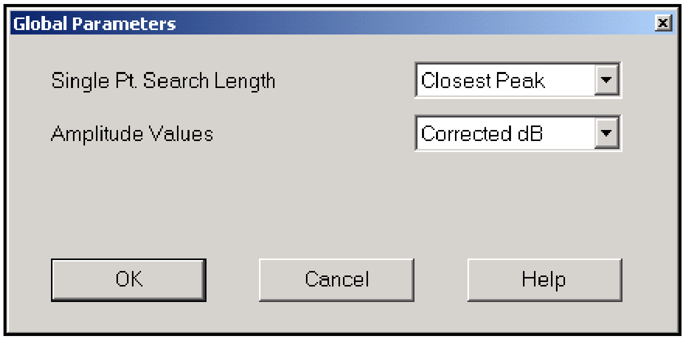


Figure 97: Global Options dialog accessed by selecting Global Options from the Main Menu.

Single Pt. Search Length: This option permits the user to select the search distance when adding single points. There are two options: (1) Closest Peak and (2) Cursor Length. The closest peak search type will perform a search until the first peak is located or the start or end of the scan is reached. In other words, the search may potentially extend over the entire scan. The Cursor Length search method only performs a search for a peak over the vertical length shown by the mouse cursor. The Closest Peak method is the default option.

Amplitude Values: This option allows the user to specify how the amplitude values for each layer are calculated. The different options are: (1) Data Units, (2) dB, (3) Normalized dB, and (4) Corrected dB (with Horn antenna files). The data units option provides the layer bottom reflection amplitudes in the actual data values. The dB option converts the data units amplitudes to decibels (dB) by using the equation 20*log10(x) where x is the absolute value of the data amplitude. The normalized dB option normalizes the data amplitude relative to 32767 before converting to dB. The Corrected dB option corrects for amplitude loss related to reflections from preceding layers. The corrected amplitude would therefore be a more representative value of the portion of energy reflected at the layer bottom. The importance of this value is that is can be used as one parameter in the assessment of the integrity of the layer bottom reflection. This option is only available with horn antenna data processed through the Road Structure module.

Exporting a KML File for Use in Google Earth

A KML file is a file type used to display geographic data in an earth browser, such as Google Earth and Google Maps. KML files have a tag-based structure with names and attributes used for specific display purposes. In RADAN you can export certain kinds of information as a KML file and easily view that information in Google Earth. This section discusses exporting layers identified in Interactive Interpretation.

Note: This is new functionality provided on a trial basis to users of 6.6. See the note on page 2 for more information.

Note: In order to create a KML file, you must have collected the data with GPS.

To export, right click on the Interactive Interpretation data pane and go to Save Changes>Export. You will see the dialog pictured in Figure 98.

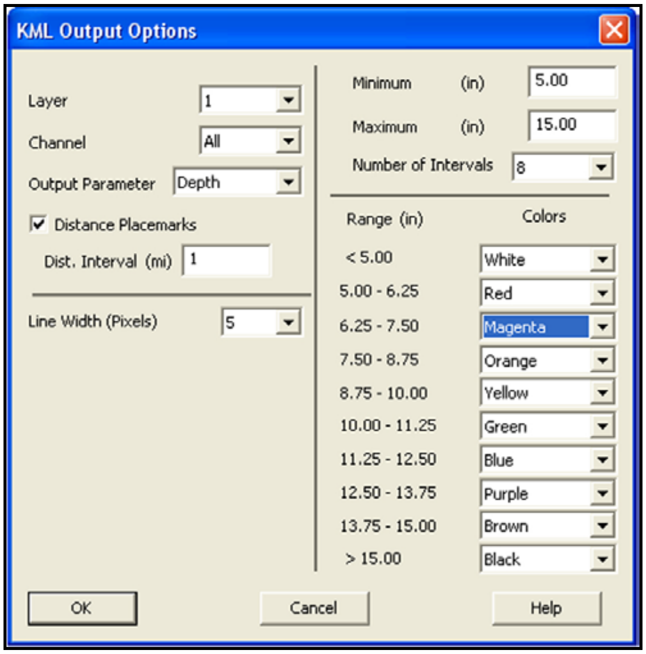


Figure 98: KML file Export Options.

Layer: Selects the Layer that you want to export. If you have multiple layers, you must export them one at a time.

Channel: Selects the data channel to export. You can export different channels if you have collected a multi-channel file.

Output Parameter: This can be pick depth, amplitude, velocity, or time depending on the type of data that you want to depict.

Distance Placemarks/Distance Interval: This option outputs a notation at a prescribed distance.

Line width: The KML output line width in pixels.

Minimum/Maximum: This sets the range of output values specified in the Output Parameter option.

Number of Intervals: The number of evenly spaced breakpoints for the output data.

Range/Colors: The range will be set by the number of output intervals. You can decide to code different intervals with colors.

The output of this is a KML file with the same root name as the ASCII pick LAY file. To import into Google Earth, simply drag this file onto Planet Earth and it will zoom to the given location of the data.

Exiting the Interactive Interpretation Session

Exit the Interactive Interpretation session by clicking the left mouse button on the X at the top right corner of the Interactive Interpretation window or by exiting RADAN. If changes have not been saved, you will be prompted to save them to the current output file.

Chapter 4: Basic Processing Tutorials

These tutorials are designed to familiarize you with basic process functions available in RADAN. They are not exhaustive and are meant to get you started working with the software. The data examples for the tutorials can be found included on your RADAN CD.

Note: These tutorials are written to work with RADAN 6.6. If you have an earlier version of RADAN you should download the update from GSSI's support site: www.support.geophysical.com.

Datafile: TestPit.DZT, Excavation1.DZT

This tutorial will cover the following topics:

- Changing RADAN working directories and Linear Units.
- Loading a data file into RADAN.
- Changing display parameters.
- Performing a position correction.
- Performing a horizontal background removal.
- Performing a constant velocity migration.

Topic 1: Changing the RADAN working directories

1 Double-click the RADAN program shortcut from your desktop to start the RADAN program.

2 Choose View > Customize. Note that this option will only be active if there are no data files open. A small window will appear with four tabs: Directories, Appearance, Linear Units, SIRVEYOR.

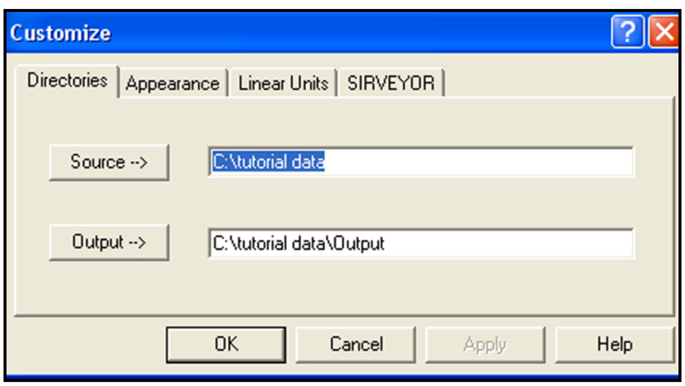


Figure 99: Customize dialog box.

3 Click the button for Source to bring up a browser window and navigate to the folder where your data is located. You can also specify an output folder by clicking the button for Output and navigating to that location. The option for output is provided if you wish RADAN to save processed data to a different location than the raw data.

4 Click the tab for Linear Units and select the Units that you wish to use. This example was collected with metric units. This data was collected without a GPS, but if you have GPS data you can choose to display the coordinates as Latitude and Longitude or UTM values.

5 The Appearance tab controls the look and feel of RADAN. Changes you make here control the display size of the icons as well as sound signals that RADAN will make when it finished processing functions.

6 The SIRVEYOR tab is a GPS control interface for the SIR-20 control unit. It is not used in post-processing.

Topic 2: Loading a data file into RADAN

There are two ways to load a DZT file into the RADAN software.

1 From RADAN, choose File > Open. RADAN will default to the Source folder that you specified in View > Customize. RADAN will also default to the DZT file type. Click on TestPit.DZT and then click Open.

2 You can also drag a data file into the RADAN software from an open Windows browser window. For this method to work, RADAN must be open and the file that you drag must be a DZT file.

Topic 3: Changing Display Parameters

1 Open TestPit.DZT. Initial gain setting may be weak, so right click on the data and choose display gain from the pop-up menu. Select 4.

2 Right-click on the vertical scale at the left side of the data window and select Show Scale from the Horizontal Scale portion of the window. RADAN will display a distance scale across the top of the data window.

3 Right-click on the vertical scale again and select Color Table from the section at the bottom of the pop-up window. Choose Color Table **1**. Right-click on the vertical scale again and select Color XForm. Select Color XForm **1**.

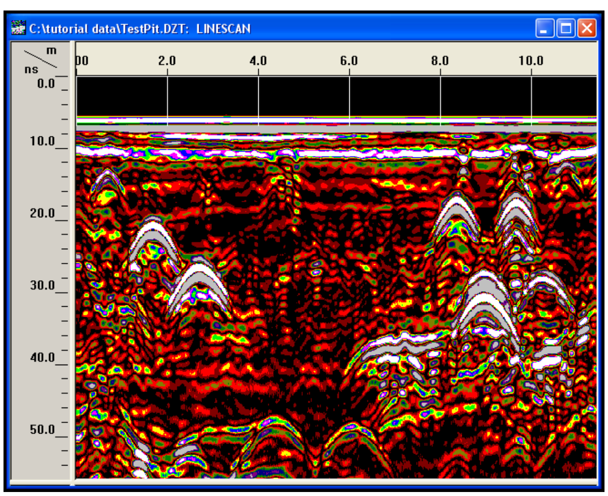


Figure 100: TestPit.DZT with Display Gain of 4, Color Table and Transform of 1.

Topic 4: Performing a Position Correction

This topic covers Position Correction (sometimes called Time-Zero correction). Position correction is used to remove the section of data that occurs before the direct wave. This topic will use TestPit.DZT.

1 With the data file open, choose Process > Correct Position. The window shown below will appear on the screen. The scan is displayed tipped on its side with zero at the left of the horizontal scale and a 1 to -1 amplitude scale on the vertical.

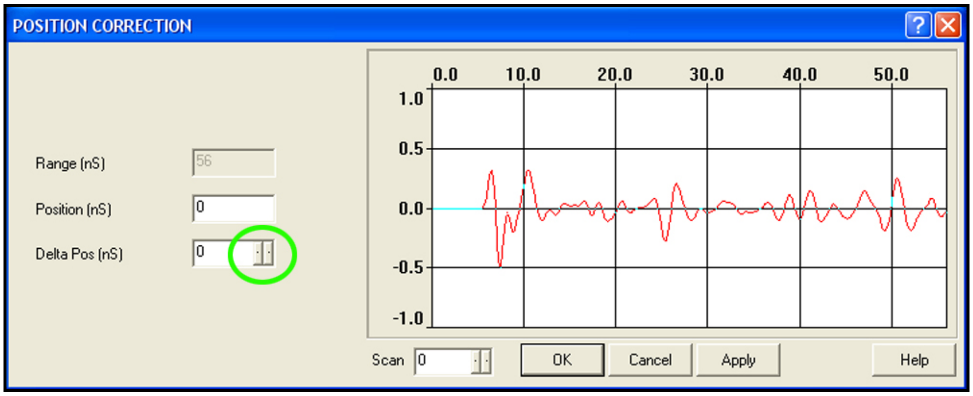


Figure 101: Position Correction window.

2 On the Delta Pos (nS) option (green circle) use the small buttons to cause the scan to shift to the left until the maximum of the first positive peak is as the left edge. The model scan is Scan 0 which is the first one in the profile. If this scan is not representative, click on the small buttons next to the scan window to select a more appropriate model.

Note: There is some discussion in the GPR industry as to the proper position of time zero. For the sake of consistency, GSSI recognizes the first maximum as the correct point.

3 Click OK to run the process and save the data file with a unique name. The filename TESTPITTZ.DZT is used in this example.

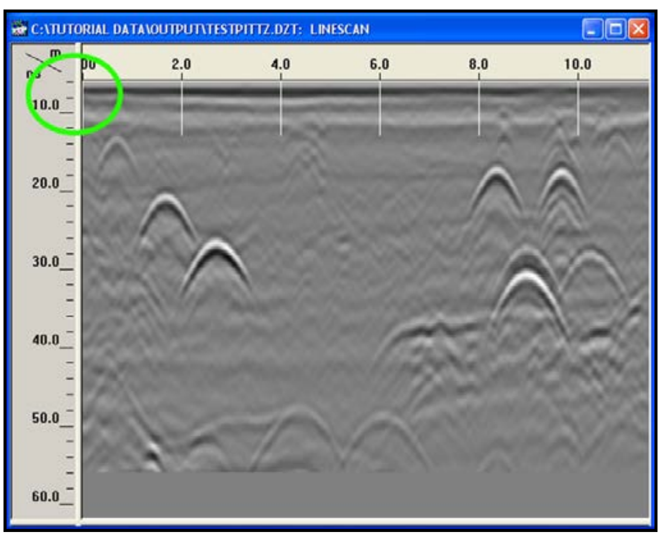


Figure 102: Result of process after Step 3.

4 Notice that the vertical scale on the processed file no longer begins with zero. Choose Edit > File Header and reset the position to zero. Then click Save.

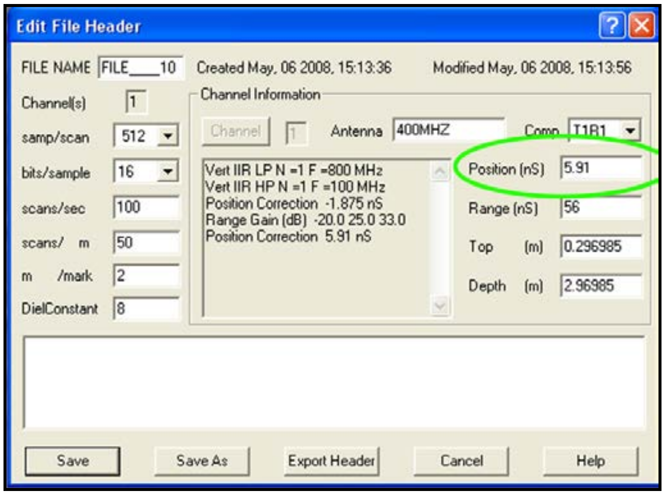


Figure 103: Edit File Header dialog box.

Topic 5: Background Removal

Background Removal is a horizontal high pass filter that is meant to removal constant horizontal banding in the data. This horizontal banding is usually the result of a poor signal to noise ration that can stem from nearby metal or surveying over conductive conditions. Since it is constant in the data, it is easy to remove.

A background removal is a scan length filter. It will average together a number of scans and subtract the averaged value at each sample from all scans. For normal situations, it is best to set this filter very long. For example, if your collection scans/meter was 50 and you set your filter length to 49, then you will remove all horizontal features 1 meter long (or longer).

This filter will also remove the direct wave, so position correction should be done first.

For this topic, we will use file Excavation1.DZT.

1 Open Excavation1.DZT and perform a position correction on the file. Save it as Excavation1pc.DZT.

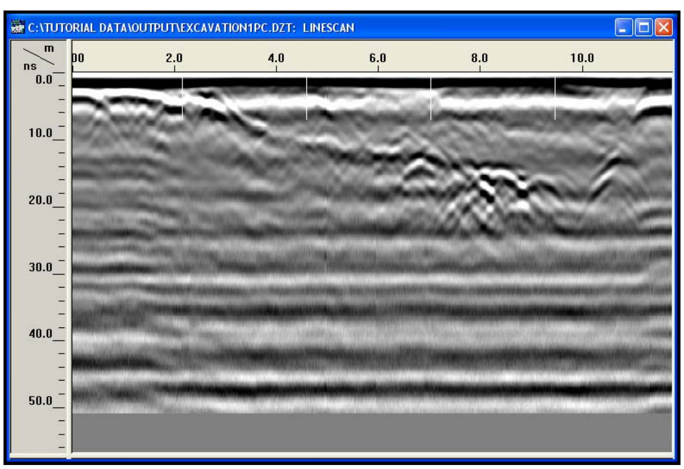


Figure 104: Excavation1pc.DZT. Color table 17, display gain = 4.

2 Choose Process > FIR Filter. While the FIR filter can perform a number of different processes, this tutorial will only use the background removal.

3 Excavation1.DZT was collected in English units. The scans/meter is approximately 60. In the window next to background removal, enter 299. You will need to enter in 299 instead of 300 because the value entered needs to be negative. A value of 299 means that the filter will remove horizontal features 5 meters in length or longer. Click OK and then save the file as Excavation1pcbr.DZT.

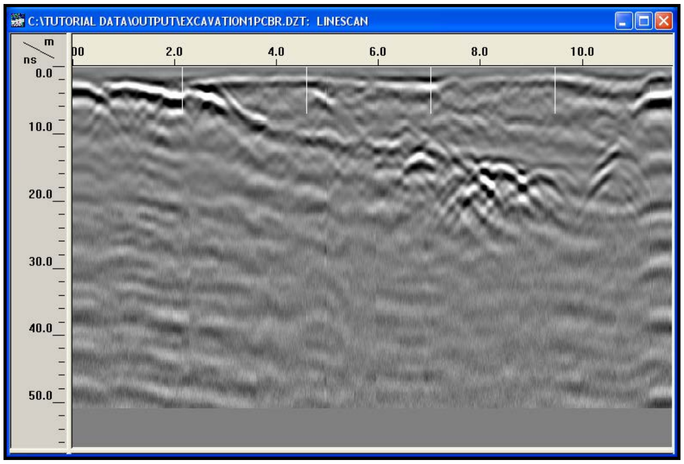


Figure 105: Excavation1pcbr.DZT. Color table 17, display gain = 4. Filter length = 299 scans.

4 Now go back to Excavation1pc.DZT and choose Process > FIR Filter again. This time use a value of 3 scans in background removal. Click OK and save the data as Excavation1pcbr2.DZT. Notice that much of the data are gone. This is an example of improper settings.

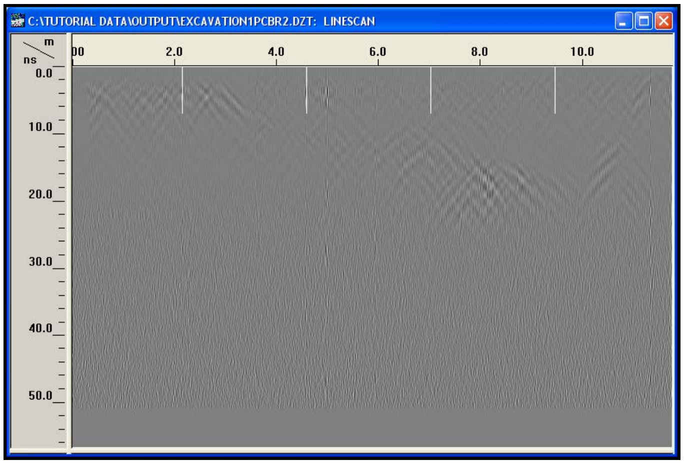


Figure 106: Excavation1pcbr2.DZT. Color table 17, display gain = 16. Filter length = 3 scans.

You can also choose to enter in an extremely large number. A window will then pop up and note the maximum possible filter length. This will be either 1023 or the total number of scans in the profiler, whichever is smaller.

Topic 6: Constant Velocity Migration

Migration is a filter designed to remove the dipping tails from hyperbolas and give a clearer image of the target's location and total reflection amplitude. It is a necessary step for 3D surveys in which the goal of the survey is to locate linear objects such as pipes or rebar. Constant velocity migration also provides a dielectric value and can thus be useful for estimating depth to target in a homogenous matrix.

Since a successful migration requires a time zero position correction to be performed, we will use the output of Topic 4. Open the file TESTPITTZ.DZT.

1 Choose Process > Migration. You will see the migration window pop up and a hyperbolic selection tool will be superimposed on the data. If your color table is a grayscale, this may be difficult to see. Changing the color table to 25 will make this easier.

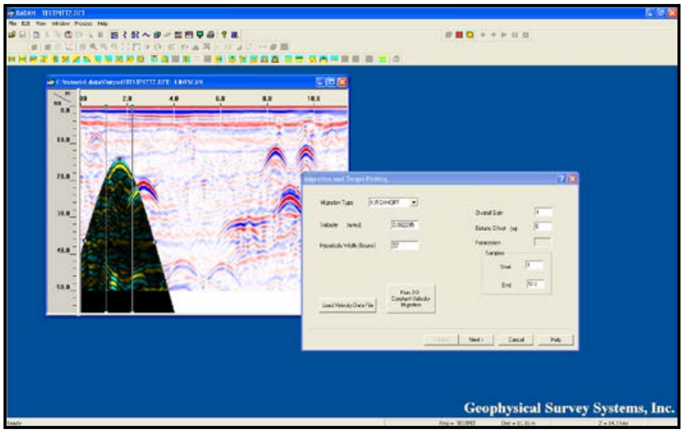


Figure 107: Migration window. Color table = 25, Display gain = 2.

2 Click in the center of the selection tool and hold down the mouse button. You can now drag the selection tool to cover up one of the hyperbolas in the data.

3 Use the small, square handles along the edges of the selection tool to reshape the toll to match the shape of the data hyperbola as closely as possible. This is changing the velocity shown in the migration window.

4 Click on the handle at the top of one of the vertical line and drag the lines so that they are approximately 90% down the tails of the data hyperbola.

5 Click Run 2D Constant Velocity Migration and save the file with a unique name. For this tutorial we will use TESTPITTZM.DZT. If the hyperbolas collapse to small points, then the migration velocity was correct. If hyperbolas remain or if they have become inverted, then the velocity is incorrect.

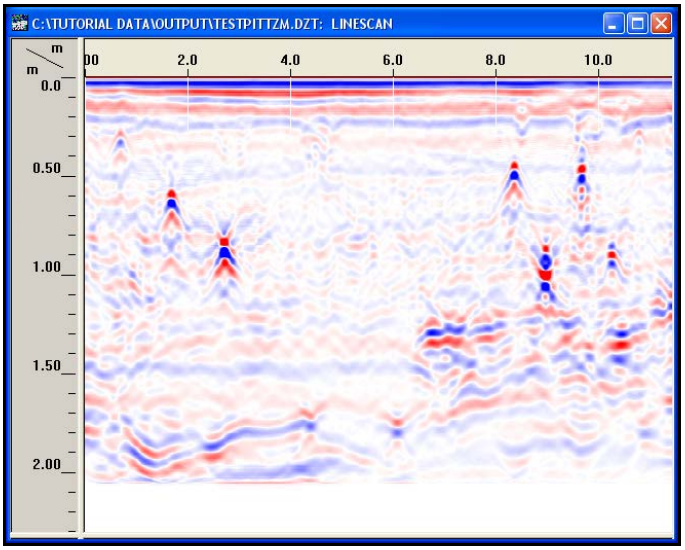


Figure 108: Accurate migration velocity.

6 Right-click on the vertical scale and select Depth.

Chapter 5: Advanced Processing Tutorials

Topic 1: Distance Normalization

If data were collected without a survey wheel or cart, it may be necessary to distance normalize the profile before it is useful. Distance normalization is a necessary process step to run before any distance-based process function such as migration or spatial fft.

For this topic, open the file DistNorm.DZT. This file was collected with a SIR-3000 and 400 MHz (Model 5103) antenna in northern Florida, USA. It was collected with metric units, so make sure that your horizontal and vertical units are set to Meter in the View > Customize window. The file is shown below. Note the short, dotted white lines at the top. Those are user marks that were input every 5 meters during collection. User marks are essential to tie the scans to actual distances.

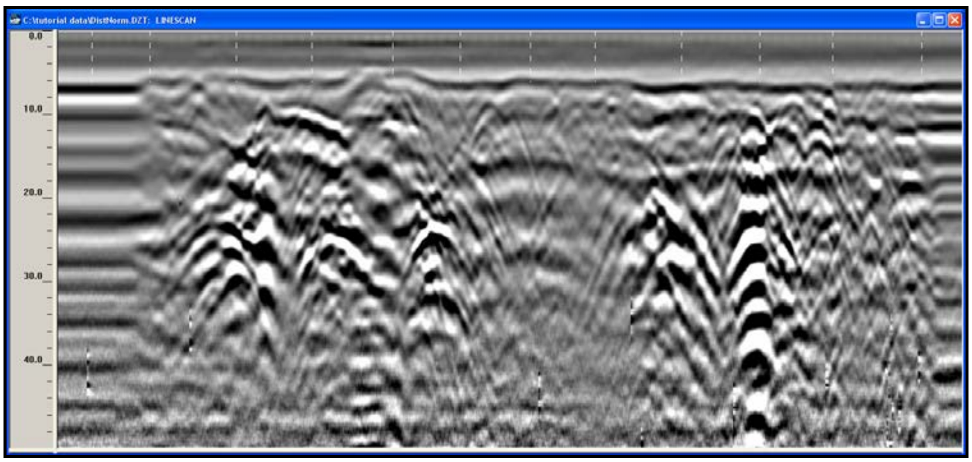


Figure 109: DistNorm.DZT, Color table = 17, Display gain = 4.

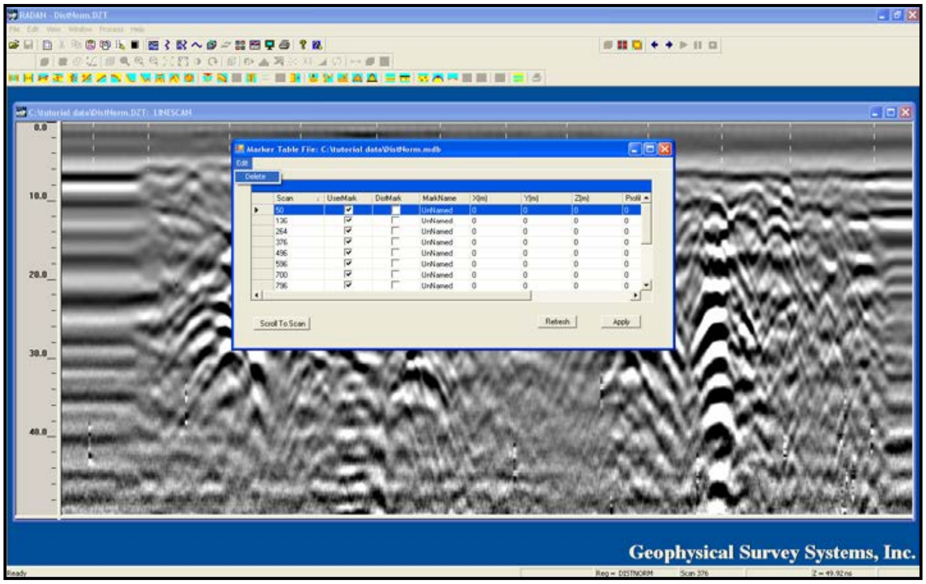
1 There is one extra mark in the data toward the beginning of the file. The section of flat horizontal banding represents data collected when the antenna was stationary. That extra mark is an error and must be removed. Right click on the vertical scale bar and set the horizontal scale to display scans.

2 Click on Edit > Edit Markers. Identify the scan which corresponds to the first mark (50).

3 Click on that scan's row in the marker table to highlight the whole row and then click Edit > Delete. Then click Apply and close the database window.

4 At this point, you may need to close the file and reopen it to get the database to update.

5 Click on Edit > File Header and input the correct scans/meter and correct meters/mark. This information is arbitrary and must match the true mark interval that you collected in the field. For convenience, the values of 25 scans/m and 5 m/mark have been saved in the notes area of the file header. This will not be present for actual survey data. Click Save after the values have been entered.



6 Click Process > Distance Norm. The software will read the file header for the scans/m and m/mark that were input in step 5. Check the box next to “Apply to User Marks.” Click OK and save the file under a unique name.

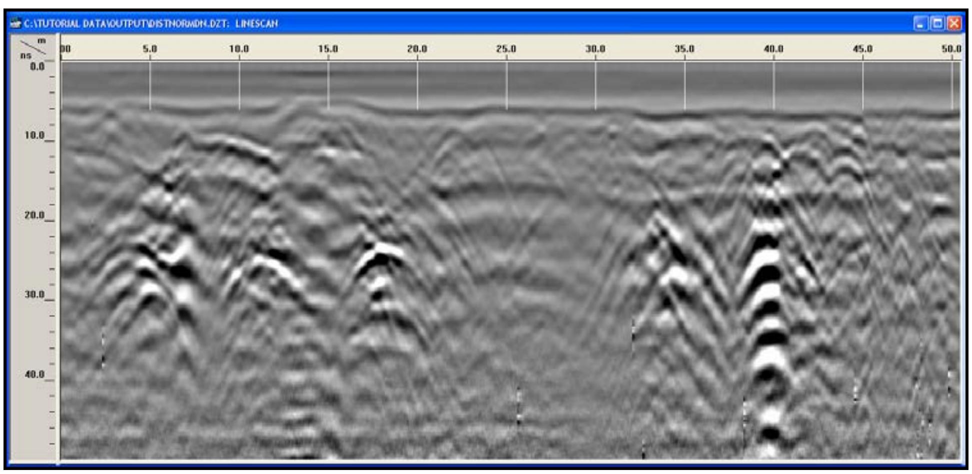


Figure 110: DistNormDN.DZT: Output of Distance Normalization process. Color table = 17, Display gain = 2.

Topic 2: Band Pass Filtering

This topic covers the use of high and low pass FIR frequency filters. It will use the file BandPass.DZT.

The data below were collected without any frequency filters. Data are typically collected with a high and low pass filter that is somewhere outside of the frequency range measured at -3 dB from the peak power center frequency. At -3 dB for the 400 MHz antenna, these measured values are at 200 MHz and 600 MHz. Data collection filters are placed outside of these values. The high pass filter is usually set at 100 MHz and the low pass is set at 800 MHz. These filters are meant to stabilize the signal and weaken any noise.

The lack of collection filter allows a great deal of noise to be recorded. This manifests as both a high-frequency oscillation and a low-frequency shift.

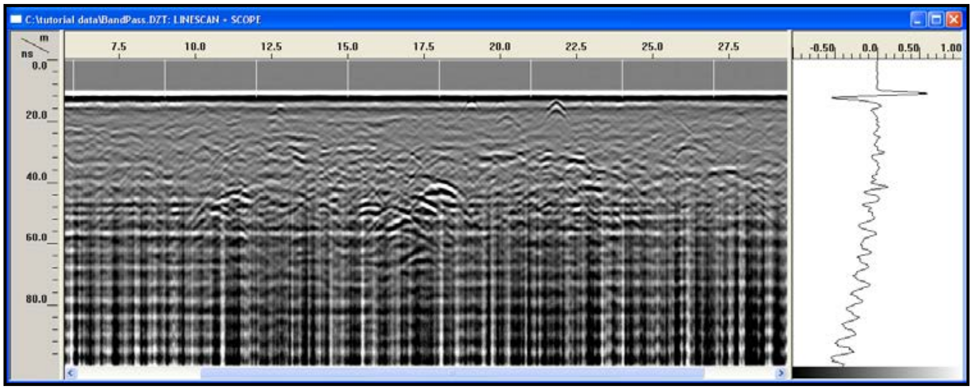


Figure 111: BandPass.DZT. Color table = 17, Display gain = 4.

1 Open the file BandPass.DZT.

2 Select Process > FIR Filters

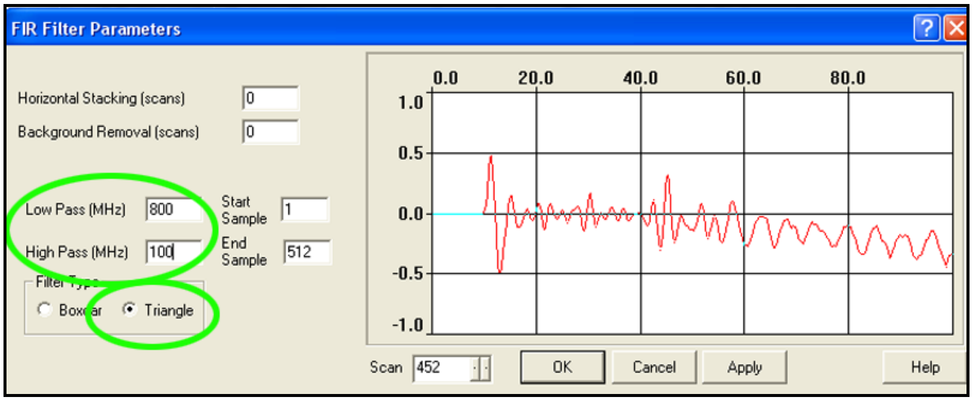


Figure 112: FIR Filter Parameters dialog.

3 The top section of the dialog concerns horizontal filters. This topic focuses on the options noted by the green enclosure in the above window. The Low Pass and High Pass are denominated in units of frequency (MHz). During data collection, the Low Pass is typically two or three times the center frequency. The High Pass is usually one-quarter or one-third of the center frequency. For the 400 MHz antenna, set the Low Pass to 800 and the High Pass to 100.

4 The Filter Type window will set the shape of the filter. The default is boxcar. A triangle shaped filter is less likely to cause phase, time, or amplitude shifting in the data. Click the box next to Triangle.

5 Click Apply to see a preview of the filter effect and then click OK. Save the data file as BandPass_Filt.DZT.

6 To go further, this data would also benefit from a time-zero correction and a horizontal background removal.

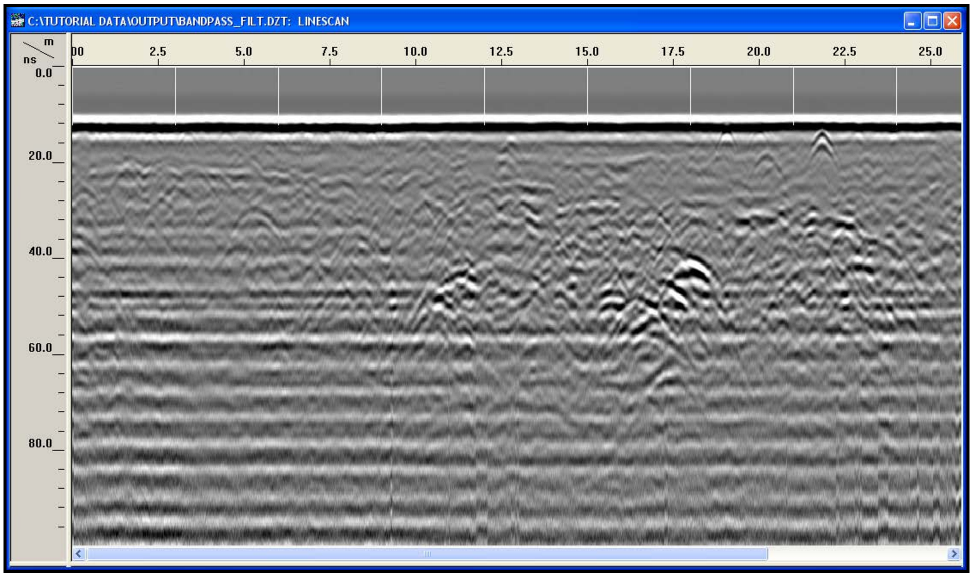


Figure 113: BandPass_Filt.DZT. Color Table = 17, Display Gain = 4.

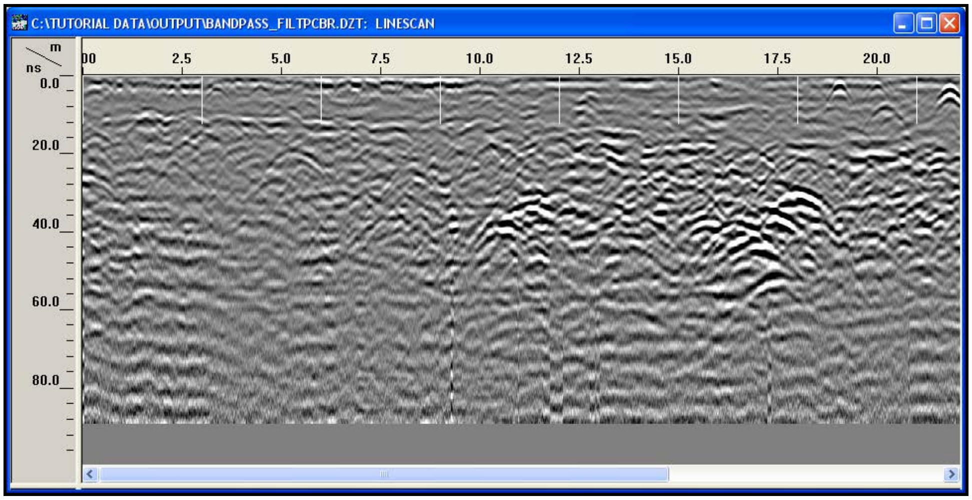


Figure 114: BandPass_Filt with corrected time-zero and horizontal background removal.

Topic 3: Range Gain Adjustments

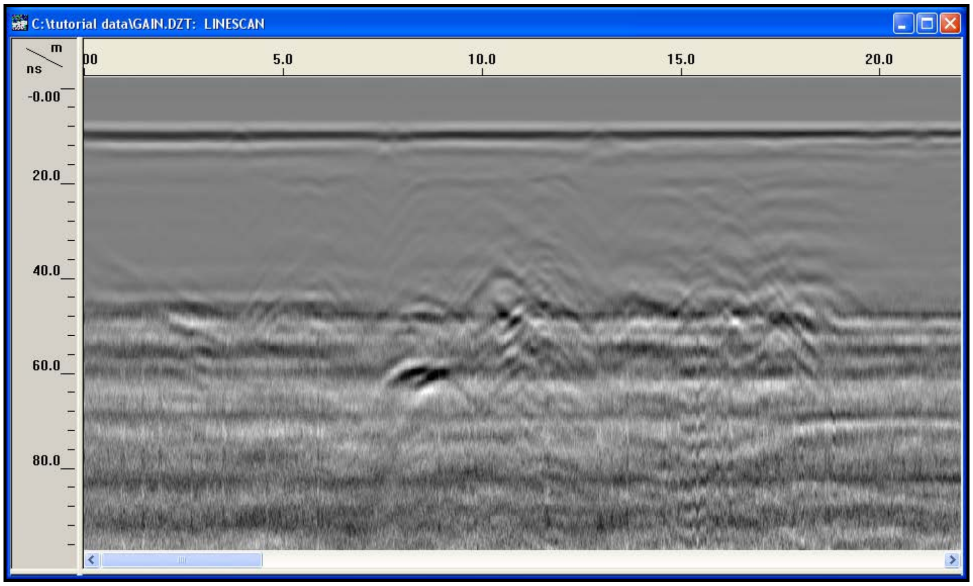


Figure 115: Gain.DZT. Color table = 17, Display Gain = 1

This tutorial addresses manual corrections to the time variable gains that were recorded during data collection. In the example above, the top 50% of the data appears under-gained relative to the lower portion. The function used to correct this is range gain.

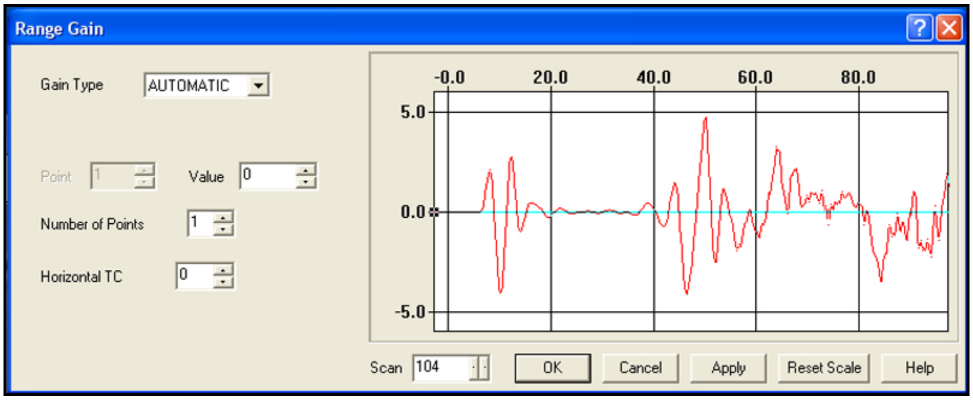


Figure 116: Automatic Gain.

Automatic Gain Correction

This type of gain correction is preferable for finding objects in the data as opposed to changes in ground conditions. Since the amount of gain applied is not constant along the profile, it will downplay or eliminate overall differences in signal amplitudes along the horizontal direction.

1 Select Process > Range Gain. The window pictured above will appear. We will try the automatic correction first.

2 Select 7 for the number of points. Note that a black square appears along the center of the scan each time you click on the "up" box in the Number of Points window. These will be evenly spaced.

3 Click Apply to see a preview of the changes. You will notice that the upper portion of the data will brighten and the lower portion of the data will dim. The algorithm is making decisions about the amount of gain to apply at different locations along the time scale. The amount of gain applied will vary along the time range and between scans.

4 Click OK and then save the file as GAINAG.DZT

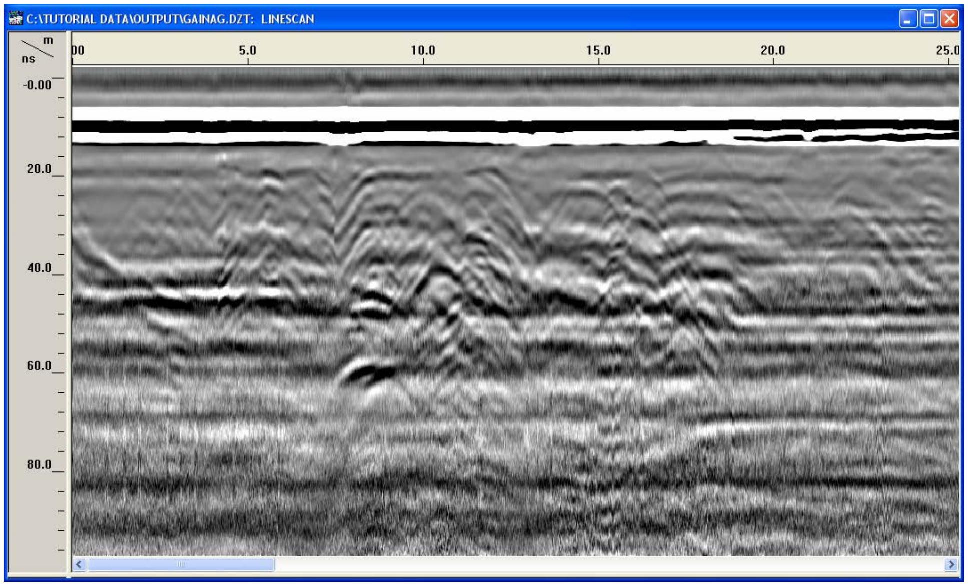


Figure 117: GAINAG.DZT. Color table = 17, Display Gain = 1.

Exponent Gain Correction

This type of range gain correction applies a constant gain curve to the data. Each scan thus has the same amount of gain applied. This is appropriate for situations where you need to preserve the relative reflection amplitudes along the profile. The amount of gain applied changes as an exponential function between points.

This section will use the file GAIN.DZT.

1 Select Process > Range Gain.

2 Change the Gain Type to Exponent.

3 Set the number of points to 7. The idea here is to set the number of points so that there is a gain point located in the center of the time range portion that is under-gained.

4 Drag each point up or down. You will notice that the red trace will get larger or smaller along the vertical scale. You can also select different scans to model the output. A proper curve will should amplitude peaks of approximately the same height.

Note: If you collected the data with no gain or have performed a gain restoration prior to range gain corrections, the slope of the gain curve must either be zero or positive between points.

5 Click OK and then save the file as GAINEG.DZT.

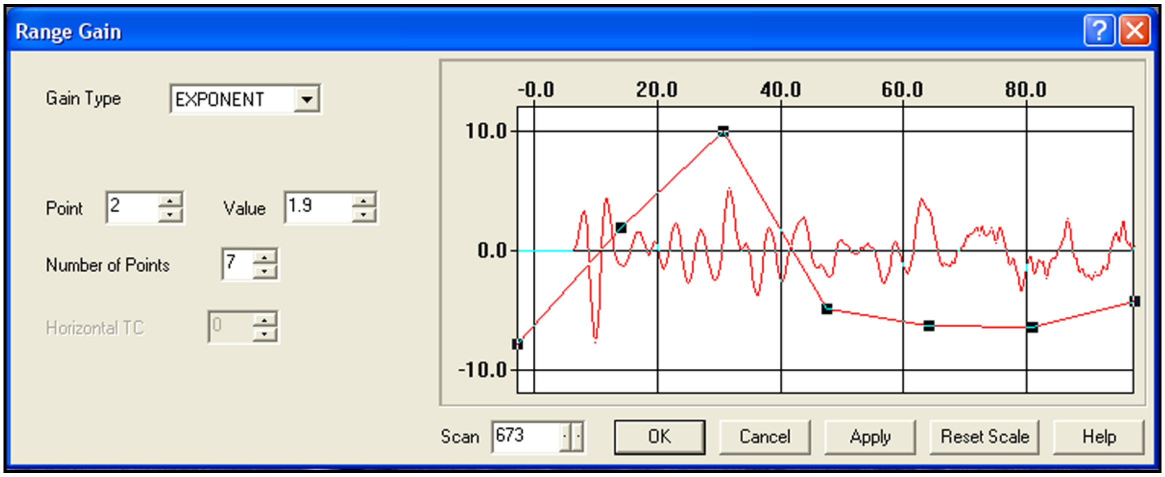


Figure 118: Exponent range gain correction window with adjustments made.

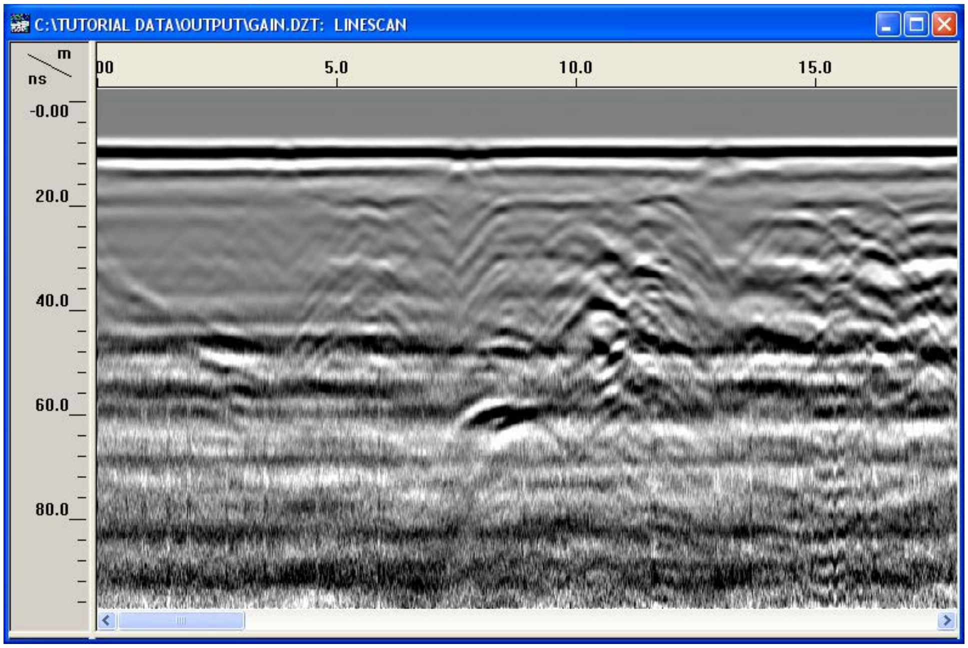


Figure 119: GAINEG.DZT. Color table = 17, Display gain = 4.

Chapter 6: Processing Large Amounts of Data

Note: The features in this chapter are only available with the RADAN modules. They are not available if you have the Main module only.

Introduction

Large data sets may be processed in either the Macro Programming or Project Modes. The Project Processing capability requires an optional module. If a project file is open, but all of the menu items in the Project menu remain inactive (menu entries are gray), you do not have this module. Please contact GSSI or its sales representative for more information.

The Macro Programming Mode is a semi-automated mode that allows the user to create a macro program that will execute specified processing steps upon the designated active file. The Project Mode allows the user to automatically process data sets (i.e., numerous files) assigned to a project using a macro program. Large and numerous data files may be assigned to a project, all of which will be processed using the processing steps outlined in the specified macro program. This chapter explains how to set up and run macro programs and execute projects.

Macro Programming

Macro Programs are used only on a file by file basis. They only operate on ONE file at a time. Macro Programs are designed to use only the processing functions that appear on the processing toolbar. It is possible to associate a different macro with each open file simply by creating or loading a macro while a specific file is active. It is necessary to have at least one file active in order to create a macro.

Creating a Macro Program

1. Choose Process > Macro Process or use the Macro toolbar. You will have a choice between creating a new macro or loading an old one.
2. Select Create from the Macro Process menu.
3. RADAN will ask you for a file name. Type in the name of the file you wish created. This new macro file will be saved under the *.cmf extension. Note the directory path for the file to be saved. If you have created a macro subdirectory as suggested earlier, use this directory.
4. Click OK.
   - At this point, the macro is open and waiting for input. From here on any processing function you choose from the menu or from the toolbar will be input into the Macro Program.

   Note: Processing functions will not be activated until the macro is closed or you load and run the macro. So it is normal that the display of the active file will remain unchanged while adding processes to the macro.

- For example, you may wish to choose to apply an IIR Horizontal High Pass filter, after which you would like to modify the Range Gain. To add these functions, go to the toolbar and click the IIR Filter button. A dialog box will appear, and you will have to input the required parameters for the IIR Horizontal High Pass filter. Next click the Range Gain button. The Range Gain dialog box will then appear. As above, input the appropriate parameters.

5 When you are satisfied with the functions you have selected for your Macro Program, go to the Macro Process menu in the Process menu and select Close. This will close and save the Macro Program.

Loading and Modifying an Existing Macro Program

You must Load a Macro Program before running it. It is possible to modify an existing Macro Program instead of creating a new file. Use the following procedure:

1 Go to the Macro Process menu and select Load. A dialog box will ask which Macro Program you wish to load.

2 Highlight the Macro Program (*.cmf extension) and click OK. (Or, you may double-click on the desired file.)

3 An Edit Macro Program dialog box will appear. If you do not have any modifications to make, click OK. You are now ready to run your Macro Program.

4 If you need to edit your Macro Program, you can double-click on any function already in it (such as IIR Filter) and modify its parameters as they appear in the function dialog box.

- Or, if you wish to deactivate a function without deleting it, move the mouse cursor to the check box in the Macro dialog box, and uncheck the box by clicking on it.
- This is a good way to troubleshoot macros by eliminating specific functions from the processing list. Standard editing tools also exist, in the Edit Macro menu, which allows cutting and pasting of functions into and/or out of the macro.

5 Click OK when you have completed your changes. Note that if you simply want to load a macro program, you may skip Steps 4 and 5.

If you have performed any edits, it is good practice to save the changes before running the macro. This is done by choosing Process > Macro Process > Close**.** This saves the changes and closes the macro. To run, you need to re-load the macro as indicated in steps 1-3 above. You are now ready to run the Macro Program.

Running Your Macro Program

After loading a macro, you will be able to use either the Process menu or toolbar buttons to run the macro.

- Notice that the Start Processing button on the Command bar is active. Click Start Processing and the selected macro program will run.
- If you need to Stop processing, click the Stop Processing button.
- If you wish to Pause processing, click the Pause button.

Processing Multiple Files - Running a Project

This capability requires the Project Processing module. If you cannot access the Project menu (the entries are gray) when a project file (*.rpj) has been loaded or a new one has been created, you do not have this module. Please contact GSSI or its representative for assistance.

Large data sets may be processed in RADAN's Project Mode. Projects may be only executed if all active files are closed.

Creating a New Project

1 Close all active files.

2 Choose File > New and the Create New Project dialog box (Figure 120) will appear.

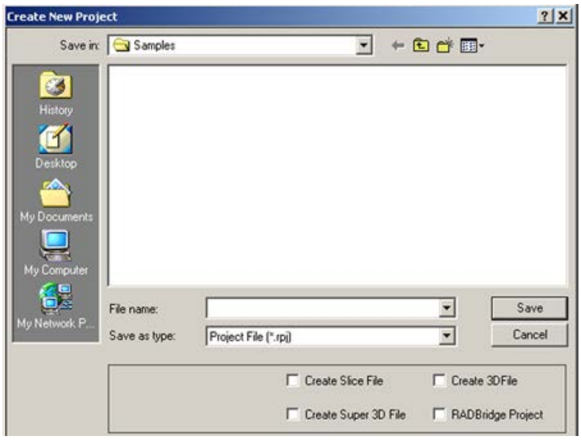


Figure 120: Create New Project dialog box.

Check the options (little boxes) applicable to your project (Create Slice File, Create 3D File, Create Super 3D File, or RadBridge Project). Type in the name of the Project file (*.rpj) you wish to create, and save it.

3 The Project Information box (Figure 121) will appear. Type in a title for the project and all the pertinent information associated with that project. You may wish to include client name, job number, location, type of antenna used, and other parameters that are important.

4 Type in or select the Output Path where you wish processed data to reside. Click OK.

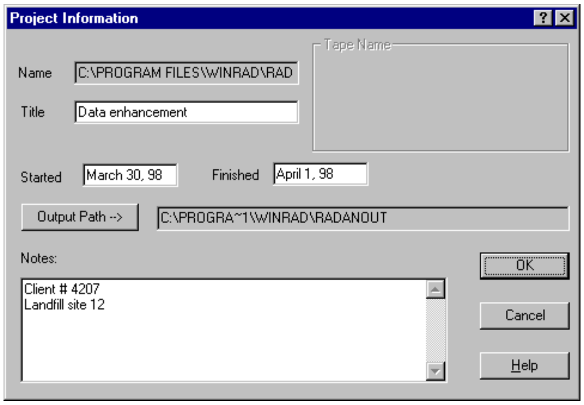


Figure 121: Project Information dialog box.

5 In the Edit Project File List dialog box that opens (Figure 122), select the files you wish to include in your project by moving the mouse cursor and clicking onto the desired file.

- Click Add to add it to the list of project files.
- You can choose from the default input directory or from any other file folder. You may choose files from different folders.
- To modify the Project File List later, this dialog box can be accessed using Edit command in the Project menu.

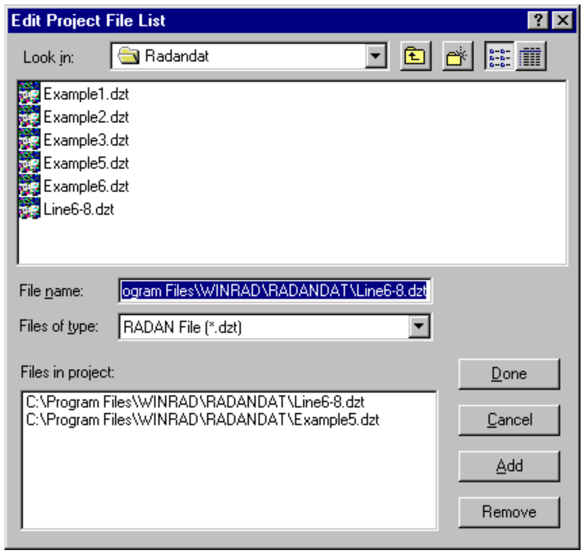


Figure 122: Edit Project File List dialog box.

6 When done selecting files for the Project, click OK.

7 The last dialog box, Edit Macro List (Figure 123), lets you select the Macro Program (or programs) needed to process your Project. You can assign macros to files individually. Click the desired macro in the macro list on top, then select the file in the file list on the bottom. Click on the Attach Macro button. Repeat this procedure until all required macros are attached.

- If you cannot see long file or macro names in the Data File / Macro File list, drag field separators on top of the selection window to the left or right to change the field width.
- After clicking Done, if no other dialog boxes pop up, you are ready to Run your Project.

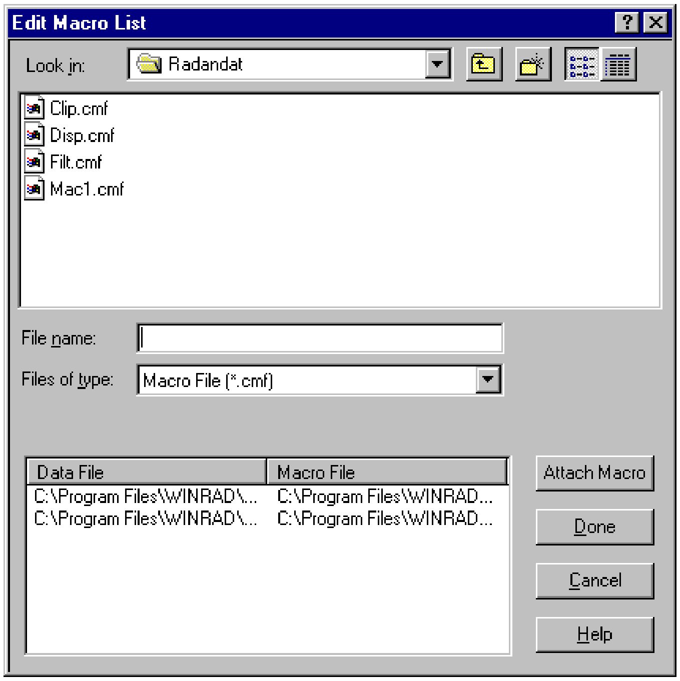


Figure 123: Edit Macro List dialog box.

Note: A macro included in the active project can be edited at any time by selecting its name in Macro submenu under Project menu. This was not possible in the earlier versions of RADAN.

Project Options

The above project creation procedure will be different if option boxes have been selected in the Create Project dialog. Some dialogs will be omitted and/or additional dialog boxes will pop up if one of the options has been selected.

Create 3D File

Use this option to generate a 3D file from multiple single profiles. See the 3D QuickDraw section of this manual for details.

RadBridge Project

If this option is selected in the Create Project dialog, the whole sequence described in Create Project above will be followed by a 3D File Parameters dialog box (Figure 124).

In the Grid Parameters tab, the user is prompted to enter a filename for the resulting 3D file, specify the number of scans per distance unit, the system configuration and the grid outline. The Files tab allows adjusting the positioning information for each file in the project.

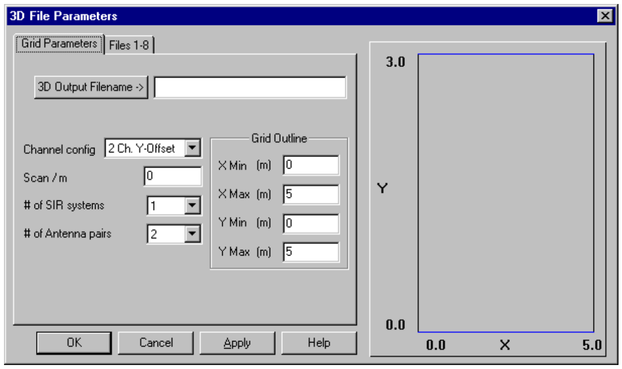


Figure 124: RadBridge Project: 3D File Grid Parameters.

Loading a Project File

1 Close all active files.

2 Choose File > Open. In the Open File box, select Project file (*.rpj) under Files of Type. Highlight the project file you wish to run and open it.

3 In the Project Information box that appears, review all the pertinent information associated with the project. Modify, if necessary, the Output Path where you wish the processed data to reside. Click OK to close the dialog box. It can be accessed again using the Info command under Project menu.

4 You can review and modify the list of files included in the project, by choosing Project > Edit. This command opens the Edit Project File List box that lets you add files to the list or delete them from it. You can choose from the default input directory or from any other directory you select. You may choose files from different directories, too. When done selecting files for the Project, click OK.

- You can also review and modify the Macro Programs used to process your Project. To do that, use the Macro submenu under Project menu. The Edit Macro List option opens the corresponding dialog box where macros can be added to the processing list. Selecting macro names below in the Macro submenu allows you to edit each macro included in the project. If you cannot see long file or macro names in the Data File / Macro File list, drag field separators on top of the selection window to the left or right to change the field width.

5 Click OK when done. You are now ready to Run your Project.

Running a Project

To Run a Project, choose Project > Run. RADAN will now begin automatically processing your data. The computer will automatically finish the Project and close it. You can select Close if you prefer to save the project file and use it later.

Note: You will not be able to interrupt a Project by the Stop Processing key. A Project must be allowed to finish its task (or closed with the **Close** command).

Appendix A: Data Input

Data Formats Supported

RADAN supports the following data formats:

- All GSSI .dzt formats
- PulseEKKO (Sensors &Software) data format
- RAMAC (MALA) data format
- SEG-Y data format

Note that RADAN does **NOT** support inputting data stored in ASCII, or other file formats. These data files will first have to be converted to the RADAN format before they can be used in the RADAN program.

Data files obtained using GSSI SIR System-10A+, SIR System-10H and SIR System 20 can often exceed several hundred megabytes in size. The maximum file size RADAN can import is limited to the available memory on the computer.

Using Data Saved With Previous RADAN Programs

Inputting data from a previously saved *.dzt file is easy. Simply:

1. Choose File > Open.
2. Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.
3. Click OK.

Your file will open up on the screen. To review the data use the Left or Right scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Using Multi-Channel Data Saved With Previous RADAN Programs

There are two methods of processing multi-channel data. The first is to keep the multi-channel file together and simply perform a processing operation to the multi-channel file. In this case, all channels will be processed with the same parameters.

For example, a 2-channel file with two different depth ranges can be processed with an IIR low pass filter at 700 MHz. Each channel will be filtered with a 700 MHz filter.

Inputting data from a previously saved *.dzt file is easy. Simply:

1. Choose File > Open.
2. Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.
3. Click OK.

The second method is to split the multi-channel file into separate files, one file for each channel process each file separately. This second method is preferable in cases where different antenna types are used on the different channels.

To split files:

1. Repeat Steps 1 through 4 above to input the multi-channel file.
2. Choose File > Save As function. A dialog box will appear and you will notice at the bottom right a small box that says Split Channels.
3. Check the Split Channels function by moving the mouse cursor to the box and clicking on it.

From here, the file splitting procedure is then automatic. RADAN will split your file into sections and designate each section by a letter sequentially coded to the channel number. For instance, a four channel file called Test.dzt may be split into four separate files called Testa.dzt, Testb.dzt, Testc.dzt, and Testd.dzt.

Importing Data From A GSSI SIR-2 System

There are two methods to transfer data from a SIR-2 system to the computer for processing with RADAN 1) data transfer via parallel port and 2) via Iomega ZIP drive.

Data Transfer Via Parallel Port

1. Load the SIRLINK software program on the computer running RADAN.
2. Connect the parallel data transfer cable from the SIR System to the computer.
3. After the data has been transferred you can open the files with RADAN.
4. Open the files with RADAN:
5. Choose File > Open.
6. Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.
7. Click OK.
8. Your file will open up on the screen. To review the data use the Left or Right scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Data transfer via ZIP Drive

1. Attach an Iomega ZIP drive to the parallel port of your SIR-2 system and transfer your data files to the ZIP drive. See your SIR system manual for details on this procedure.
2. Install the ZIP drive on the computer running RADAN. Refer to the ZIP drive instructions for details.
3. Copy files from the ZIP drive to the computer hard drive using Windows Explorer.

4 Open the files with RADAN:

5 Choose File > Open.

6 Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.

7 Click OK.

8 Your file will open up on the screen. To review the data use the Left or Right scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Importing Data from A GSSI SIR-10B System

1 Attach an Iomega JAZ drive to the SCSI port of your SIR-10B system and transfer your data files to the JAZ drive. See your SIR-10B manual for details on this procedure.

2 Install the JAZ drive on the computer running RADAN. Refer to the JAZ drive instructions for details.

3 Copy files from the JAZ drive to the computer hard drive using Windows Explorer.

4 Open the files with RADAN:

5 Choose File > Open.

6 Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.

7 Click OK.

8 Your file will open up on the screen. To review the data use the Left or Right scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Importing Data from A GSSI SIR-10H System

1 Attach an Iomega JAZ drive to the SCSI port of your SIR-10H system and transfer your data files to the JAZ drive. See your SIR-10H manual for details on this procedure.

2 Install the JAZ drive on the computer running RADAN. Refer to the JAZ drive instructions for details.

3 Copy files from the JAZ drive to the computer hard drive using Windows Explorer.

4 Open the files with Radar:

5 Choose File > Open.

6 Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.

7 Click OK.

8 Your file will open up on the screen. To review the data use the Left [←] or Right [→] scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Importing Data from A GSSI SIR-10, SIR 10A, or SIR 10A+ System

There is one method to transfer data from a GSSI SIR-10, SIR-10A or SIR-10A+ system to the computer for processing with RADAN: data transfer via parallel port

Data transfer via parallel port

1 See section for SIR-2 data transfer.

2 Load the SIRLINK software program on the computer running RADAN.

3 Connect the parallel data transfer cable from the SIR System to the computer.

After the data has been transferred you can open the files with RADAN

1 Open the files with RADAN:

2 Choose File > Open.

3 Either select the file you wish to input from the default source folder (see above to change the default folder), or use the mouse to click onto the folder in which your file is stored.

4 Click OK.

5 Your file will open up on the screen. To review the data use the Left [←] or Right [→] scroll arrows. You may wish to practice opening a file before processing your data. If so, try opening one of the example radar data files found in the RADANDAT folder.

Using Data from Other Ground Penetrating Radar Systems

Two other commercial GPR formats are supported by RADAN:

- PulseEKKO format used by Sensors & Software. Each recording comprises two files, the header and the data file. Both use the same filename with extensions *.hd (header) and *.dt1 (data file).
- RAMAC format used by MALA Geoscience.

To open these files, follow the procedure described above (Using GSSI files from previous versions of RADAN), but select the appropriate file type from the File of type list.

Appendix B: Dielectric Constants

The relative dielectric permittivity is a dimensionless measure of the capacity of a material to store a charge when an electric field is applied. The dielectric constant is the real part of dielectric permittivity, as it is normalized to air. Dielectric constant values vary from material to material. In dry materials the dry bulk density primarily influences the dielectric constant. In partially saturated or saturated soils the dielectric constant is primarily determined by the water content. Radar energy is reflected at boundaries of electrically dissimilar materials where there is a contrast in the dielectric constants (i.e., where there is electrical impedance). These boundaries typically occur at stratigraphic boundaries, but may occur at the water table and within stratigraphic units where changes in electrical properties occur.

The chosen value of the dielectric constant defines the relationship between time and depth (i.e., it is directly related to velocity) for the file. In resistive soils, those with conductivities less than 20 millimhos per meter, the average soil velocity may be approximated by:

$$Vm = \frac{C}{\sqrt{E_r}}$$

where: Vm is the average soil velocity (m/s)

C is the speed of light or 2.998×10^{8} m/s

E_r is the dielectric constant or real dielectric permittivity normalized to air (dimensionless).

Note that this equation is not valid in conductive soils (such as clays) or soils with conductive pore fluids (such as brackish and conductive groundwater).

Note: When you input a dielectric constant value in the header, RADAN makes the assumption that this value is valid throughout the entire file, which may not be representative.

The dielectric constant may be changed to evaluate the effect of different velocity assumptions of the location of features.

The dielectric constant may be determined from:

1. On-site calibrations over targets of known depth.
2. Common depth point or midpoint (CDP or CMP) calibrations using bistatic antennas over a reflector of known depth (such as the water table) or,
3. Estimated velocities or dielectric constants observed at similar sites.

A table of values of dielectric constants (at 100 MHz) for common materials follows:

Air	1
Glacial ice	3.6
PVC	3
Asphalt	3 - 5
Concrete	4 - 11 (5)
Granite	4 - 7
Sandstone	6
Shale	5 - 15
Limestone	4 - 8
Basalt	8 - 9
Water saturated sands (20% porosity)	19 - 24
Soils & sediments	4 - 30
Water	81

Table 3: Dielectric Constants of Some Common Materials

Appendix C: Glossary of Terms

Antenna: A component of an impulse radar system designed to radiate radio waves (electromagnetic radiation) from Applied voltage impulses (transmitting antenna), or conversely, to intercept radio waves and convert them back into electrical impulses (receiving antenna). Antennas radiate or receive electromagnetic energy.

Antenna Radiation Pattern: A plot of the intensity of the radiation received at a given radial distance from an antenna versus angle, relative to a given reference axis. The pattern is a three dimensional measure of the energy at a fixed radial distance from the antenna.

Attenuation: A measure of the loss of radiated signal amplitude or signal energy as it progresses through a lossy medium. The loss can be due to a spreading loss as the wave expands out into the medium and also due to an ohmic loss, due to the finite conductivity of the medium.

Background Removal: A digital signal processing function that filters by subtracting an average of a large number of scans from each individual scan. The result is horizontal changes in the data are accentuated while linear features (background) are suppressed.

Backscatter: A portion of a radar's transmitted energy that is intercepted by a target, or other object and reflected (scattered) back in the radar's direction.

Bandwidth: The band of frequencies occupied by the central lobe of the spectrum of an electromagnetic signal. Bandwidth is usually defined so that it includes most, but not all of the signal power. Generally, it includes the portion lying between the points at which the power has dropped to half that at the center of the band.

Beamwidth: The angular width of a slice through the main lobe of the radiation pattern of an antenna.

Bias: The amount by which the average of a set of values departs from a reference value.

Bistatic: The survey method that utilizes two separate antennas at a constant distance. One antenna has a transmitter and the other contains a receiver sampler. With this method it is possible to transmit a higher power signal and receive reflections with a greater time delay.

Common Depth Point (CDP): Also known as Common Midpoint (CMP). Having the same midpoint between source and detector.

Common Depth Point Method: A survey method that can be performed to calculate the electromagnetic velocity of a material. This is conducted by transmitting from one antenna and receiving from a second antenna at several known offsets (surface horizontal distance).

Clutter: Unwanted reflections from the ground, from within the ground or from above the ground. In the case of ground penetrating radar (GPR), clutter may be produced by boulders, soil interfaces and other scatterers that are not of interest. Clutter is also produced within the radar system.

Conductivity: The electrical conductivity of a dielectric material is a measure of the ease with which an electrical current can be made to flow through it. In the MDS system, the unit of conductivity is the Siemens per meter (S/m). Conductivity is the reciprocal of resistivity. The higher the conductivity of the subsurface materials, the greater the attenuation of the radar signal.

Control Unit (C/U): An electronic instrument that interfaces a transducer (s) to recorders, processors, displays, survey wheel, power supply, etc. It also has controls to allow radar functions such as range, gain and filtering to be adjusted. A C/U can be analog, digital, or hybrid.

Data Channel: A software channel on the control unit that displays and records a received signal. It is possible to have one transducer and four data channels with the same or varied processes.

Decibel (db): A unit of measure for gain. A logarithmic unit used to express power ratios. One decibel equals 20 LOG (P_2/P_1). Decibels are also used to express voltage ratios.

Deconvolution: A digital signal processing function designed to attenuate multiples and improve the recognition and resolution of reflected events. A process that restores a waveshape to the form it had before it underwent a linear filtering action (convolution).

Delay Time: The amount of time the radar wave propagates through a material, reflects off an interface and returns to the receiver. Time lag introduced by either hardware (cable length, etc.) or software (filter averaging, etc.).

Depth of Penetration: In any medium, the radar wave is attenuated as it progresses due to losses that occur. At radar frequencies in a conductive material (sea water, metallic materials, clay soils, etc.) the rate of attenuation is very great and the wave may penetrate only a short distance (<1m) before being reduced to a negligibly small value. In a resistive dielectric earth material (fresh water, granite, quartz sand, etc.), where the losses are low, the depth of penetration can be quite great (>30m).

Dielectric Constant: See Dielectric Permittivity.

Dielectric Permittivity: Dielectric Permittivity is a property of an electrical insulating material (a dielectric) equal to the ratio of the capacitance of a capacitor filled with the given material to the capacitance of the identical capacitor filled with air. Earth materials are classified generally as conductors, semiconductors and insulators (dielectrics). A dielectric material is a poor conductor of electric current. The specific capacitance of a vacuum is Eo = 8.85 x 10^{-12} Farads per meter. The relative dielectric constant, E_r for air is 1 and is approximately 81 for fresh water.

Dielectric Interface: A place in the subsurface of a dielectric material where the dielectric permittivity changes.

Diffraction: The phenomenon that causes electromagnetic waves in the beam of a directional antenna to spread out. The bending of wave energy around obstacles without obeying Snell's Law. An event that occurs at the termination of curved topped, or steeply dipping reflectors that is characterized by a distinctive curved alignment.

Diffuse: To break up and distribute the energy in an incident electromagnetic wave in many directions.

Dipole: A simple antenna having two elements driven from the center of the antenna by a balanced source.

Directivity: Ability of an antenna to concentrate transmitted energy in a given direction and to emphasize the returned energy received from that direction.

Dynamic Range: The spread between the minimum signal at the input of a system, which produces a discernible change in the output and the maximum input that the system can handle without saturating. Measured in decibels (db).

Echoes: Radar energy reflected from a given target or object.

Electromagnetic Wave: A wave that is propagated by the mutual interaction of electric and magnetic fields. Radiant heat, light and radio waves, are electromagnetic waves.

Finite Impulse Response (FIR) Filter: A digital signal processing function that convolves a finite length function (boxcar, triangle) with the data. Each data value is multiplied by the corresponding filter value and added together. FIR filters are digital filters and have no time delay.

Frequency: The number of positive and negative voltage amplitude cycles that a pure unmodulated sine wave completes per second. The unit of frequency is Hertz (Hz).

Frequency Domain: Mathematical realm in which the amplitudes of signals are expressed as functions of frequency, rather than time. The frequency spectrum of a time varying signal is obtained by translating the expression for the signal from the time domain to the frequency domain.

Frequency Domain (FK) Filter: Also called a velocity filter. A digital signal processing function that discriminates on the basis of apparent velocity. Coherent arrivals with certain apparent velocities are attenuated.

Fresnel Zone: The portion of a reflector from which reflected energy can reach a detector within one-half wavelength of the first reflected energy.

Gain: A change in signal amplitude or power from one point in a circuit or system to another, often from system input to output. See Range Gain.

Gigahertz: A unit of frequency. One GHz equals 10^9 Hz.

GPR: Acronym for Ground Penetration Radar.

GPS: Acronym for Global Positioning System.

Hertz (Hz): A unit of frequency. One Hertz equals one cycle per second.

High Pass Filter: A filter that passes without significant attenuation frequencies above some cutoff frequency while attenuating lower frequencies. The same as low-cut filter.

Hilbert Transform: A digital signal processing function that determines the magnitude envelope, instantaneous phase and instantaneous frequency of a received signal.

Horizontal Filter: A digital signal processing function that attenuates signals outside the filter function across adjacent scans.

Infinite Impulse Response (IIR) Filter: A digital signal processing function that emulates an analog filter function. An IIR filter is a filter function that offsets the data in time.

Interface: The common surface separating two different media in contact. A location in the subsurface where the dielectric constant changes.

Isotropic Radiator: An antenna that radiates equally (both in amplitude and in phase) in all directions. The imaginary source of the radiation used as a reference for the gain of a directional antenna.

Lateral Resolution: The ability of the system to resolve in a horizontal direction the smallest discernible target. This is a function of antenna frequency, scan rate and speed of travel.

Low Pass Filter: A filter that passes frequencies below some cutoff frequency while substantially attenuating higher frequencies. Same as a high-cut filter.

Magnetic Permeability: The magnetic permeability of a material is a measure of the difficulty of magnetization of the material in an external field. The magnetic permeability of earth materials is taken to be that of free space, = 4 x 10^{-7} Henrys per meter. Therefore, the relative permeability of earth materials is $U_r = 1$.

Megahertz: A unit of frequency. One MHz equals 10^6 Hertz.

Migration: A digital signal processing function that rearranges data so that reflections and diffractions are plotted at the locations of the reflectors and diffracting points rather than with respect to observation points on the profile. Migration by computer is accomplished by integration along diffraction curves (Kirchhoff migration), by numerical finite-difference downward-continuation of the wave equation and other algorithms.

Monostatic: A survey method that utilizes a single transducer with either a single antenna with transceiver or a dual antenna transducer with separate electronics.

Multiple: Also known as ringing. Wave energy that has been reflected more than once. In radar data multiples may occur when there is a large change in the dielectric permittivity or conductivity of the medium. A multiple can be identified by signals that have the same time delay as between the surface and the first reflector.

Nanosecond: A unit of time. One nanosecond equals 10^{-9} seconds; one billionth of a second.

Noise: Unwanted, usually random, electrical or electromagnetic energy that interferes with the detection of wanted signals. The term is also applied to any unwanted random variations in the measured value of any quantity.

PC: Acronym for Personal Computer.

Permittivity: See Dielectric Permittivity.

Phase: Degree of coincidence in time between a repetitive signal, such as a sine wave and a reference signal, having the same frequency. The angle of lag or lead of a sine wave with respect to a reference. Generally expressed in degrees. 360 degrees corresponds to the period of the signal.

Point Reflector: A subsurface feature with electromagnetic properties different from its surroundings, whose dimensions are approximately the same as the fresnel zone of the radar wave.

Polarization: The orientation of the electric and magnetic fields of an electromagnetic wave, such as a radio wave. By convention, the polarization of the wave is the direction of the electric field. If the polarization does not change as the wave propagates, the polarization is said to be linear.

Power: A measure of the quantity of electric energy, commonly expressed in Watts. One watt equals one Joule per second.

Profile: A graph showing the depth measurements as a vertical cross section of the medium along a horizontal line.

PRF (Pulse Repetition Frequency): The number of pulses per second transmitted by a pulsed radar.

Propagation: The outward spreading, or travel, of an electromagnetic wave, such as a radio wave.

Radar: RAdio Detection And Ranging. An electronic system that transmits electromagnetic energy and detects the location of reflected energy.

Radar Cross Section: A factor relating the power of the radio waves that a radar target scatters back in the direction of the radar, to the power density of the radar's transmitted waves at the target's range. Takes account of the cross sectional area of the target, as viewed by the radar, the target's reflectively and its directivity.

Radiation: Energy in the form of an electromagnetic wave emitted by an antenna, in which free electrons are accelerated. Radiant heat, light and radio waves are electromagnetic radiation. They differ only in wavelengths.

Range: The radial distance from a radar to a target or other object. A user adjustable setting on a control unit to determine the amount of time displayed and recorded (0 - thousands of nanoseconds).

Range Gain: Also known as time gain control or time varying gain. Control for varying the amplification or attenuation of an amplifier, used to compensate for variations in input signal strength over time.

Receiver: The portion of the antenna used, to intercept the radio waves reflected from the subsurface and convert them back into electrical impulses (receiving antenna)**.**

Reflection: The degree to which an object returns incident radio waves.

Reflection Coefficient: A description of the reflected field strength from an infinite interface between two media 1 and 2. The reflection coefficient r is defined by:

$$r = Z_2 - Z_1 / Z_2 + Z_1$$

where Z is the impedance of the respective media.

Refraction: The bending of an electromagnetic wave that occurs when the wave passes obliquely from one medium into another whose dielectric constant is different from that of the first medium. The bending results from the speed of the propagation being different in one medium than in the other. Refraction may also occur in a single medium whose dielectric constant gradually changes in a direction normal to the wave's direction of propagation.

Resistivity: The reciprocal of the electrical conductivity is the electrical resistivity. The electrical resistivity of a substance is a measure of the difficulty an electrical current can have flowing through it. In the MKS system the unit of resistivity is the ohm-meter (Ω -m). The symbol is Ω

Resolution: The ability to separate two features that are very close together. The minimum separation of two bodies before their individual identities are impossible to interpret. The smallest change in input that will produce a detectable change in output.

Sampler: A circuit whose output is a series of discrete values representative of the values of the input at a series of points in time.

Scan: One discrete sequence of events such as a sampling at all time points of the amplitudes at a receiver.

Scatter: The irregular and diffuse dispersion of energy caused by imhomogeneities in the medium through which the energy is traveling.

Signal Position: The relative delay between the time when the Radar system sends out a transmit pulse and when the Radar systems sends out a receiver pulse.

Signal-to-Noise Ratio: Ratio of the power or energy of a received signal to the power or energy of the accompanying noise.

SIR: Acronym for Subsurface Interface Radar.

Spectrum: The distribution of the power or energy of a signal over the range of possible frequencies is commonly represented by a plot of amplitude versus frequency. If the amplitude is a voltage, a plot of the square of the amplitude is the power spectrum. The area under the power spectrum corresponds to the signal's energy.

Specular Reflection: Mirror-like reflection occurring when an electromagnetic wave strikes a flat surface, the irregularities (roughness) in which are small compared to the wavelength of the incident wave.

Running Average: A digital signal processing function that averages a finite number of scans with a user designated function to produce a single output scan. This method can be operated in continuous or static modes.

Static Correction: Corrections applied to data to compensate for the effects of variations in elevation, weathering thickness, weathering velocity, or reference to a datum.

Time Domain: Mathematical realm in which the amplitudes of electromagnetic signals are expressed as functions of time.

Time Varying Gain: See Range Gain.

Top Surface Normalization: Correction of data for the effects of surface elevation changes by time (depth) shifting the data. The result is to present the data as if all measurements had been made on a flat plane.

Transducer: An antenna or antennae with built-in or plug-in transmitter and receiver electronics.

Transducer Input Connector: The connector on the control unit that connects the cable from the transducer/antenna.

Trans-illumination: This a method of surveying where a transmitting antenna transmits one way through a material to a receiving antenna. Example; crosshole investigations.

Transect: The line along the surface that a profile is acquired.

Transmit Pulse: The impulse of radar energy from the transmitting antenna as seen at the receiving antenna. This is shown on the recorded data at the top of the display. When the transducer is moved on the ground surface the first arrival of the transmit pulse is interpreted as the surface.

Transmitter: The electronics, which after receiving a trigger pulse from the control unit, sends an impulse of electromagnetic energy to the attached antenna.

Travel Time: The amount of time (nanoseconds) that the radar signal takes to travel from the transmitting antenna to a target or receiving antenna. This is used for transillumination methods (also called Transit Time).

Trigger Pulse: Pulse generated in the control unit that is sent through the cable to the transmitting antenna.

Two-way Travel Time: The amount of time (nanoseconds) that the radar signal takes to travel from the transmitting antenna, reflect off a target and return to the receiving antenna. This is used for most standard GPR field methods.

Velocity: The speed at which electromagnetic signals propagate. In air or free space, electromagnetic energy propagates at the speed of light. In dielectric materials, the velocity of propagation is slower by the square root of the dielectric constant.

Vertical Filter: A digital signal processing function that attenuates signals outside of the filter function for each individual scan

Vertical Resolution: The ability to separate two feature within one scan that are very close together. The minimum separation of two bodies before their individual identities are lost on the resultant map or cross-section. A function of transducer frequency, sampling interval and range.

Some of the above definitions are from the following sources:

Encyclopedic Dictionary of Exploration Geophysics, Third Edition, R.E. Sheriff, Society of Explorations Geophysicists, Tulsa, OK, 1991.

IEEE Standard Dictionary of Electrical and Electronics Terms, John Wiley and Sons, Inc., New York, NY, 1972.

Van Nostrand's Scientific Encyclopedia, Fifth Edition, D.C. Considine, Van Nostrand Reinhold Company, New York, NY, 1976

List of References and Suggestions for Further Reading

Davis, J.L., Annan, A.P.

1989 Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophysical Prospecting 37, 531–551.

Hatton, L., Worthington, M.H., and Makin, J.

1986 Seismic Data Processing Theory and Practice, Blackwell Scientific Publications, Boston, MA., 177p.

Jackson, J.D.

1975 *Classical Electrodynamics. Wiley & Sons.*

Jordan, E.C., Balmain, K.G.

1968 *Electromagnetic Waves and Radiating Systems.* Prentice-Hall, NJ, pp. 139–144.

Oppenheim, Willsky and Young

1983 *Signal and Systems*. Prentice Hall.

Roberts, R.L., Daniels, J.J.

1996 Analysis of GPR Polarization Phenomena. JEEG 1 2 , 139–157.

Sheriff, R.E., and Geldart, L.P.

1985 Exploration Seismology Volume 1 - History, Theory, and Data Acquisition, Cambridge University Press, New York, 253 p.

Sheriff, R.E., and Geldart, L.P.

1985 Exploration Seismology Volume 2 - Data-Processing and Interpretation, Cambridge University Press, New York, 221 p.

Telford, W.M., Geldart, L.P., Sheriff, R.E.

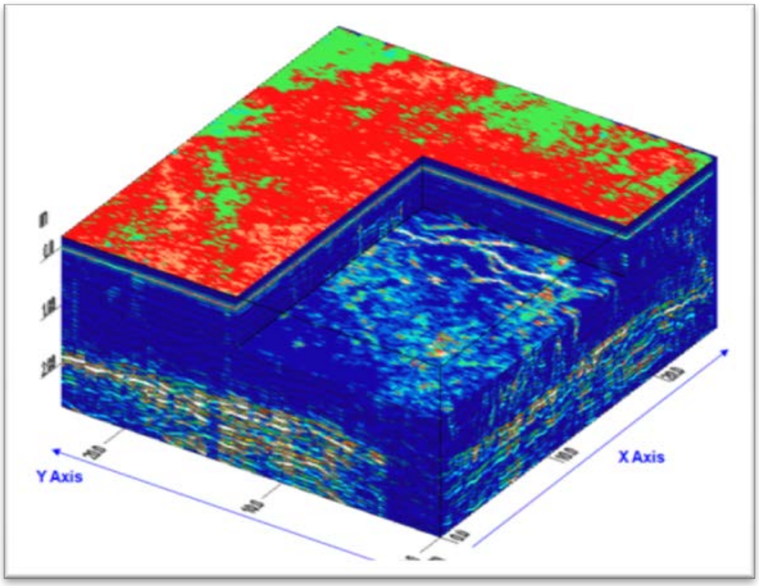
1990 *Applied Geophysics*. Cambridge Univ. Press, MA, p. 291.

Wait, J.R.

1982 *Geo-Electromagnetism.* Academic Press, New York.

Yilmaz, Oz

2001 *Seismic Data Analysis: Processing, Inversion, and Interpretation or Seismic Data.* Investigations in Geophysics No. 10, Society of Exploration Geophysicists, Tulsa, OK.



RADAN

3D QuickDraw Module

Geophysical Survey Systems, Inc.
www.geophysical.com

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Table Of Contents

Chapter 7: Introduction

The 3D QuickDraw module for RADAN has been designed to create and analyze three-dimensional (3D) displays of GPR data. It overcomes the obvious limitations of the common form of GPR data display, which is a two-dimensional vertical cross-section.

Analysis of several such cross-sections (survey lines) covering a surface area usually involves viewing them individually and then manually plotting the results. Three-dimensional display has the advantage of looking at the entire survey site at once. It allows the creation of plan views (maps) at different depths as well as perspective views (Figure 125). Subtle features that are easily missed or misidentified in single profiles can be readily detected in 3D.

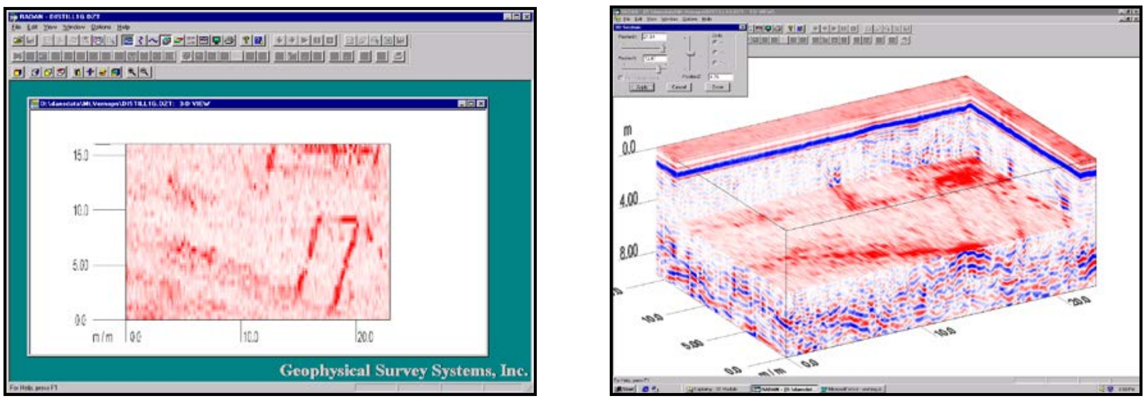


Figure 125: Examples of 3D display.

Three dimensional displays have important advantages for applications that require linear feature recognition. Identifying pipes, cables or structural elements in soil or concrete becomes an easier task when they appear as continuous lines in a 3D display. This is especially important in areas with multiple intersecting, dipping or layered targets (pipes, rebar, etc.) that may be hard to identify in single radar profiles. Using a 3D display in this type of complex area makes detection and classification of multiple targets much easier.

3D QuickDraw provides tools designed specifically for optimizing the display of linear features (Migration), displaying them in a plan view (3D slice) and automatically recognizing them in a dataset (Auto Target).

Structure of a 3D Dataset

A 3D dataset in RADAN is a stack of parallel survey lines (radar profiles) in an XYZ coordinate system shown in Figure 126.

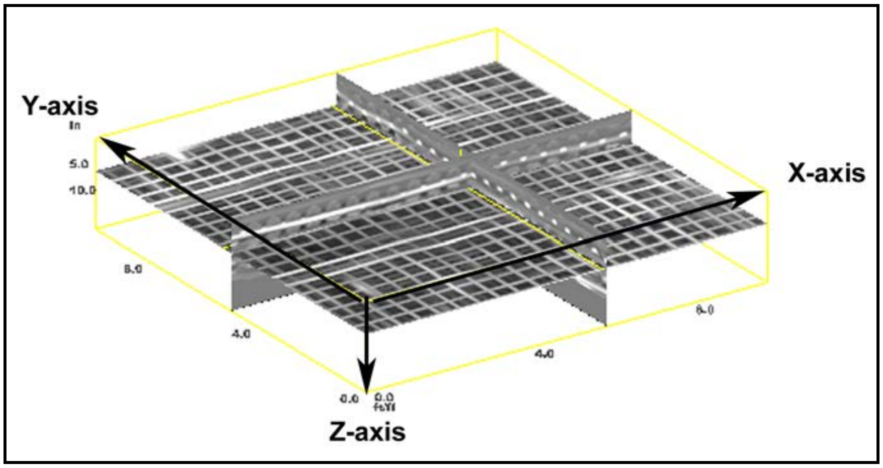


Figure 126: Structure of a 3D dataset.

Two of the profiles are shown in Figure 126. The rest of them can be seen as curtains parallel to each other and filling the entire cube.

When a 3D display is generated, the computer examines each profile and fills in the gap between it and its neighbor with generated data. This is called *interpolation*, and it produces a solid cube of data that can be 'sliced' at a particular depth. The quality and detail of a 3D set increases as the number of profiles increases – as a rule of thumb, 20 survey lines are necessary for a good 3D display. The more data you have, the better the picture.

3D File Format

In RADAN, 3D files appear on the file list along with regular (profiles) radar files. They have the same *.DZT extension and there is nothing in their names that indicates that they are 3D files. It is therefore recommended to name the 3D files in a way that would distinguish them from regular files. For example, instead of Area1.dzt, call it Area1_3D.dzt.

Note: Every DZT file is accompanied by a *.MDB file having the same name as the DZT data file. The *.DZT and *.MDB files must be kept in the same folder. The *.MDB file tells the computer that it is a positioning information which is important for the 3D display.

A 3D file sticks together each individual profile (survey line) in the order of increasing Y-coordinate to create one what looks like one long file. You can scroll manually through the file using either the Windows tools or arrows on the RADAN toolbar. Clicking on the slider bar on the bottom enables scrolling through the data like frames in a movie. Whenever the mouse cursor is placed within the active 3D data window, the boxes in the lower right hand corner of the RADAN window provide the X, Y, and Z (time or depth) coordinates of the cursor. You may notice that the horizontal scale (if shown) is different from the X coordinate box at the bottom: while the X box displays the true X coordinate of the scan, the horizontal scale shows the total distance from the beginning of the file. Blank spaces may appear between survey lines and at the ends of the grid if lines vary in length.

A 3D file appears in linescan display as a regular data file and can be handled in the same way. As you scroll right through the data, you'll see that the survey lines comprising the 3D dataset are all appended to each other. RADAN automatically recognizes a 3D file (because of the *.MDB file) and activates the 3D functions and toolbar buttons.

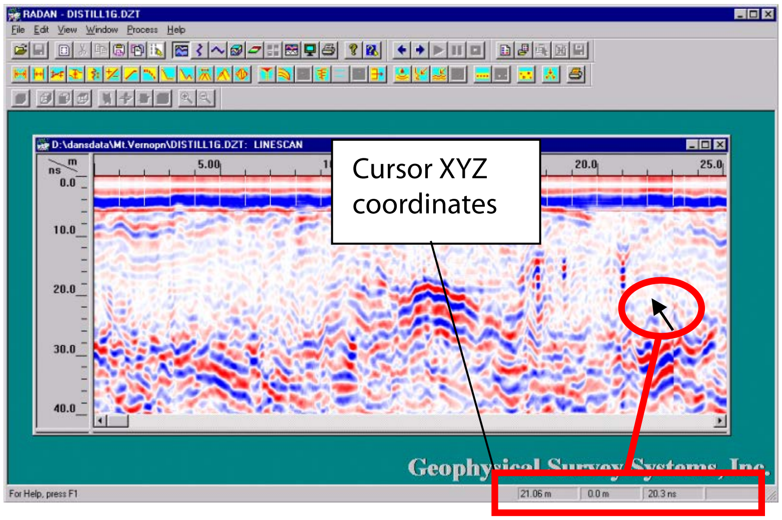


Figure 127: 3D file display.

Radar data used for 3D display may require processing. Most processing procedures that can be used on a single file are applicable to a 3D file. Use the conventional guidelines for noise removal, gain modification, etc. For more information on basic processing, see the RADAN User's Manual.

Data Sources for 3D QuickDraw

- Manually collected grids of individual parallel survey lines.
- These can be collected using any GPR system with accurate distance control. In addition to the GSSI data format, RADAN accepts the PulseEKKO (Sensors & Software) and Ramac (MALA Geoscience) data formats.
- When using a single antenna, remember that it can only provide good visibility of linear features that are parallel to the antenna dipole(s), usually positioned across the survey lines. This means that you must survey over a pipe so that your profiles are at right angles to the direction of the pipe.
- Linear features parallel to your profiles will be more difficult to see.
- Quality of these data is also subject to human error during survey. Data collected with a survey wheel is the best, but you must be careful to start and stop profiles consistently. The next Part, Collecting Data for a 3D Project, explains how to avoid many common data collection errors.
- Files collected using the GSSI Pathfinder System capable of real-time collection of geo-referenced 3D datasets with multiple polarizations. These files contain the information necessary to create a complete 3D image of the subsurface. Each scan is automatically positioned in X and Y, which assures a high dataset integrity. These files are ready for 3D display immediately after collection.
- Files collected using the GSSI UtilityScan, or the survey pad data collected with the GSSI HandyScan or the GSSI StructureScan systems.
- Files collected on the GSSI survey pad with HandyScan or StructureScan are automatically positioned in the X and Y. A 3D cube can be drawn after each file is subjected to the auto-processing.
- Files collected with GPS.

Chapter 8: Collecting Data for a 3D Project

Data Requirements

A 3D file in RADAN stacks regular survey lines that are parallel to each other that are then interpolated to create a solid cube of data. The two ways to collect 3D data are either as a single .DZT file with your SIR-system's 3D collection program, or as individual profiles that are later assembled into a 3D file by the software. If you are using the SIR-20, Pathfinder, StructureScan, or 3D data collection mode in the SIR-3000, it may be easier to enter grid parameters and collect as a single file. See your hardware documentation for instructions on how to perform a 3D survey with your particular piece of equipment. Whichever way you choose, bear in mind that certain requirements must be satisfied in order to produce a high-quality 3D display:

- The survey lines must form a regular parallel grid;
- All lines must be collected using the same system settings (range, samples/scan, scans/sec, scans/m);
- The total number of lines should be as high as possible; 20 lines are recommended for good results.

When planning a survey, think about line spacing, feature size, and desired resolution. Use the general rules that apply to GPR *scan spacing* according to the frequency and target size. The *line spacing* should make radar beams from adjacent lines overlap at the minimal depth of interest. A spacing of 2 feet (60 cm) is adequate for 3D utility mapping using a 400 MHz antenna, but a 3D rebar map based on 1600 MHz data would require a line spacing of 2 inches (5.1 cm). The more information in the original data set, the finer final images will be.

Using the survey wheel for data collection will produce the best 3D results. If the survey wheel is not an option, regular distance marks must be carefully entered during data collection. Data must then undergo Distance Normalization (See the RADAN Main Module User's Guide) before being processed in the 3D Module.

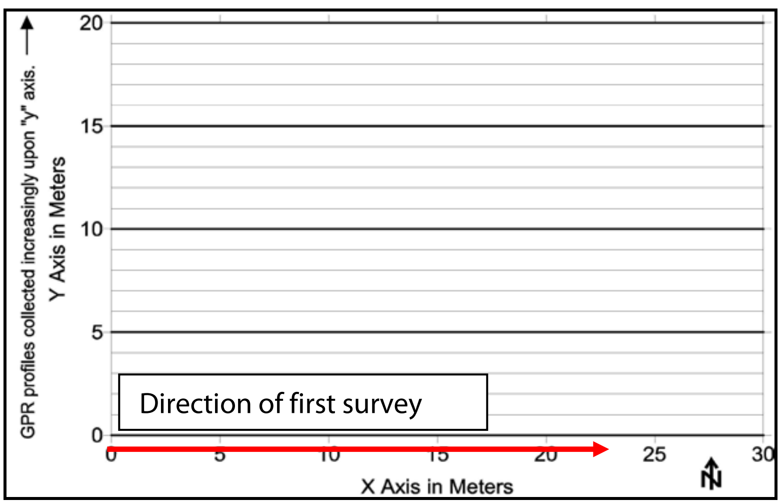


Figure 128: Survey grid setup for 3D data collection.

How to Determine Survey Parameters for a 3D GPR File

Recommended Reading available from GSSI:

Petroy, David E. 1994. *Assessment of Ground Penetrating Radar Applicability to Specific Site Investigations: Simple methods for pre-survey estimation of dielectric constants, target resolution & reflection strengths*. Presented at SAGEEP 1994, Boston, MA.

Choosing GPR Settings

Appropriate site sampling will provide the most reliable images in 3D QuickDraw. When determining how many samples/scan, scans/meter (or feet), and transect spacing take site, target and antenna frequency information into consideration.

Sampling decisions are based on the minimum dimension of target, the dielectric of the material that your target is in, antenna frequency, and target depth. For example:

Pipe Mapping:

Assuming pipes are 3 - 6 inch diameter, no more than 3-4 m deep in loamy soils, gravel/sand grade, steel, terracotta, PVC.

Optimal Survey parameters are:

- 400 MHz antenna
- 512 samples/scan
- 50 scans/meter or 24 scans/ft
- Transects at 0.5 m spacing, 2 ft.
- Normal survey direction
- Survey perpendicular to target

Structure Foundation Mapping:

Assuming foundations are of a material with contrasting E to site media, no deeper than 3-4 m, loamy soils (not clay).

Optimal Survey parameters are:

- 270 MHz or 400 MHz antenna
- 512 samples/scan
- 20 scans/meter
- Transects at 1 m spacing
- Zig-zag
- Survey perpendicular to target

Landfill Mapping:

Optimal Survey parameters are:

- 200 or 100 MHz antenna
- 512-1024 samples/scan
- 20 scans/meter
- Transects at 3 m spacing
- Zig-zag

Burial mapping:

Assuming the burials are ~ 1.5 to 2 m in length, ~2 m deep, historic period (not Native American), loamy soils (not clay).

Optimal Survey parameters are:

- 400 MHz antenna
- 512 samples/scan
- 30-50 scans/meter, 18-24 scans/ft
- Transects at 0.5 m spacing, or 2 ft.
- Uni-directional survey (or careful zig-zag)
- Survey direction perpendicular to target

Antenna Specifications:

1600 MHz (Model 5100/5100B):

- Lateral Resolution: 2 in
- Vertical Resolution: 1 in
- Vertical Scale Accuracy: ¼ in or 5% of total depth (whichever is larger)

  Accuracy depends on calibration through measured (or known) depth to a feature in the radar profile OR after 2D Constant Velocity Migration. If velocity is assumed (by guessing the dielectric of the material that the target is in) depth calculations may be off up to 20% of total depth.
- Footprint: ~ 2 in

900 MHz (Model 3101D):

- Lateral Resolution: 3 in
- Vertical Resolution: 2 in
- Vertical Scale Accuracy: 0.5 in or 5% (whichever is larger)

  Accuracy depends on calibration through measured (or known) depth to a feature in the radar profile OR after 2D Constant Velocity Migration. If velocity is assumed (by guessing the dielectric of the material that the target is in) depth calculations may be off up to 20% of total depth
- Footprint: 4 in

400 MHz (Model 5103):

- Lateral Resolution: 6 in
- Vertical Resolution: 4 in
- Vertical Scale Accuracy: 5%

  Accuracy depends on calibration through measured (or known) depth to a feature in the radar profile OR after 2D Constant Velocity Migration. If velocity is assumed (by guessing the dielectric of the material that the target is in) depth calculations may be off up to 20% of total depth
- Footprint: 2 ft

200 MHz (Model 5106):

- Lateral Resolution: 1 ft
- Vertical Resolution: 8 in
- Vertical Scale Accuracy: 5%

  Accuracy depends on calibration through measured (or known) depth to a feature in the radar profile OR after 2D Constant Velocity Migration. If velocity is assumed (by guessing the dielectric of the material that the target is in) depth calculations may be off up to 20% of total depth
- Footprint of scan beam: 3 ft

100 MHz (Model 3207AP):

- Lateral Resolution: 2.5 ft
- Vertical Resolution: 2 ft
- Vertical Scale Accuracy: 5%

  Accuracy depends on calibration through measured (or known) depth to a feature in the radar profile OR after 2D Constant Velocity Migration. If velocity is assumed (by guessing the dielectric of the material that the target is in) depth calculations may be off up to 20% of total depth
- Footprint of scan beam: 5 ft

Uni-Directional Survey: Collecting Data in One Direction Along Survey Lines

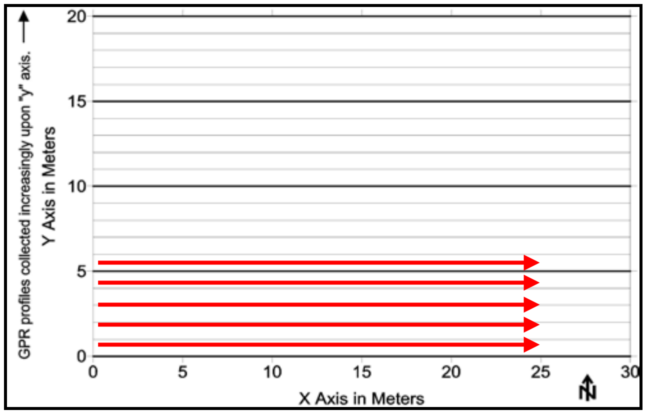


Figure 129: Uni-directional survey grid.

This is the most accurate method of collecting 3D data but it is the most labor-intensive.

When using the higher frequency antennas to map small features such as rebar, wire mesh, conduits, or some archaeological features, the best method for data collection is to begin each survey line on the same X coordinate while moving incrementally up along the Y-axis
(Figure 129).

Because of the high resolution of higher frequency antennas and the typically smaller targets they find, data collection must be correspondingly more accurate and careful.

- If using the survey wheel (optimal for 3D data), place the middle of the antenna on the X-minimum coordinate and then begin data collection.
- The length of each transect can vary as the software will end each file at the X-maximum coordinate entered in the Geometry window. If the file runs short of the X-maximum coordinate, that area will show up blank in the 2D profile and 3D cube.

Warning: If you are using a SIR-2000 or a SIR-3000 and it beeps, it means a scan is dropped because the survey wheel is moving faster than the machine is running. The dropped scan is not recorded, thus resulting in undersampled transects with incorrect distance scaling. The SIR-20 and the SIR-3000 fill in missing scans instead, thus preserving the scaling.

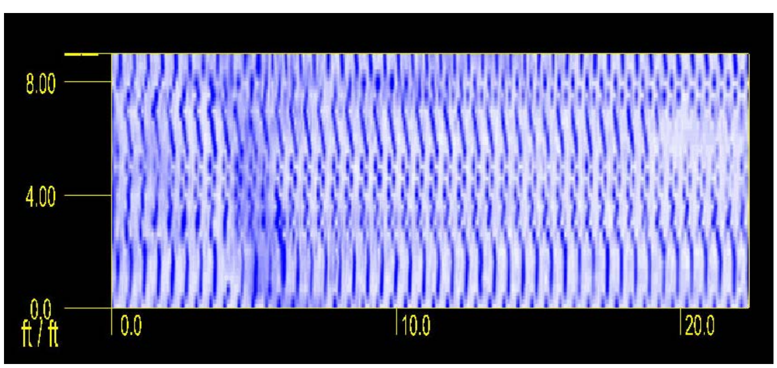


Figure 130: Uni-directional survey with varying starting points (up to 3 inch variation).

If you vary the start points of your survey lines even slightly, straight lines will appear broken.

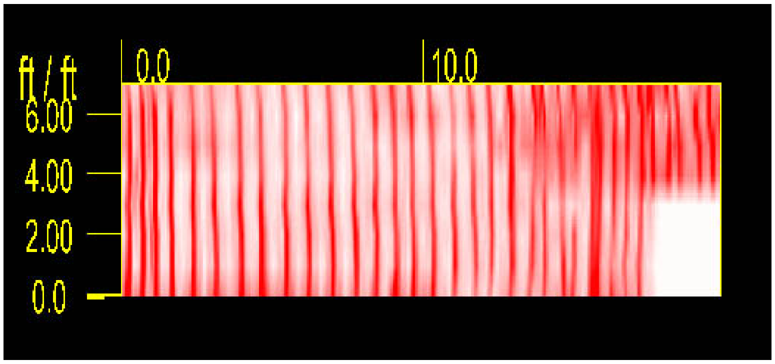


Figure 131: Carefully collected uni-directional file with all start points beginning on X = 0.

- Files can always be edited after viewing to correct for position inaccuracies during data collection.
- If an obstacle is present at the start of the survey line, make a note (in field notes) of the X coordinate where data collection begins. This can later be corrected during 3D file creation. If you are using the SIR-20, Pathfinder, or 3D mode in the SIR-3000, follow the instructions in the equipment manual to skip over the obstacle.

Zig-Zag Survey: Collecting Data In Two Directions Along Survey Lines

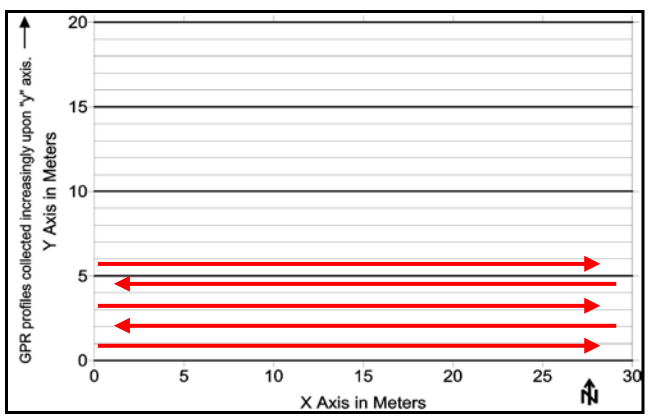


Figure 132: Zig-zag survey grid.

On larger survey areas data collection in the zig-zag mode can save time and be less tiring. With careful attention to start and end points, final images can reveal linear features almost as accurately as uni-directional survey.

- Be sure to note start coordinates of every line (whether the zig or the zag) for easy 3D Project file assembly.
- 3D QuickDraw places files according to X-minimum and X-maximum coordinates.

- When zig-zag mode is selected the software will automatically reverse every other line. The first line in the 3D project will begin on the Y-minimum and X-minimum coordinate (antenna traveling WEST to EAST, for example). The next line will be reversed beginning on the X-maximum coordinate (antenna traveling EAST to WEST).
- Careful data collection avoids editing start points for each transect during 3D file creation.
- It is important to keep in mind if the starting coordinate for each transect is not precisely measured, linear features in the ground may appear in a broken or “zipper pattern”.

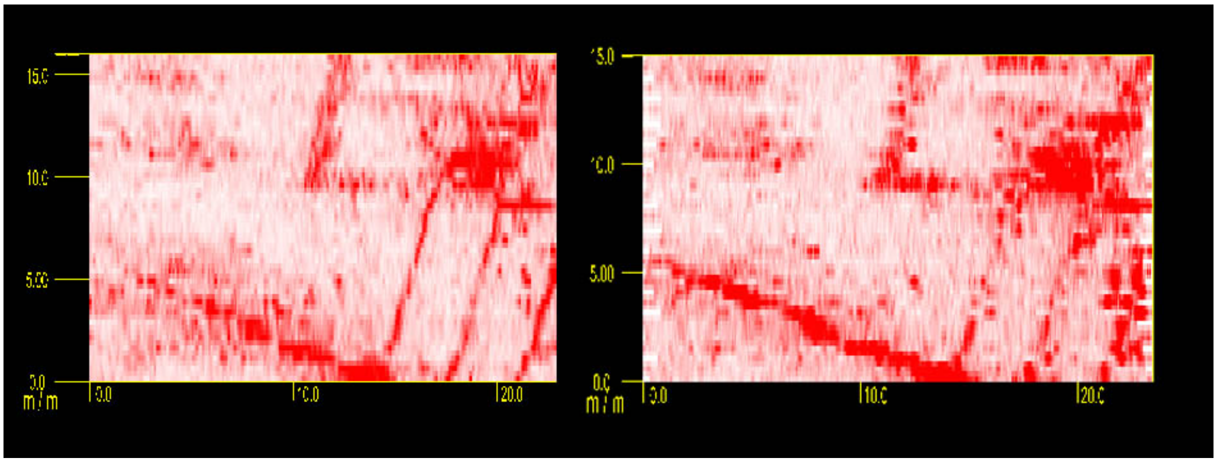


Figure 133: Examples of well-collected and poorly-collected data.

Both slices have the same parameters (thickness and depth). The slice on the left has precisely collected data beginning and ending each transect on the same coordinate. The slice on the right of the image does not have the same start and end points for each transect, resulting in not only poor linear features, but some site features may not appear at all.

Chapter 9: Compiling A 3D File

This section assumes that you are creating a 3D file from multiple single profiles. If you have collected a 3D file as a single continuous .DZT file on the SIR-20, Pathfinder, StructureScan, or SIR-3000, you should skip this section.

When the data collection procedure is complete, you will have a number of files equal to the number of survey lines. All these files now have to be compiled into a single 3D file using Project Processing.

Basic Project Setup Guidelines:

Step 1: Examine the data. Display a file (or several files) from the dataset to assess data quality and determine what processing is needed before the 3D display.

Step 2: Create New 3D Project File. This file (extension *.m3d) will store information on how to assemble a 3D file from the available single GPR files.

Step 3: Enter grid dimensions, file order, and collection method.

Step 4: Enter Data.

Step 1: Examine the Data

Looking at all files in the dataset may be too time consuming and unnecessary. Open as many files as you need to evaluate the integrity of the dataset and to determine what processing is needed. Try the processing on one or several files to see the results and to define the exact processing parameters. Most processing operations can be performed (and are best performed) after completion of the 3D file.

Step 2: Create New 3D Project File

The project file controls the way individual files are processed and (in the case of a 3D project) assembled into a 3D file. Think of it as the box that holds all of the information that the computer needs to create your 3D file.

- To create a new 3D Project choose File > New.
- The dialog shown in Figure 134 will appear. Enter a project filename and check Create 3D File. The file will be saved into the Source Directory selected through View > Customize at start of session.

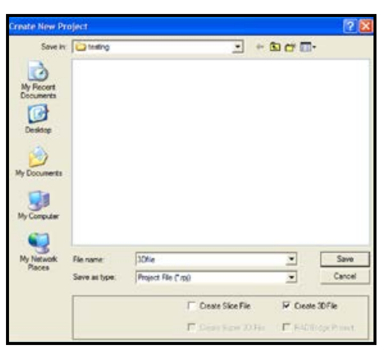


Figure 134: Create New Project dialog. Enter a filename and check Create 3D File as shown.

Step 3: Entering Grid Dimensions

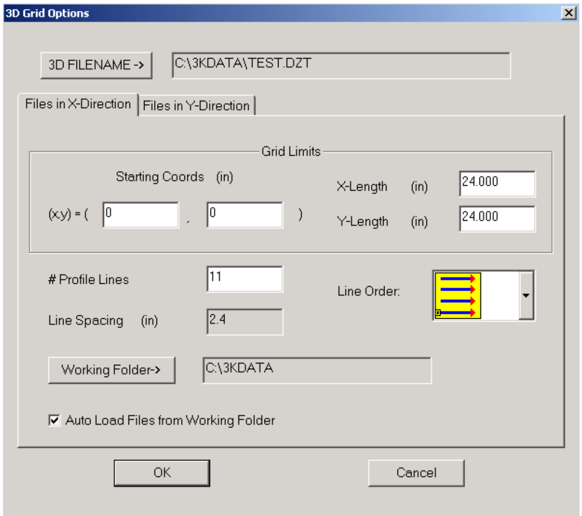


Figure 135: Adding files and Defining Grid geometry.

3D Filename: This is the name of the single .DZT file that RADAN will construct from the individual profiles, and the location where it will be stored. Clicking on this button will allow you to change either the name or the storage directory.

Files in X/Y Direction: If you collected the same grid twice, but with perpendicular transects, these tabs allow you to define different input parameters for each direction. For example, if you collected the X transects in zig-zag, but the Y as unidirectional lines, you can input the different line order here. Also if you collect data in the Y direction as with some other geophysical instruments (Geoscan RM15 or FM36, or Geometrics 858), you can just check the Files in Y-Direction tab.

Starting Coords (units): This is the coordinate of the bottom left corner of your grid. If your area is tied into a larger site grid, you can input those coordinates here so that the axis of the resultant 3D file matches with the larger area.

X-Length/Y-Length: These are the maximum coordinates or your grid. For example, if your grid is 100 inches × 100 inches, you would put those values in here. If your profile lines are not all the same length, you should put in the measurement of the longest one.

 # Profile Lines: Total number of lines in either the X or the Y direction.

Line Spacing: This is the distance between each survey transect. The software figures out this number by dividing the grid size by the number of profile lines. You should use this as error checking. If you collected data with transects placed one foot apart, and you have the correct number of transects for the grid size, than this number should be 1. Anything else and you have a positioning error.

Helpful Hint: Do not forget to count the "0" transect. If you are scanning a 10 × 10 foot area with profiles every one foot, and your first profile is at 0 and your last is at 10, you will have 11 profiles.

Line Order: This is a pull down menu. Visualize your site grid and the order that your files were collected, and choose the orientation that matches your collection method.

Working Folder: This is where your data is stored. Clicking this button will open a browser so you can select a different directory.

Auto Load Files: If you check this box, RADAN will go to the working directory and automatically input the data files in alpha-numerical order. This is the same order that is shown when you sort the data files by name in Windows Explorer (by clicking on the “Name” column header). If the files are not in the correct naming convention, you may find it easier to rename them in Windows Explorer.

After you have worked with all the selections in the dialog, click OK to open the 3-D File Creation window.

Step 4: Adding and Editing the Data File Coordinates

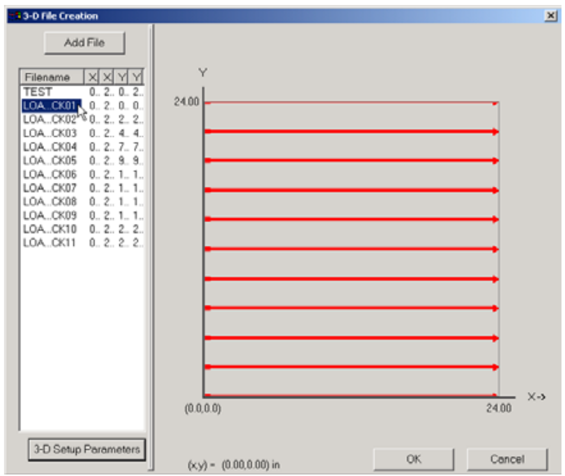


Figure 136: Editing Profile line coordinates can be performed by double-clicking on the filename.

The window in Figure 136 shows the actual locations and orientations of your data profiles. If you clicked “Auto Load Files…” on the previous window shown in Figure 135, the left pane will show a list of file names with starting and ending coordinates.

Existing filenames and coordinates can be edited two ways. The first way is shown in Figure 136. The filename is highlighted by pressing the left mouse button. A double-click then opens up the File parameters dialog shown in Figure 138. The second way to edit a file is to move the mouse cursor to a line as shown in Figure 137.

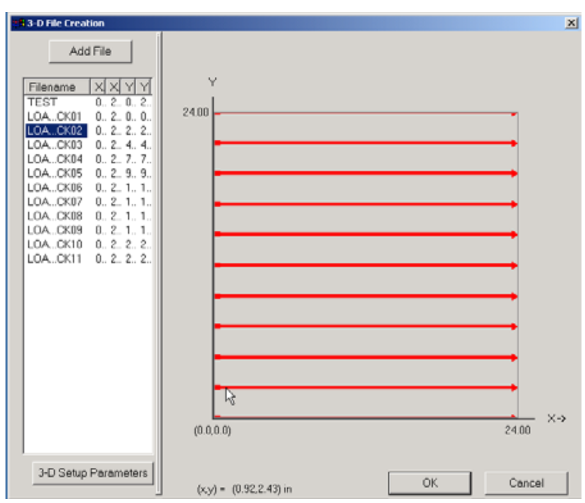


Figure 137: Mouse cursor positioned on red line. A left mouse click can then open up the corresponding file for editing.

When you choose to edit a filename or its coordinates by double-clicking on the filename or clicking on the line drawn on the right half of the window (Figure 137), the File parameters dialog pops up.

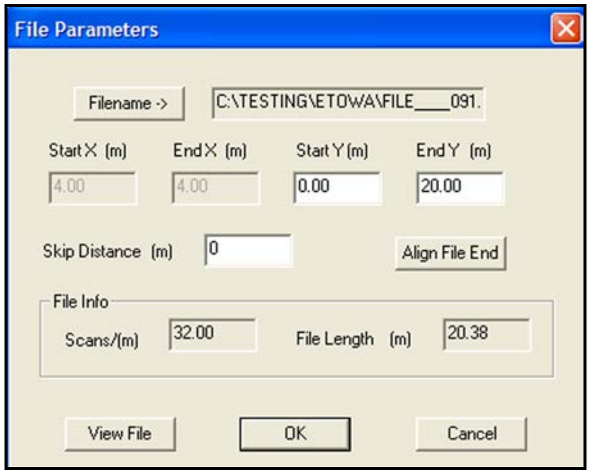


Figure 138: File Parameter Dialog used to edit filenames and profile line coordinates.

The file parameter dialog (Figure 138) allows you to change filenames associated with the profile line, or change the profile line coordinates. All of the profile line coordinates are relative to the grid origin. Files collected in the reverse direction will automatically be flipped in the output 3D file.

For example, suppose you collected a data file in the reverse Y-direction. You'll need to specify a starting Y-coordinate that is greater than the ending coordinate. If the file shown in Figure 138 above was collected in the reverse direction, its Starting Y-coordinate would be 0.00 and its ending Y-coordinate would be 20.00.

The Skip Distance option shown in Figure 138 permits you to skip a certain distance from the start of the file when writing to the 3D output file. This is particularly beneficial for files that were mistakenly started with the antenna in back of the starting point for the grid.

If your files were collected in Zig-Zag, you will see the align file button: Align File End to the right of the Skip Distance window. This button will adjust the file so that the last scan is aligned with the end of the grid. This option is typically used in cases where the user is more confident in the ending position of the profile than the starting position. This option is only available for evenly spaced x- or y-directed files.

Files can be deleted from the 3-D file list by clicking on the filename shown in Figure 136, then pressing the Delete key on the computer keyboard.

New files can be added by clicking on Add File which brings up the dialog shown in Figure 138. The user needs to add the filename and starting and ending coordinates of the file.

Step 5: Run Project

1. To run the active project, simply click OK once you are finished with the 3D File Creation window.
2. The project may take some time to process the data files, depending on the size of the files, the RAM memory in the computer, and the speed of the computer.

3 When finished, RADAN will display a 2D linescan of your 3D project. All of the data files have been appended together.

4 The 3-D project file (*.m3d) is now closed, but can be re-opened and edited many times.

5 Perform any necessary signal processing on the 2D linescan file, then click the 3D cube button .

3-D Project Features and Limitations

Features

The 3-D project provides a great deal of flexibility in creating a 3-D file from a series of straight line profile lines. As noted above, data can be collected in either the x- or y-direction. In addition, data from profile lines collected in 2 directions can be combined as shown in Figure 139.

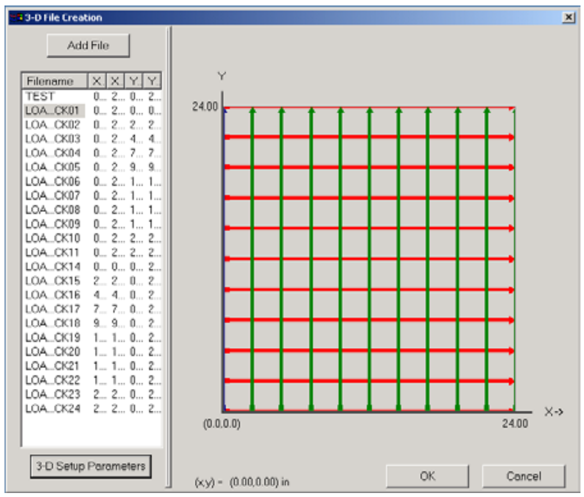


Figure 139: Example data collected in perpendicular directions that will be combined to form an output file.

Data from 2 separate files can be combined to form 1 profile line.

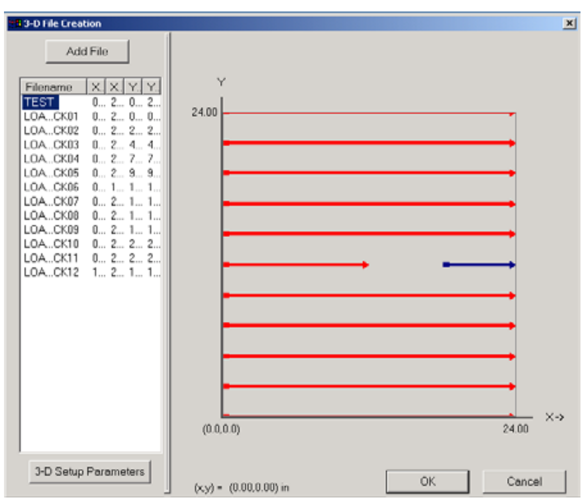


Figure 140: Example of data from 2 input files located on the same x-directed profile.

Figure 140 shows an example where there is a gap in the data collection grid. The user has a short file, then a gap, then an added file along one of the grid lines. When the 3-D file is created, the gap will be filled with zeroed scans.

Varying density profile lines are permitted. Figure 141 shows an example where a greater density of profile lines has been collected near the bottom of the grid.

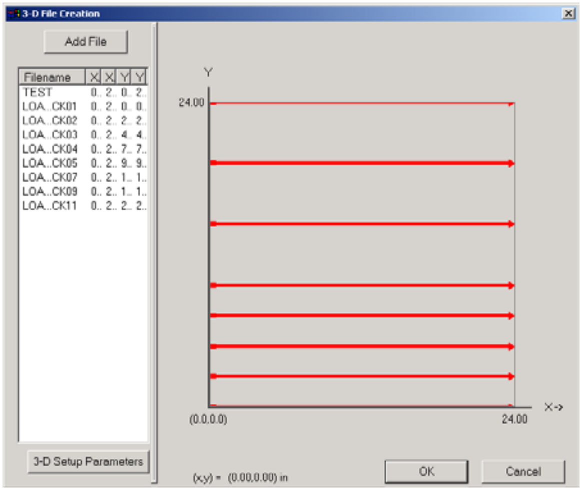


Figure 141: Example of different density profile lines

Non-regularly spaced profile lines: Figure 142 shows an example with non-regularly spaced profile lines. In this case the user has specified a regular grid, than added two very-closely spaced profile lines, which are shown in the figure as blue lines.

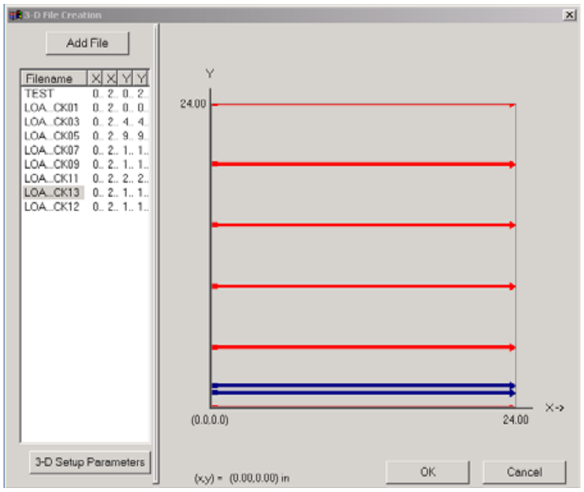


Figure 142: Example of non-regularly spaced profile lines.

Files collected at angles relative to the X and Y-axes: Figure 143 shows a 3-D file that will be created from a series of regularly spaced profile lines and one profile line at an angle that is not perpendicular to them.

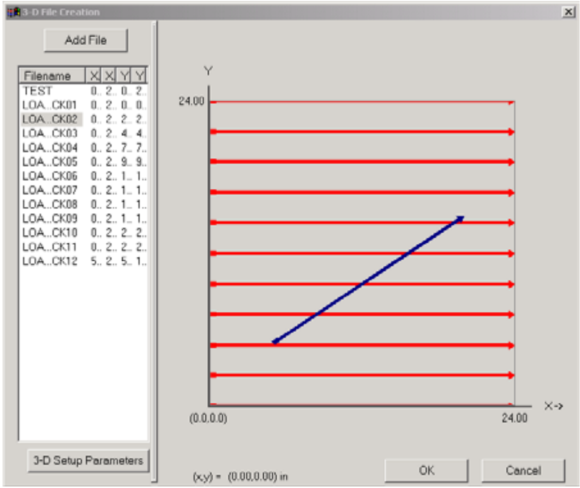


Figure 143: 3-D file being created from a series of regular profile lines and one crossing profile line

Non-regular line starting and ending points: Figure 144 shows a regular 3-D grid where the starting or ending points of 2 files are not located at the grid boundaries. The user has edited the 3-D info associated with these profile lines. When the 3-D file is created, scans with zero amplitude will be written to fill these gaps.

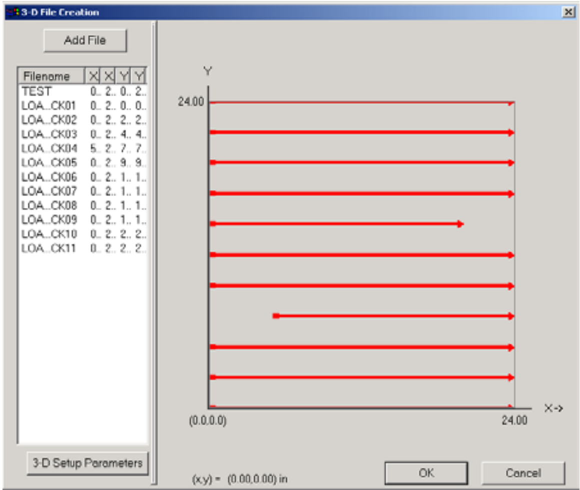


Figure 144: Example showing non-regular line starting and ending points.

The 3-D project information is stored in a *.M3D file that is written in ASCII format. This file can be opened up in Notepad as shown in Figure 145. It is highly recommended that this file not be modified outside of RADAN. However, this file can be viewed to examine all of the project properties.

TEST.M3D - Notepad

File Edit Format Help

```
WARNING: Modification of this ASCII file outside of RADAN may cause unpredictable behavior when
this file is reloaded into RADAN.
3-D FILE CREATION PROJECT
VERSION =  1
Horizontal Unit =  in
Number of X-Directed Lines =  11
Starting X-Coordinate =  0.000000
Ending X-Coordinate =  24.000000
Starting Y-Coordinate =  0.000000
Ending Y-Coordinate =  24.000000
Input Folder =  C:\3KDATA
Auto Load Files From Input Folder =  1
Line Order =  0
Total Number of Lines =  12
Filename,XSt,XEnd,YSt,YEnd,St. Dist,Orientation,Line Type,Scans/U,NumScans/File
C:\3KDATA\TEST.DZT,0.000000,24.000000,0.000000,24.000000,0.000000,1,0,0.000000,0
C:\3KDATA\LOADING DOCK01.DZT,0.000000,24.000000,0.000000,0.000000,0.000000,1,0,5.080000,254
C:\3KDATA\LOADING DOCK02.DZT,0.000000,24.000000,2.400000,2.400000,0.000000,1,0,5.080000,254
C:\3KDATA\LOADING DOCK03.DZT,0.000000,24.000000,4.800000,4.800000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK04.DZT,0.000000,24.000000,7.200000,7.200000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK05.DZT,0.000000,24.000000,9.600000,9.600000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK06.DZT,0.000000,24.000000,12.000000,12.000000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK07.DZT,0.000000,24.000000,14.400000,14.400000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK08.DZT,0.000000,24.000000,16.800000,16.800000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK09.DZT,0.000000,24.000000,19.200000,19.200000,0.000000,1,0,5.080000,254
C:\3KDATA\LOADING DOCK10.DZT,0.000000,24.000000,21.600000,21.600000,0.000000,1,0,5.080000,160
C:\3KDATA\LOADING DOCK11.DZT,0.000000,24.000000,24.000000,24.000000,0.000000,1,0,5.080000,160
```

Figure 145: 3-D project file opened up in notepad.

Chapter 10: Specialized 3D Process Functions

3D display capacities are frequently used for detecting and mapping such targets as pipes, cables or reinforcing bars in concrete. QuickDraw works with RADAN to use a set of tools specifically designed to visualize and map linear targets:

Gain Equalization: Removes striping and mosaics resulting from differences in gain between transects;

Migration: Advanced migration algorithms that help to create clear 3D displays of pipe-like features in QuickDraw;

Time Slice: Instant map-like display of 3D files with automatic Find Linear capability;

3D Slice: Creates slice maps of 3D datasets at user-specified depths.

Gain Equalization

Gain Equalization is a very basic, automated processing algorithm that looks for differences in the average gain values of data files in a 3D set. It is ideal for correcting data sets that have been improperly gained, or have had gain differences from profile to profile. To use, click on the gain equalization button, or Process>3D Gain Eqz. RADAN will analyze the relative amplitude values of each profile and alter the gains accordingly. After the process is run, you will be prompted to save the data file with a new name. Below is an example of data before and after gain equalization. Notice the horizontal stripes in the top data example.

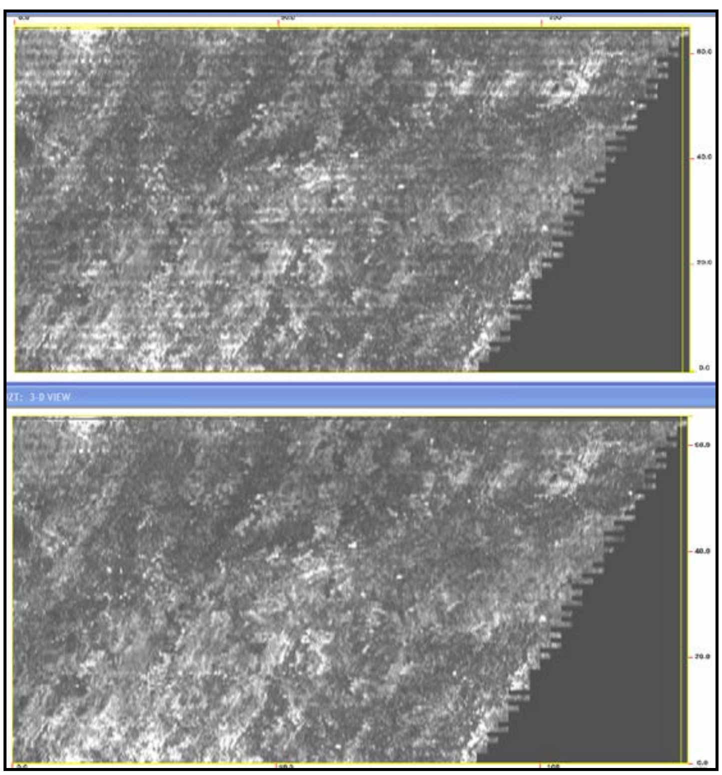


Figure 146: Gain Equalization Before and After.

Migration

Migration is a processing procedure that reduces or eliminates hyperbolic diffraction patterns in the data. Basically it takes out the tails of the hyperbolas to more accurately represent the location, and in some cases, the size of the target. This makes the recognition of point reflectors much easier, especially in 3D files. Migration also offers a simple and accurate way of calculating the radar velocity (and thus dielectric) of the material your target is in from the shape of the hyperbolas. The migration function is a part of RADAN but is discussed here because of its special importance for linear feature display and detection. You can also see the RADAN User's Manual for details on the Migration function.

Any hyperbolic reflections in a 3D dataset will clutter the display. It is strongly recommended to migrate data containing pipe-like features before displaying them in 3D QuickDraw.

Figure 147 shows the end result of migration with a comparison of the raw data of a 3D file (top) and the same file after migration (bottom). Each hyperbola has been reduced to a single point in the resulting migrated file.

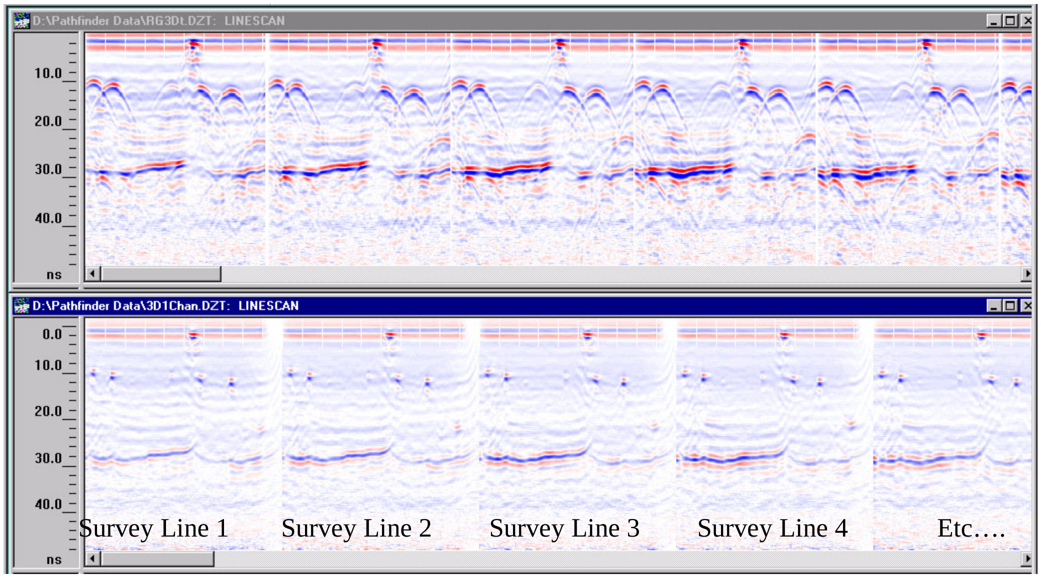
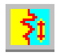


Figure 147: Comparison of raw data (top) and migrated data (bottom).

Position (Time-0) Correction 

Before migration, data must be Position (Time-0) corrected. The Correct Position command is in the Process menu or can be activated by clicking the  button. By correcting the Time Zero, you are telling the computer where the actual ground surface is. The computer needs this information to accurately figure the velocity of radar energy in the ground. See the RADAN manual for more information.

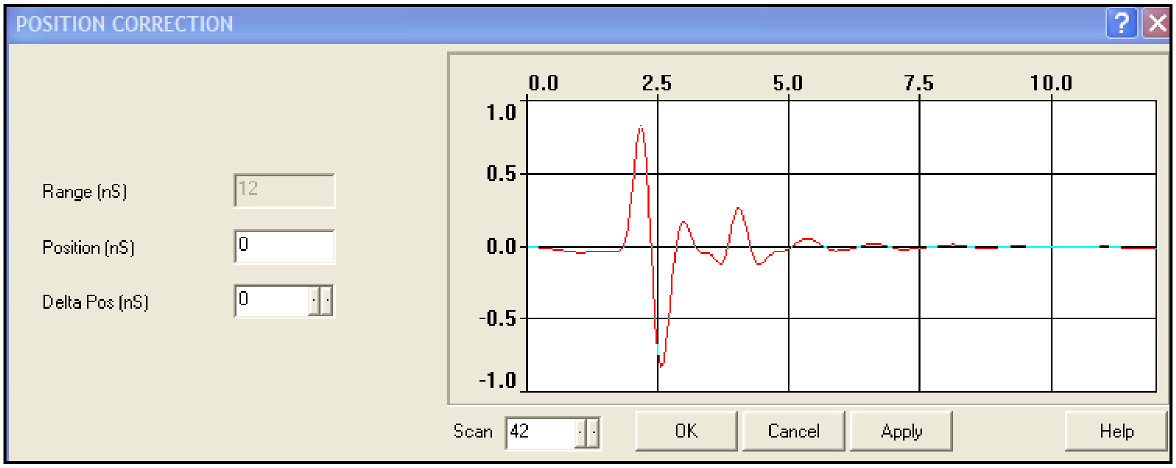
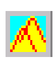


Figure 148: Position Setup dialog.

In the dialog box the position of the beginning of the trace on the time scale can be entered.

- The trace can also be shifted in small increments using the Delta Pos (nS) arrows.
- The scan to be displayed is selected in the Scan box, but any modification is applied to the whole file. (See more information on Position correction in the RADAN Main User's Manual.)

Migration Setup 

1 To start the migration procedure, open the data file in Linescan format and click the Migration button to open the first migration window (Migration and Target Picking).

2 Match the colored hyperbolic overlay to a hyperbolic reflection in the data. The colored hyperbola may be difficult to see if your color table is one of the grayscales. Switching to a different table, 23 for example, will make the colored hyperbola more visible. Try not to choose hyperbolas that are partially in the ground-coupling wave because the computer might not be able to accurately separate them from the stronger ground-coupling.

- You can change its shape by dragging square boxes at the edge of the overlay and move it by dragging the cursor within the colored area.
- The hyperbola shape sets the signal velocity value. The two vertical lines on both sides of the shaded hyperbola should be roughly matched to the hyperbola width (Figure 20). These lines set the Hyperbola Width parameter. The quality of the migration is dependant on how well you are able to match the colored hyperbola to the actual hyperbolas. This can be frustrating at first, but it gets much easier with practice.

3 Once velocity and hyperbola width are set, you have a choice of running a Constant Velocity or a Variable Velocity migration.

2-D Constant Velocity Migration

1 Press the Run 2-D Constant Velocity Migration button. The entire data set will be migrated using the single velocity value you have chosen. This assumes that your material is all the same throughout your vertical profile (concrete, for example). You'll be prompted to save the resulting file.

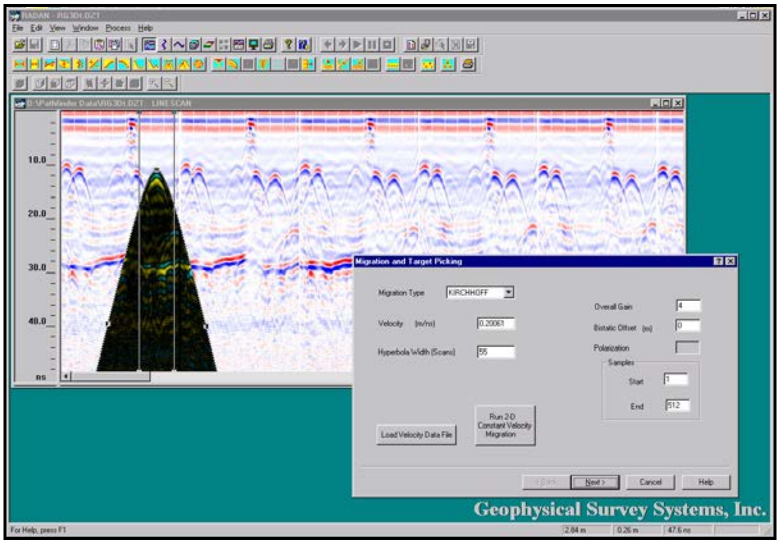


Figure 149: 2-D Constant Velocity Migration.

2 Check the results visually to make sure the hyperbolas have collapsed into dots, not into “smiles” or “frowns.”

- If this is the case, the velocity setting was either over- (smiles) or under- (frowns) migrated. Click Cancel and repeat the procedure, matching the colored hyperbola more accurately. Save the file when satisfied with the results.

Keep in mind that a constant velocity is assumed throughout the entire depth range, so some hyperbolas may be over- or under-migrated. This can only be avoided by using Variable Velocity Migration.

2-D Variable Velocity Migration

After matching the hyperbola, click the Next button to go to the next dialog. Variable Velocity Migration allows the user to enter different velocity values for different depths. This method is most often used when the survey material changes with depth, like dirt. Soil chemistry, porosity, and moisture can all change with depth and using a simple 2-D migration may produce tremendous error. In an area of changing conditions, hyperbolas are collapsed more accurately using variable velocity migration, which leads to accurate depth calculations.

1 Using the mouse, click on the peaks of several hyperbolas in the data window.

- They will appear as colored circles and the hyperbolas originated at them will be used to automatically calculate the velocity at each of these targets.
- Try to pick targets at different depths, as the velocity of the survey area material may vary not only laterally, but also with depth (IMPORTANT).

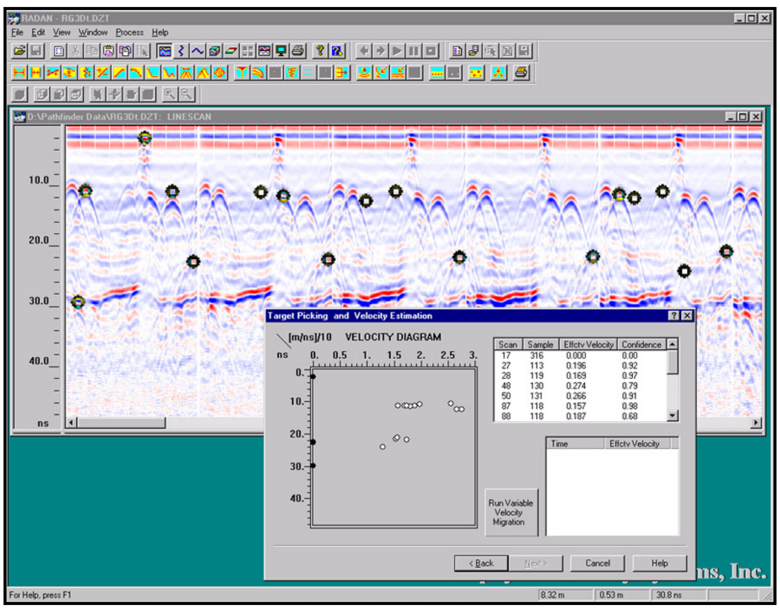


Figure 150: 2-D Variable Velocity Migration.

- The results are plotted in the left pane of the dialog box and shown in tabular form in the right pane.
- Each target position and velocity are determined with a confidence level. The levels of confidence are displayed in the left pane of the dialog box with three different colors: White – high; Black – low; gray – medium.
- The spreadsheet in the right pane of the dialog box provides numerical information on selected targets: target position (scan and sample #), estimated velocity and its confidence level.

Velocity Profile

1 Double-click in the left pane to create a velocity profile. The profile is constructed by selecting a point in the upper level of clustered plotted points (with high confidence, i.e., white), double-clicking, then proceeding down defining the curve as a function of point-velocity cluster (see Figure 151).

2 Using the selected points as reference, you may drag breakpoints left or right to define an optimal velocity profile.

- The resulting profile is used by the migration function when the Run Variable Velocity Migration button is clicked. Point targets at different levels will now collapse more accurately than using constant velocity migration.

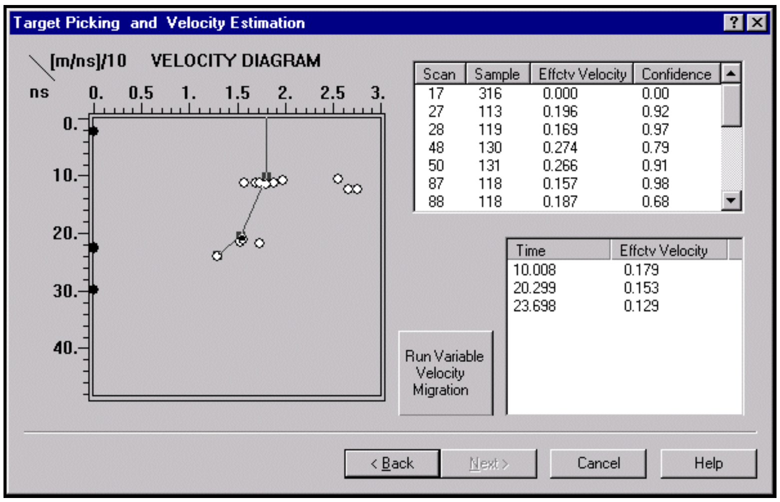


Figure 151: Migration Velocity profile.

Chapter 11: Understanding Imaging for 3D Data

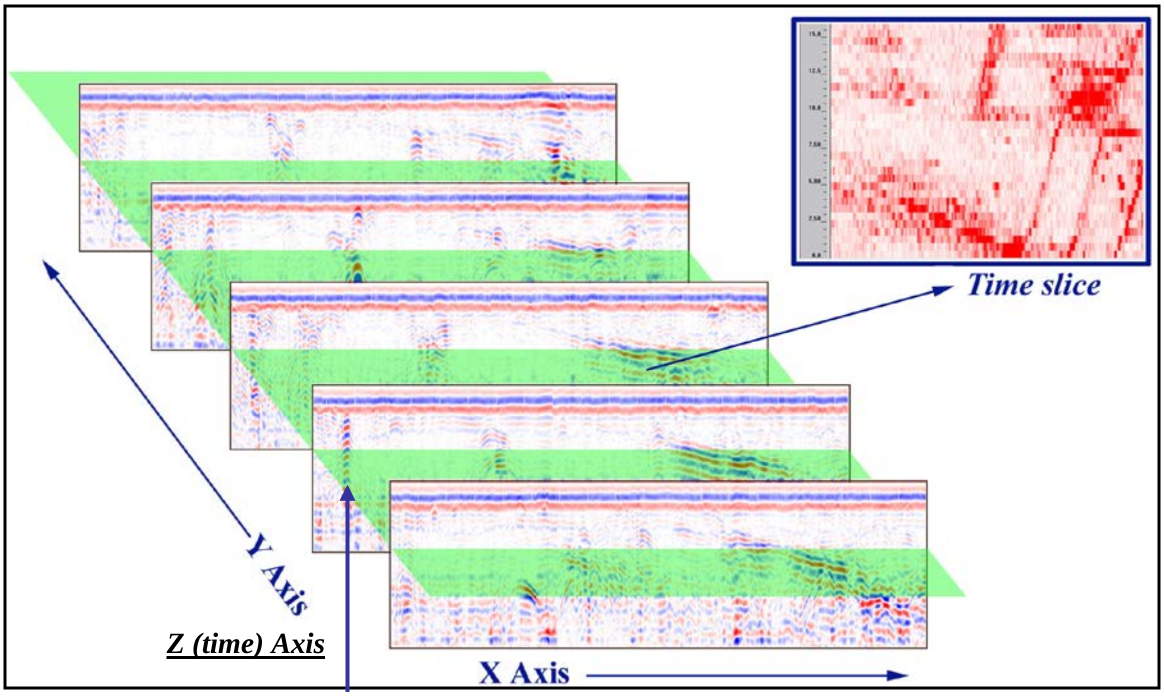


Figure 152: Construction of a Time Slice.

3D Cube Display 

3D QuickDraw generates a 3D “cube” display of the dataset. It allows you to view the entire dataset at once as a transparent or solid cube, to look at it from any direction, slice it along any coordinate axis, etc.

1 First, open a 3D file. The 3D file is the DZT profile that was created after you ran the 3D project. Select an appropriate color table – the same color table will be used for the 3D display (for 2D we often use color table 17 but for 3D we often use, 20,23,25).

2 The 3D cube can now be created by selecting 3D Display in the View menu or by clicking the 3D Mode button . The default view that appears on the screen is an angled plan view of the 3D cube from above.

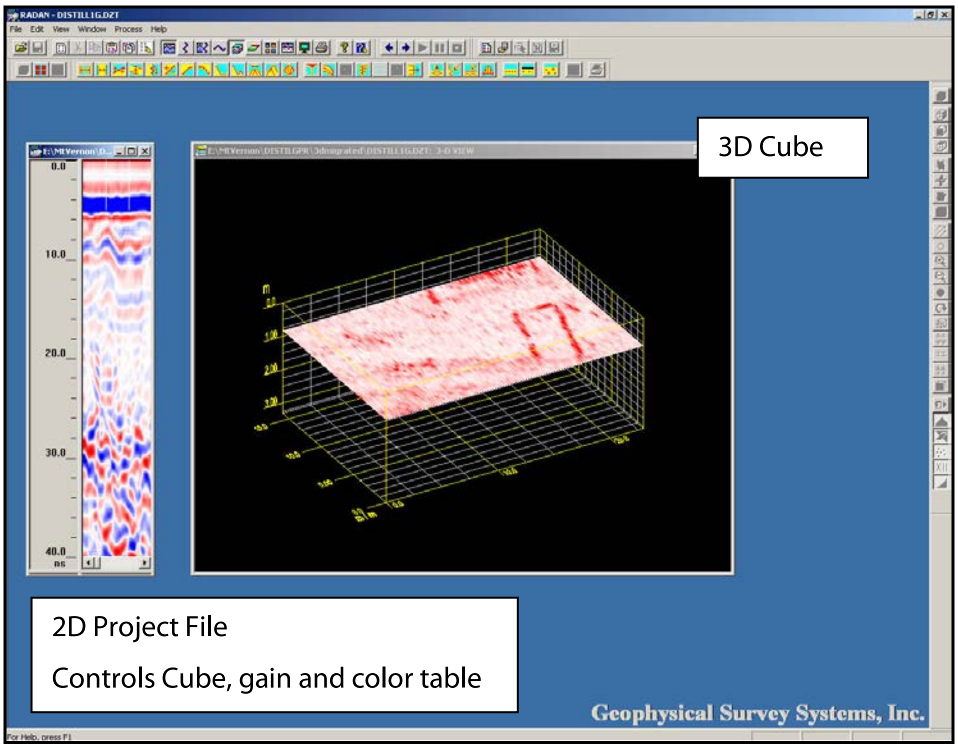


Figure 153: 3D Cube mode (default view).

- When a 3D window opens, most processing and editing buttons on the toolbars turn gray which shows that they are deactivated. At the same time, the 3D Options toolbar becomes activated (colored) and an Option menu replaces the Process menu.
- If no 3D toolbar is shown, open it by selecting 3D Options under Toolbars in View menu. The initial default display is a Z-slice (horizontal slice).

Note: Color and gain of cube data are controlled through the 2D project file (profile). Reduce the size of the 2D project file window for easy movement from window to window.

3D Cube Manipulation

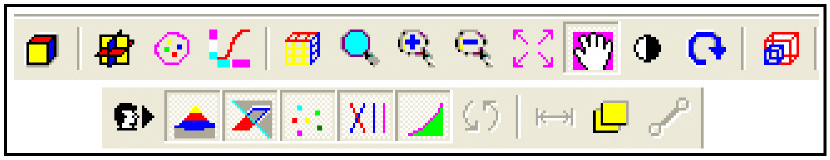


Figure 154: 3D Options toolbar.

Figure 155: 3D Stretch toolbar.

After you generate a 3D cube display by clicking the 3D display mode icon on the Toolbar or by selecting View>3D Display, the 3D tools bars will light up. Manipulation of the 3D cube is controlled by 2 toolbars which are accessed under View>Toolbars. These toolbars are the 3D Options bar and the 3D Stretch bar.

Some of the icons will be grayed out initially when you open the 3D file. Be sure to read through this entire section in order to gain a full understanding of the function of each icon.

Zooming and Adjusting the Viewable Range

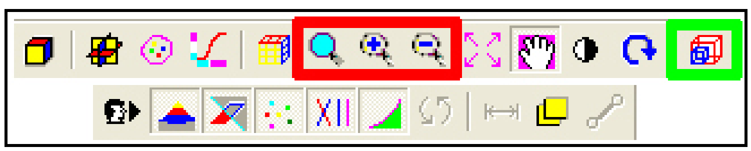
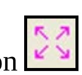


Figure 156: Zoom (Red) and 3D Range (Green).

Zooming: Zooming in and out on a data section can be done several different ways.

- If you have a wheel mouse, spinning the wheel forward zooms into the center, while spinning it backward zooms out from the center.
- Holding down the Control key (Ctrl) on the keyboard while left clicking on the + magnifying glass zooms in to the center. Clicking on the – magnifying glass zooms out.
- Clicking on the open magnifying glass will activate the zoom chooser window. This will look like a green square that overlays your z-slice. You can change the size of the zoom chooser window with the wheel on your mouse. Once satisfied, click the left mouse button and RADAN will zoom to that area while cropping data outside of it. To undo, click the Full Extent button.
- Clicking on a + or – magnifying glass will activate it and change the cursor to a magnifying glass. You can then click on a portion of the data and it will zoom and re-center to the point that you clicked on.
- Clicking on the Full Extent button  will undo any zooming.

3D Range 

Used to zoom selected areas of cube in display window.

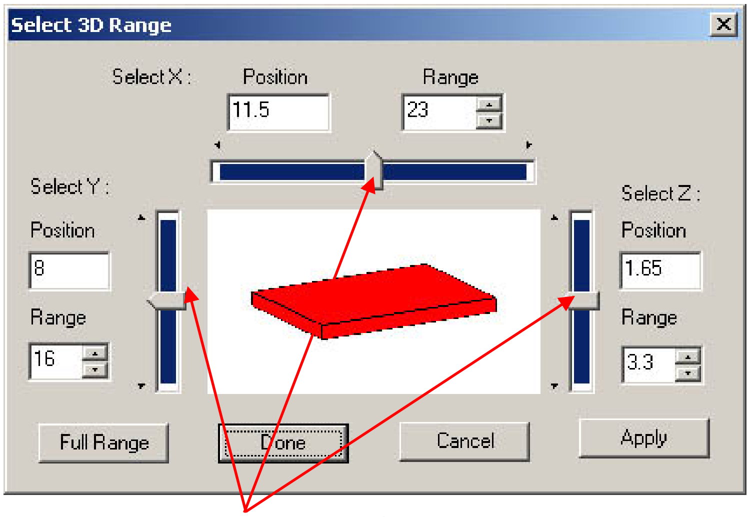


Figure 157: 3D Range Select dialog.

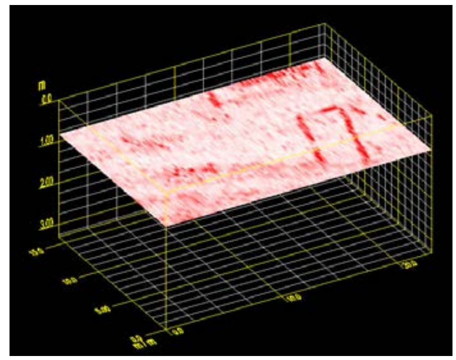


Figure 158: Full 3D Range display.

1 Slide tabs on each axis to select an area of the 3D data set to view.

2 Click Apply to check viewing window selection.

3 When satisfied with viewing window selection, click Done and view using all of 3D QuickDraw's tools.

4 To return to the full cube view click Full Range.

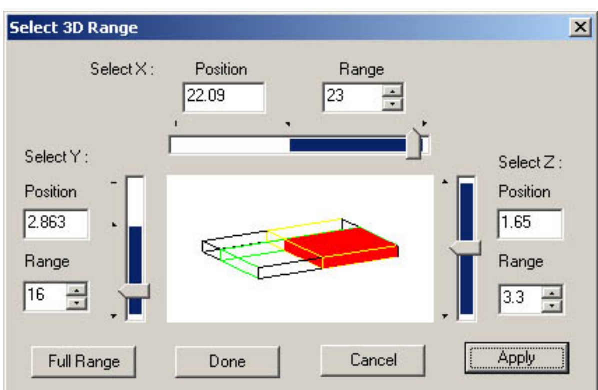


Figure 159: Select 3D Range dialog.

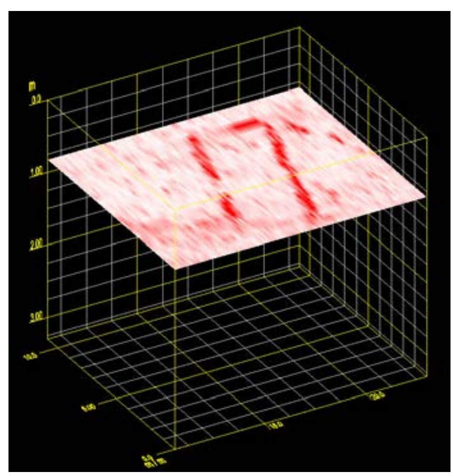


Figure 160: Selected 3D range display.

3D Cube Orientation 

The cube can be rotated using three different methods:

- Put the mouse cursor on the cube, hold down the left mouse button and drag the cube with the cursor. The cube will rotate as you move the mouse.
- Click on the image. Then use the up/down left/right arrows to rotate. This is especially useful for getting some axis Face On.
- Click the 3D Cube Orientation button  for the 3D Angles dialog. The cube shown in the dialog box will rotate to reflect user input rotations. The data cube will rotate as numbers are entered for the x, y, and z parameters.

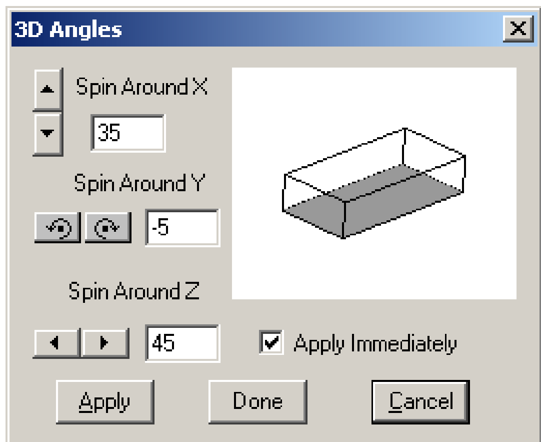


Figure 161: 3D Angles dialog for cube orientation.

Change Background 

Clicking this button will toggle the background between white and black. If you want to output images for printing, a white background may be preferable.

3D Grid Density 

To display 3D data with a mesh line overly or to change the interval that the outside wire grid marks are show at, click the Grid button.

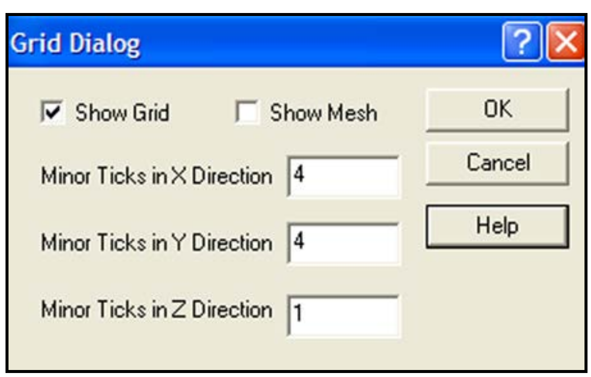


Figure 162: 3D Grid Density.

Re-map Color Transform 

This button allows you to re-map the color transform, contrast, and display gain on the 3D slice in real time. Clicking it will open the window below. None of these functions actually changes your data, they are for display and interpretive purposes only. In practice it is best to simply drag these sliders back and forth to get the best picture.

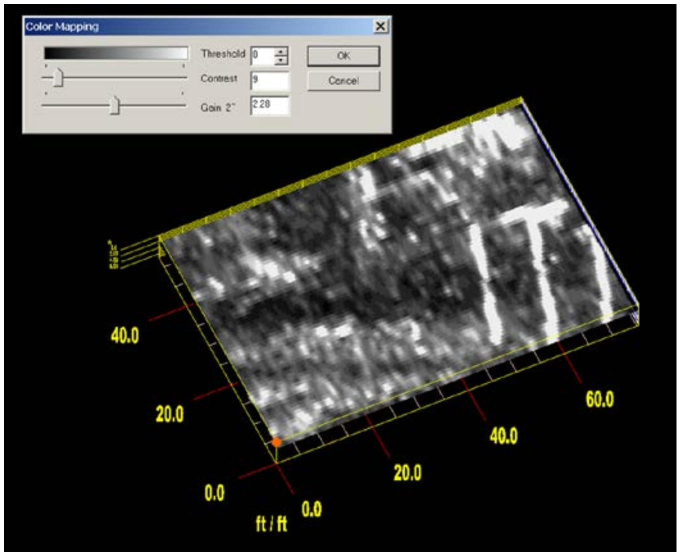


Figure 163: Color Mapping control window.

Color Threshold: The input here is a percentage of data that will be given the color of 0 amplitude (in grayscale, this is medium gray). In other words, if this is set to 90, then the middle 90% of your data will be set to one color, while the extremes will be accentuated.

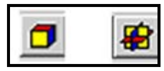
Contrast: This input is also a percentage. The higher the number, the more 'washed-out' your data will become, and the more colors will be distributed over the extremes. This function operates in a very similar fashion to the Threshold selection, except that Contrast is gradational, while the Threshold is a sharp break.

Gain: This is display gain. The input here is 2 raised to some power. For example, putting a 2 in here really means 2^2, or a display gain of 4. Negative numbers are fractions.

Horizontal and Vertical Scale Adjustments. 

This toolbar, called the 3D Stretch Bar, allows stretching and shrinking of both the vertical and horizontal axis.

- The first three buttons control the vertical axis. They stretch, restore, and shrink respectively. The last three buttons control the horizontal axis.
- To manipulate the horizontal axis, hold down the letter key (on the keyboard) of the appropriate axis while clicking the desired function.
- These same functions can also be performed by holding down the letter key (on the keyboard) and by spinning the wheel on your mouse. For example, holding down Z and spinning the wheel forward will stretch out the Z axis.

3D Cube View Options 

The Control-Click Interface

Individual X, Y, or Z slices can be moved simply by left-clicking and dragging them while holding down the Control (Crtl) key on the keyboard. Note that if your 3D file has multiple regions, then only the region that you have clicked on will move. If you would like to be able to move the entire Z slice with the Control-Click interface, you will need to merge the regions into a single one by going to Edit Database>Edit>Merge Regions. This cannot be undone.

Single X, Y, Z Axis Slicing 

Data in the 3D project file can be viewed on multiple axes. Sometimes, looking at data from the X and Y axis can help to answer questions that the Z alone cannot.

To navigate through the cube, left click on the handle and drag. The position will change to reflect the location of the handle and the slice in the cube.

Unless you zoomed in too far, the position of the slice can also be seen by placing the cursor on the slice image and reading the coordinate values in the lower right corner of the display.

To open this display, click on the XYZ fence button. The window below will pop up:

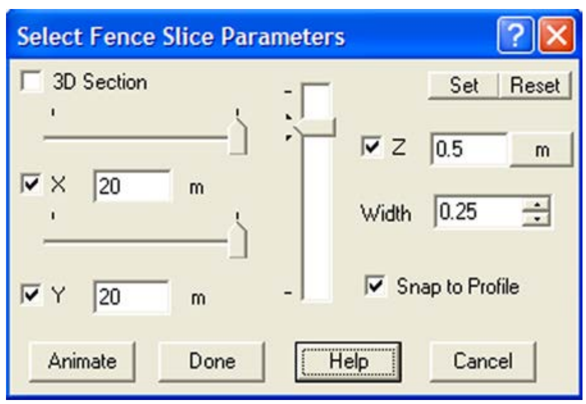


Figure 164: Fence Slice Parameters

The units displayed here will be the same as those you selected in View > Customize.

3D Section: This display is discussed in the next section.

X and Y: These slider bars control the positions of the X and Y fence diagrams on the data display. They are visible as long as the boxes next to them are checked. If you only want to see the Z slice, uncheck the X and the Y.

The numbers shown in the white boxes indicate the position of the slice. Note that the slices are perpendicular to the axis listed, so that the X slice runs along the Y axis. The location number for X in the white box is thus the location along the X axis where that slice starts from.

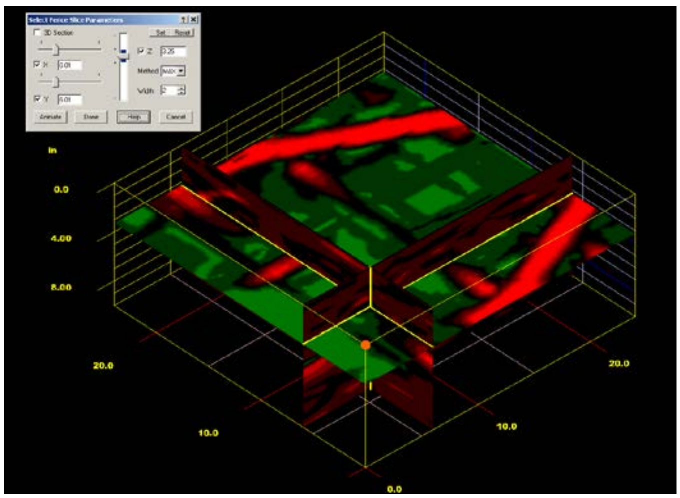
Z: This slider bar controls the position of the Z-slice. The position of the center of the slice is shown in the box to the right of the Z check box. The Z-slice can be displayed in units of distance (ft/m), time (ns), or samples (smp). You can toggle through the 3 display types by clicking on the button to the right of the Z-position indicator.

Width: This is the thickness of the Z-slice. It is represented in the Z-slice slider bar by the blue region. The data is displaying everything within that width. In the window above, the Width is 2 inches and the Z position is 3.27 inches below surface. The displayed range is thus 2.27 to 4.27 inches below surface.

Snap to Profile: If you slice along the X or Y profiles, clicking snap to profile will ensure that you only see actual, collected data rather than interpolated data along those axes. If you leave this box unchecked, then the computer will create data between profile lines. The most scientifically sound way to analyze your data is to keep the interpolation to a minimum.

Animate: Clicking this button will automatically scroll the data along the Z-axis. You can speed up the scroll rate by pushing the arrow key (on the keyboard) in the direction of the scrolling and slow it down (or stop it) by pushing the arrow in the opposite direction.

Set: Clicking this will preserve the current Z-slice on the screen. This will allow you to scroll to another slice and compare the two at once. You can have any number of Z-slices preserved at once. Clicking Reset will remove them.



To Set Up A Section Display (Cutout Cube) 

You can display a 3D Cut Cube by clicking on the XYZ fence display and checking the 3D Section box.

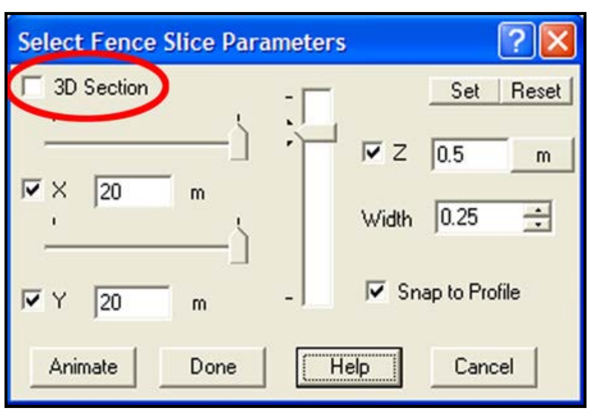


Figure 165: 3D Section axis control.

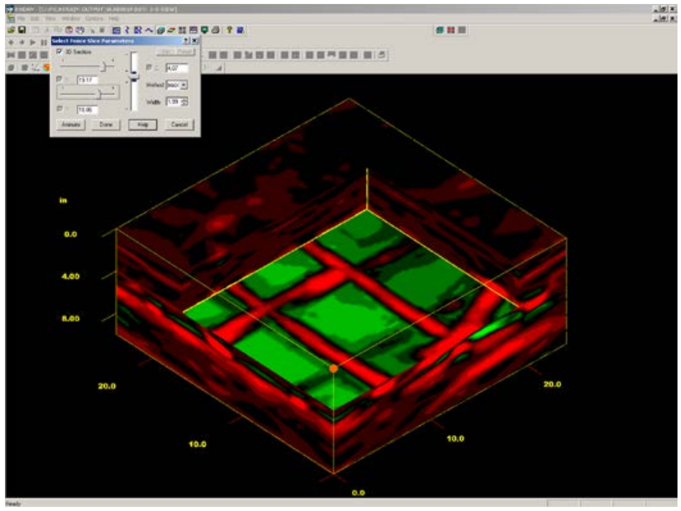


Figure 166: 3D section (cutout cube).

3D Transparency 

Highlights the peak amplitudes in a solid cube by making the center values transparent. Color scale values represent amplitude. This feature works best when there are a number of high amplitude reflections in the data area. Figure 167 shows metal targets in a concrete slab.

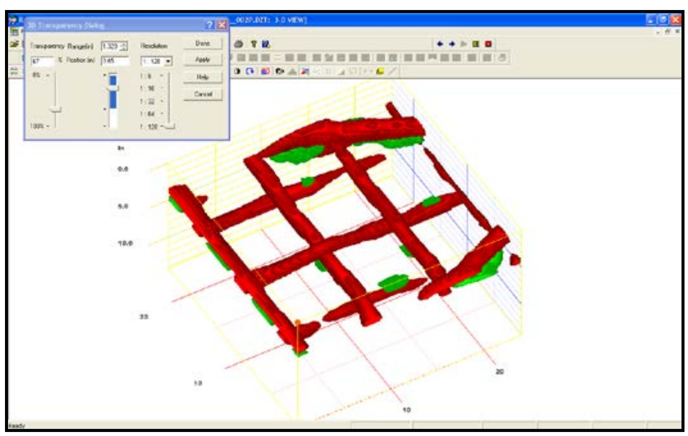


Figure 167: 3D transparency view.

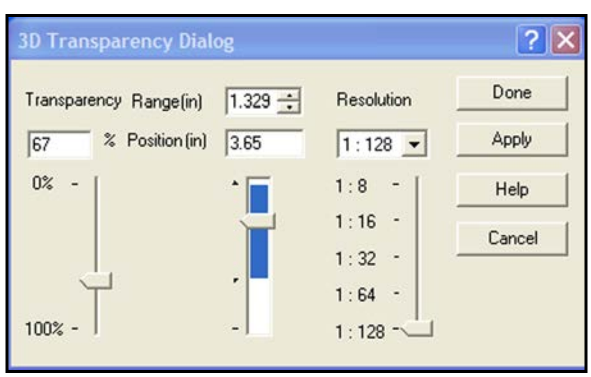


Figure 168: Transparency control dialog.

Transparency: 0% transparency is a solid cube, and 100% transparency is a nearly empty cube.

Transparency Range: The range of data to be imaged.

Position: The depth of the center plane of the image (i.e. your cube is 4 m thick, with the position at 2 m – the entire cube is displayed.)

Resolution: The number of faces drawn for each axis (X, Y, and Z) within the cube. The higher the resolution, the more information will be included in the data cube. This will also take longer for the computer to display. For this reason, we recommend keeping the resolution set low until you are sure of correct settings for the other parameters. Then you can ramp the resolution up to higher levels.

3D Data Display Methods 

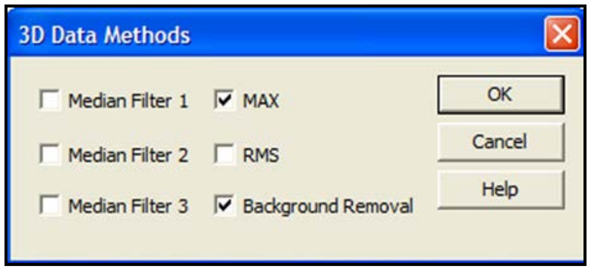


Figure 169: 3D Data Display Methods.

This function allows you to apply different level of horizontal smoothing and perform simple image processing on the 3D Z-slice.

- **Median Filter:** This will perform a horizontal smoothing on your data. There are 3 levels of filtering with the amount of smoothing increasing from level 1-3. No median filters are applied by default. The filters are 8x8, 16x16, and 32x32 respectively.
- **Max:** Checking this box will display max amplitude for each X and Y location no matter at what level it is in the slice. This choice is on by default.
- **RMS:** Checking this box will display the root mean square (RMS) of amplitude values within the specified slice width. This is off by default.
- **Background Removal:** This will subtract the average of amplitudes from the whole displayed window. This can improve visibility of the 3D slice. This is on by default.

Multi-Region Files

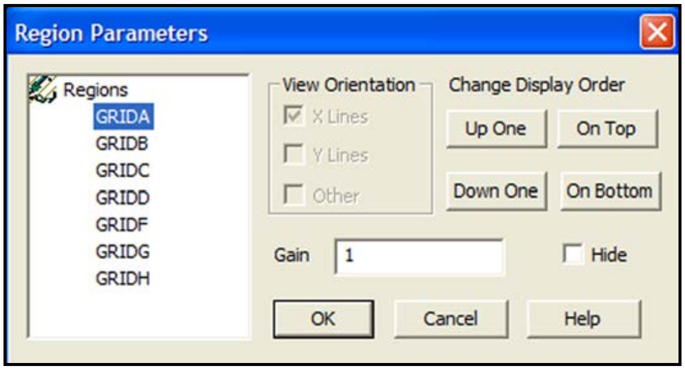


Figure 170: 3D Region Parameters.

The 3D Region Parameters window allows you to manipulate the individual regions in a multi-region 3D file. A 3D file may be built of multiple individually collected and processed 3D grids. These grids may be displayed as one large map (a Super3D file), but they still retain their individual identity. You can merge the regions into a single one by going to Edit Database>Edit>Merge Regions. This cannot be undone.

- Regions are listed in the window at the left. For regions with both X and Y profiles, you can decide to view either X or Y or both under the View Orientation option.
- Regions that overlap spatially can be reordered by selecting a region from the window at the left and then clicking one of the display order buttons. You can also hide a region by selecting it from the list and clicking “Hide.”
- Individual regions can have different display gain values assigned to correct general differences in the visible gain.

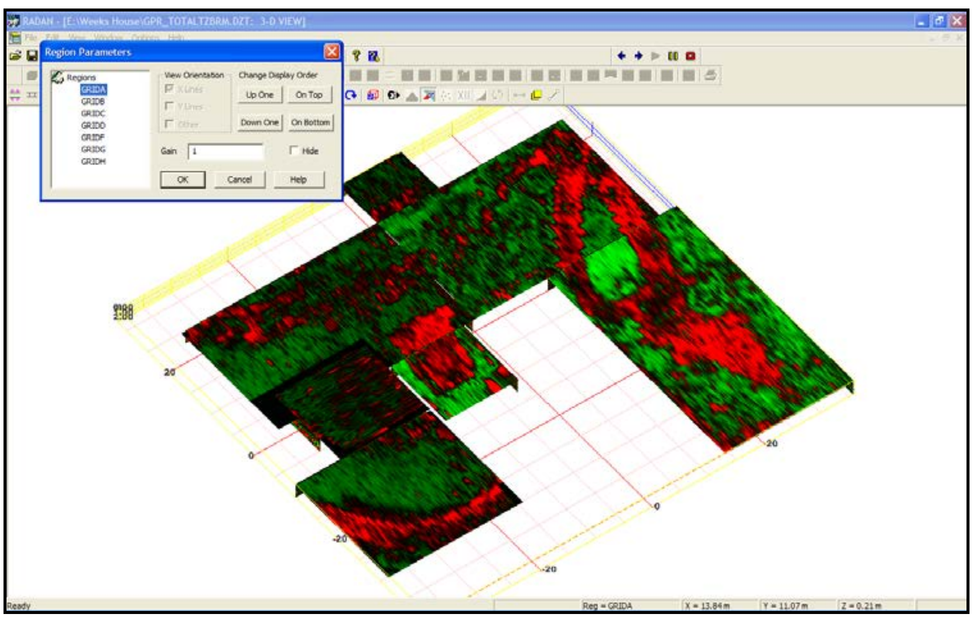


Figure 171: A Large Multi-Region 3D File.

Chapter 12: Advanced 3D Functions

On-Screen Feature Identification

Once 3D data are imaged, linear features can be highlighted. Features are identified while viewing data in the X, Y, or Z-slice mode. The points or linear "pipes" can be hidden or shown in any 3D viewing mode. The points and "pipes" file can be exported in .dxf format for use in any CAD, GIS or other mapping program.

To Draw A Point or a "Pipe" Line On The Data

1 The four corners of a single (x, y or z) slice must be visible. If you can see coordinates in the bottom right of the screen as you float your mouse over the slice, you can draw pipes.

2 Double-click with the left mouse button on one end of the feature and you will see a point. Move cursor to the other end of the feature and hold down the Spacebar and click again with the Left mouse button. A red line will be drawn over the feature. Make sure the "show pipes" and the "show points" icons   are on!

3 Linear features do not have to be on the same plane. If a linear feature dips, double-click the left mouse button on one end of the feature, then move the slice until the other end of the feature appears, then double-click the left mouse button.

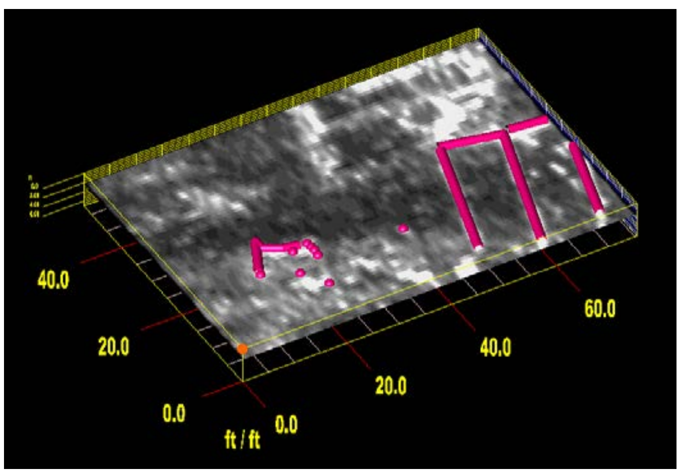


Figure 172: On-Screen Feature Identification

To Highlight Or Delete A "Pipe" Line

1 Right click on the "pipe" line to be highlighted or deleted.

2 A flashing yellow halo will appear around the pipe.

3 To delete the line, select Delete from the pop-up menu.

Drill Hole

This function is useful if you are using 3D data to find a location for drilling or coring and want to find a location with no obstructions. This function puts a simulated drill hole running vertically through your data set so you can slice up and down to use Movie Mode to note clear areas to drill.

Create Hole: Right click the 3D Slice where you want the hole to go. This will open a pop-up menu. Highlight Drill Hole, and the one of the preset sizes or Custom and enter in a custom diameter. This will create a transparent green shaft at that location. You can create as many holes as you want.

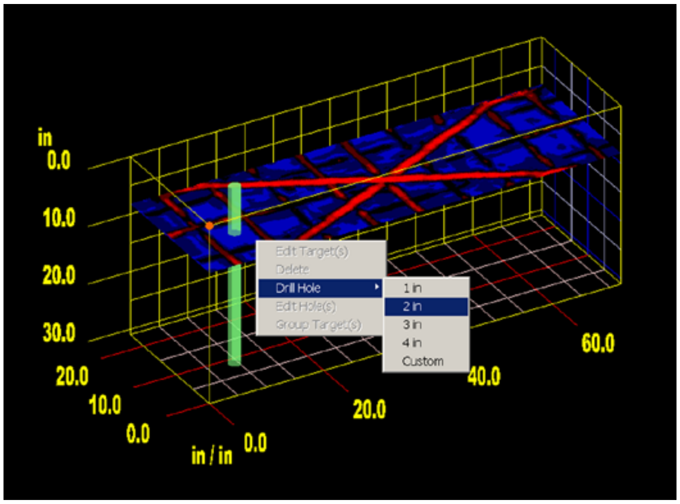


Figure 173: Drill Hole Creation

Edit Holes: Right clicking on the hole will bring up another pop-up menu that will allow you to delete the hole or to change hole diameter.

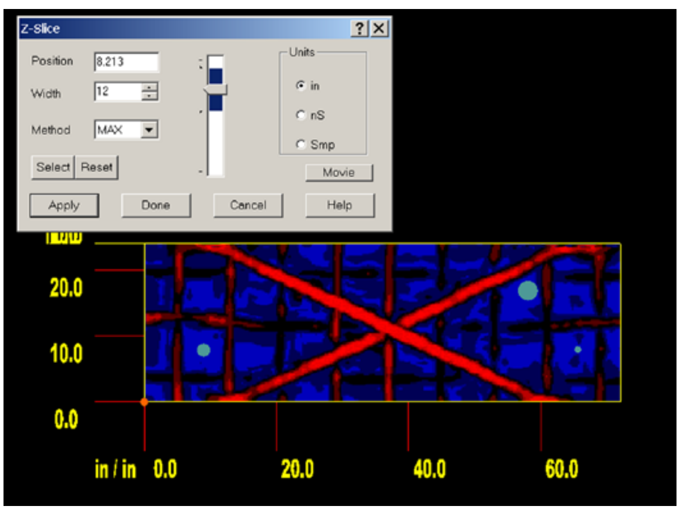


Figure 174: Z-Slice planview of data with 3 holes.

Shape Manager 

Shape Manager Control 

The Shape Manager controls these functions:

- Export Targets.
- Load Shape Files from previous work.
- Import Profiler EMI files. (see Profiler manual for details)
- Add or Update Contour.
- Edit your drawn-in target legend.
- Fix Pipe Aspect Ratio.

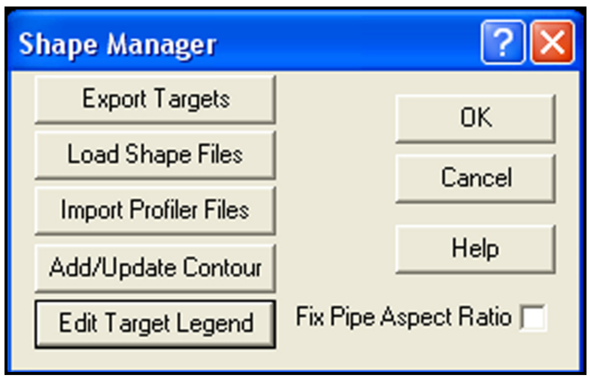


Figure 175: Shape Manager dialog.

Export Pipes to CAD

1. To export Pipes, or Linear features, to a .dxf formatted file, click the Shape Manager  button.
2. Click Export Targets while the 3D cube with target picks is displayed.

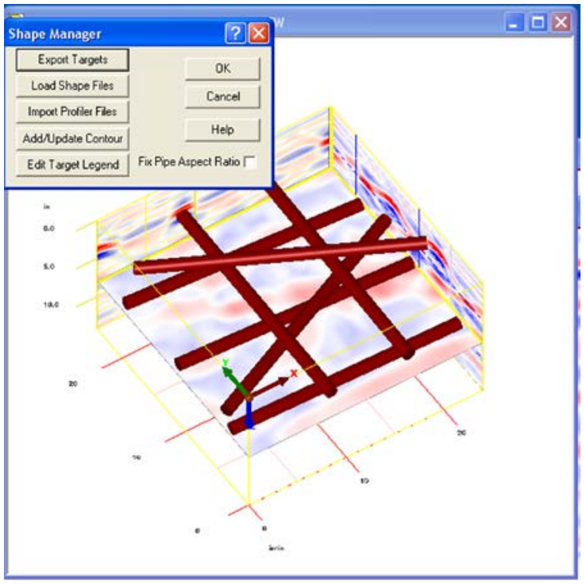


Figure 176: Exporting a Linear Feature ID file to *.dxf.

3 Enter a file name and select the proper folder in which to save the new .dxf file. You can choose either a 2D DXF or a 3D DXF file. You can also save the "pipes" as a SHP file. Shape files can be added to and edited in RADAN. This is the best way to save a work in progress for later editing in RADAN.

- Software will default to the Output path selected during initial RADAN setup (Customize > View).

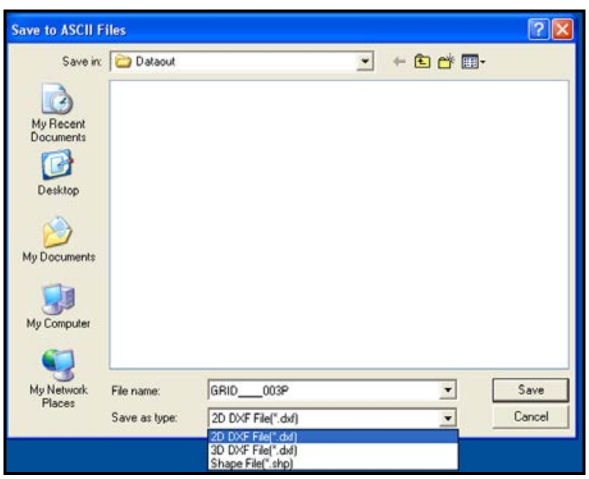


Figure 177: 2D.dxf export of linear features.

Export Z-Slices to CAD

Though not in the Shape Manager, Z-slices can be exported to CAD and other mapping programs in *.csv format. The CSV format can opened in MS Excel or other spreadsheet.

1 Display Z-Slice to be exported.

2 Select File > Save As and enter the file name and folder it is to be saved in.

Load Shape Files

1 Once the Auto Target function has been run, open the Migrated 3D file in the 3D cube.

2 Click the Shape Manager button .

3 Click Load Shape Files.

4 Select desired file from the Open Shape File dialog and the Auto Target results will be displayed in the 3D cube.

- Any viewing option (X slice, Z slice, fence diagrams, etc) can be used with the Shape File overlay.

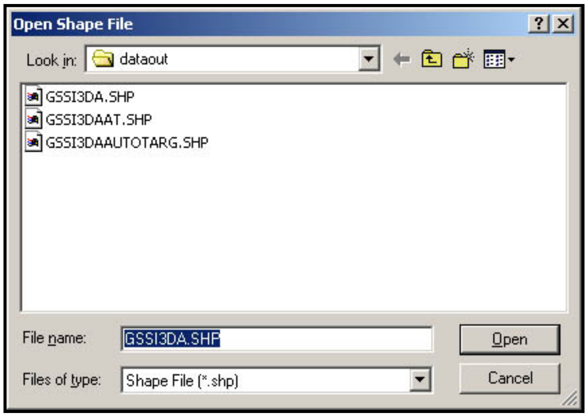


Figure 178: Shape file selection dialog.

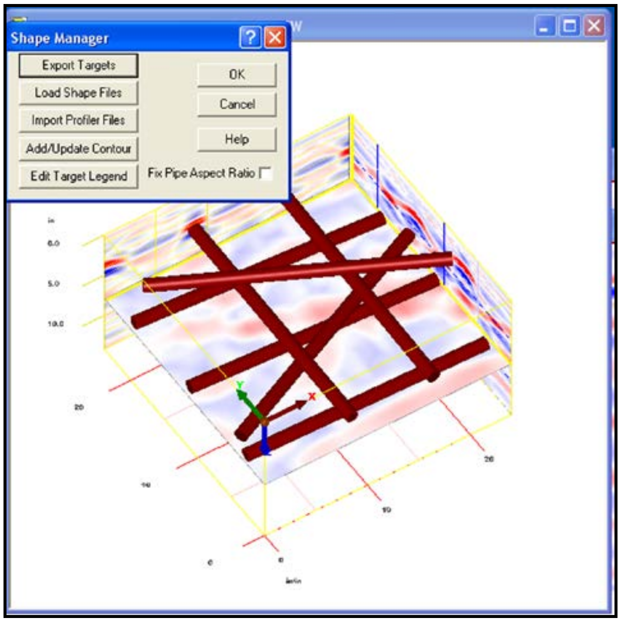


Figure 179: Z-slice with linear features, “pipes.”

Points On/Off 

To turn the points on and off, click On/Off button .

"Pipes" On/Off 

To turn user drawn or Auto Target drawn "pipe" lines on and off, click the Pipes button . Auto Target is a feature of InterActive 3D.

Add Contour 

1. To get more information on feature amplitude to assist in data interpretation, position the Z-slice at the desired depth and click the Shape Manager button .
2. Click Add Contour. A contour file will appear above the 3D cube.
3. The contours of this image reflect amplitude values of the displayed slice.
   - If you wish to change the displayed Z-slice, turn the Contour file off by clicking the Add Contour button , then change the Z-slice. When you have the new Z-slice displayed, go back into the Shape Manager and click Add/Update Contour..

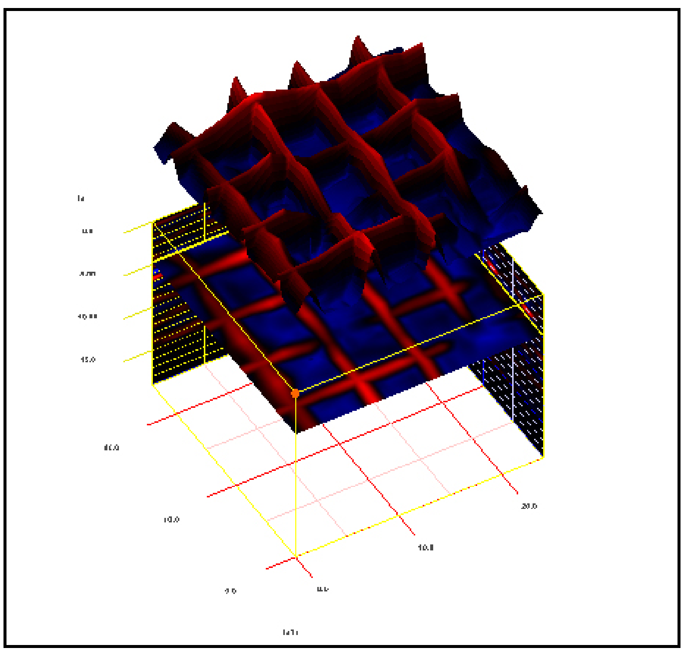


Figure 180: Z-slice contour display.

Slice View On/Off 

During any 3D cube display with overlain features, the slice(s) can be turned off and on with the  button.

Time Slice 

Time Slice provides a “plan view” of survey data. This is another convenient method for manual or automatic search for linear features in a 3D dataset.

1 Open a 3D file.

2 Create a time slice by selecting View > Time Slice or clicking the Time Slice button . A data window and a Time Slice Parameter box will be displayed that shows a plan view of the data, the window can be adjusted to display the true shape of the survey area.

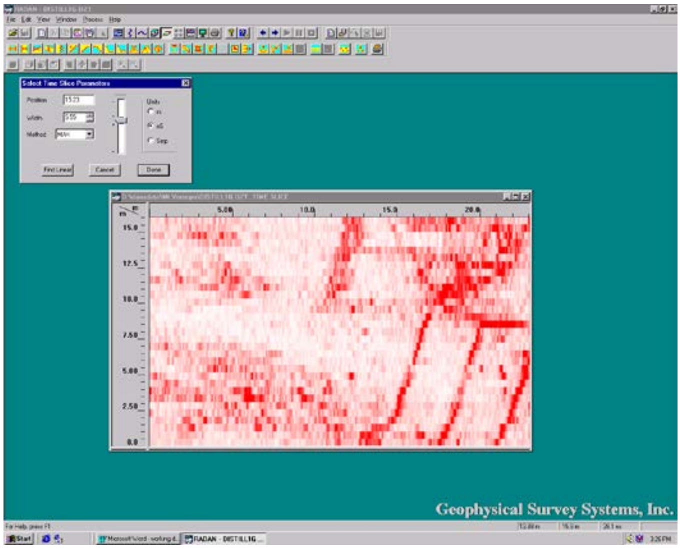


Figure 181: Time Slice display.

Time Slice Parameters

Four time slice parameters can be modified:

Position: Position of the slice on the vertical (Z) axis.

Width: Desired “thickness” of the slice you are imaging.

Method: Determines the type of values that form the slice.

- MAX: Maximum Amplitude within the slice width is displayed.
- RMS: Root Mean Square (i.e. Standard Deviation) within the slice is displayed.

Units: Determines whether the slice position and width are shown in:

- Linear Units
- nS – nanoseconds (two-way time)
- Smp – samples

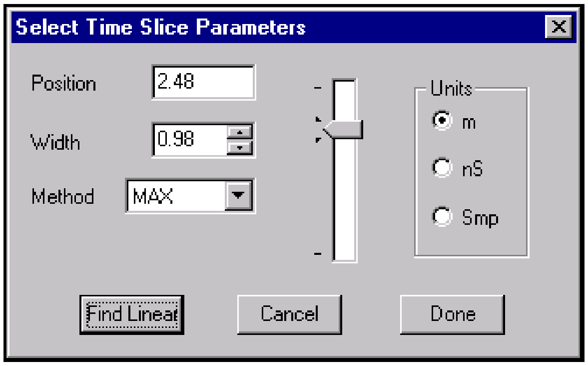


Figure 182: Select Time Slice Parameters dialog.

Once a slice is displayed, you can move it up and down between the surface and the maximum depth. This can be done by entering numbers in the Position box or by dragging the handle in the middle of the dialog box. You can also change the slice width (thickness) using the Width box. Try different combinations of Width, Method and color table for optimal display.

A time slice window can be modified using the same display options and right mouse button commands that are available for any regular radar profile (Display Gain, Color Table, etc.). On the left side of the time slice, the Y-scale is displayed. To display the X-scale, right-click on the Y-scale and select Show Horizontal Scale. Both are shown in distance units selected in Customize menu.

Find Linear: Automatic Tracing Of Linear Features

This feature is currently disabled in this release of RADAN.

This part of Time Slice performs an automatic search for linear features (pipes, rebar, etc.) with specified parameters. Find Linear generates slices of specified width (thickness) throughout the file, starting from the surface, then detects linear features in each slice.

The slice file is a file that can be displayed in RADAN like any regular radar profile. Instead of radar scans, it contains several time slices. The number of slices in a file depends on the selected slice width. The entire 3D file will be sliced with a 50% width overlap.

The identified linear features are shown as lines of colored dots. At the same time, they will be saved in a 3D graphic file in AutoCAD format (*.dxf). It will be assigned the same filename as the time slice file.

1 With the data file displayed in Time Slice, first select the Width and Method that provides the best display of linear features.

Width: Start with a ***thicker*** slice, perhaps set Width to the entire depth range, then decrease as desired. Remember: low Width settings (thin slices) will result in increased noise, longer processing times and large output files.

Method: Either method (MAX or RMS) may provide good results; the best choice in each case depends on the data set.

2 Find a slice with prominent linear features and then click the Find Linear button. In the Linear Feature Parameters dialog, adjust the following parameters:

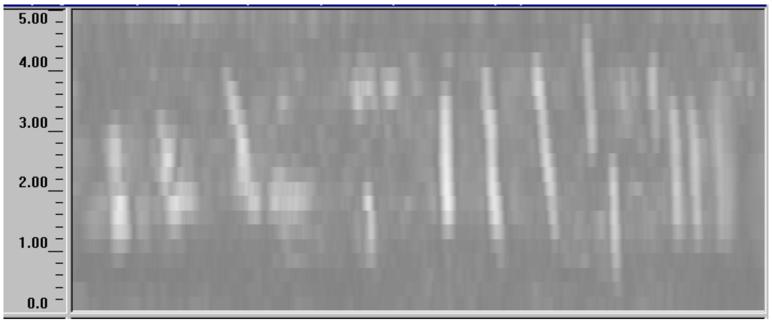
Minimum Pipe Length: Any feature longer than the specified value will be considered; any feature shorter than that will be rejected. This setting should be maximized as much as possible to the extent of expected linear features.

Max. Residual: The acceptable non-linearity of the feature. Depends on the data quality and is typically between 2 and 10 cm (1 to 4 inches). This setting should be minimized as much as possible.

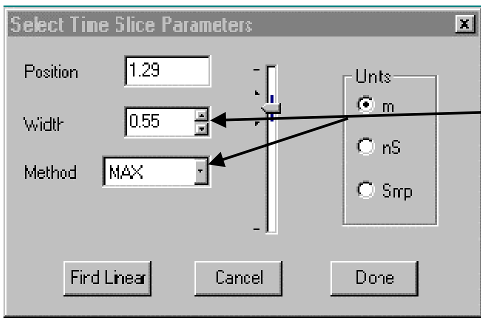
3 Click Apply as many times as you like until the visible linear targets are correctly identified.

4 Click OK.

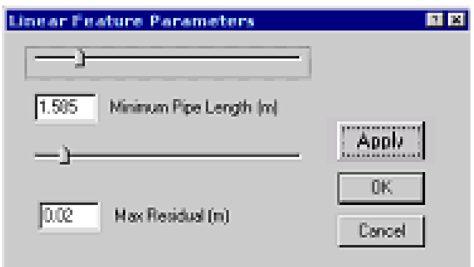
- The file will be processed and you'll be prompted to save the slice file. The identified linear features will be added to the Time Slice display as colored dotted lines and can be viewed using the same Time Slice Parameter box. You can view the results by right-clicking on the time slice view.



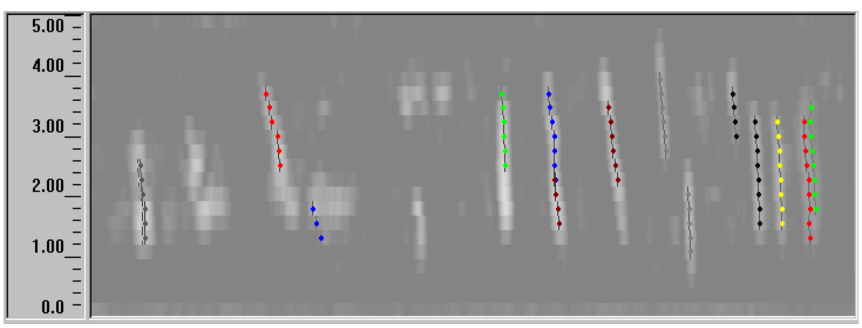
1. Time Slice of a survey area.



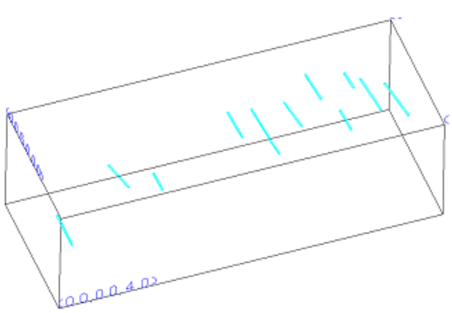
2. Settings for the Time Slice - set Width and Method used by the Find Linear function.



3. Settings for Linear Feature Parameters should be adjusted to *maximize* the Minimum Pipe Length and *minimize* the Max Residual.



4. Resulting time slice file with superimposed colored lines over the detected linear features.



5. 3D graphic file of identified linear features displayed in AutoCAD.

Figure 183: CAD drawing of Linear Feture *.dxf file

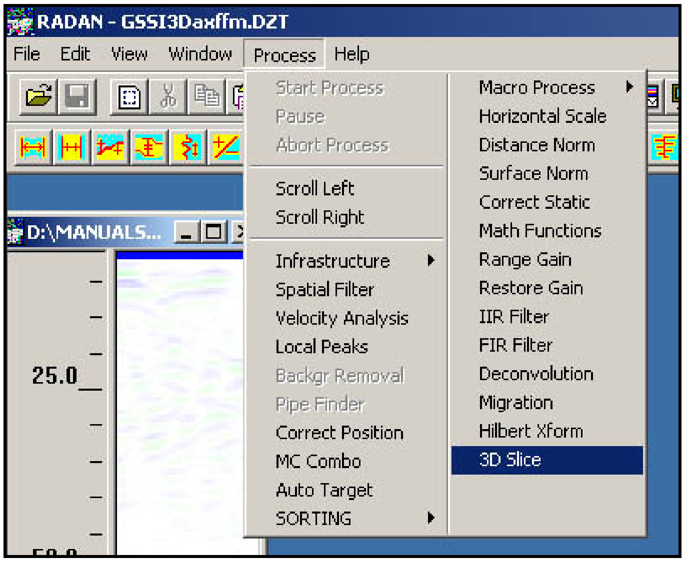
3D Slice

This feature is currently disabled in RADAN 6.6.

The 3D Slice tool allows the user to directly generate a slice file. Unlike Time Slice, it does not allow interactive display or perform a linear feature search. This tool can be used whenever a printable plan view (or views) of the survey area needs to be quickly generated.

3D Slice offers more flexibility than Time Slice for creating slice files – for example, the number of slices in 3D Slice is independent of the slice width (thickness).

1 Select Process > 3D Slice.



2 The dialog box will prompt you to enter desired slice parameters.

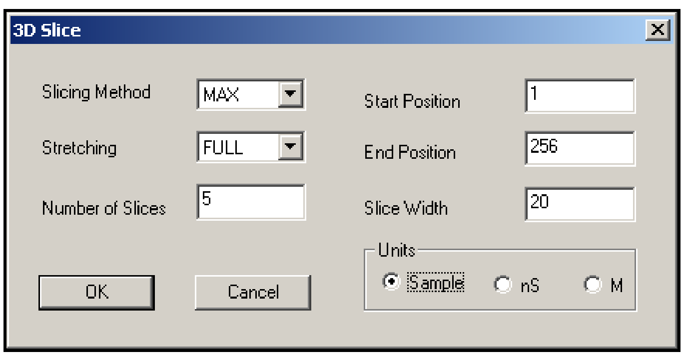


Figure 184:3D Slice dialog.

Slicing Method: Determines whether the slices will consist of maximum amplitude values within the slice width (MAX), standard deviation values (RMS), or a smoothed median filter (MED).

Stretching: Interpolates (add samples) between adjacent survey lines in the 3D dataset. It varies from NONE (no stretching) to the FULL option that stretches the slice to the height of the data window (512 samples).

- Stretching results in a smoother image and compensates for the large difference between the number of lines in a dataset (typically 20-50) and the number of scans in a line (typically hundreds or thousands).

Number of Slices: Determines the total number of slices that will be generated.

Start and End Positions: Set the top and the bottom of the depth range to be sliced. User has a choice of slicing the entire depth range or only a part of it. The slices will be evenly spaced within the selected range.

Slice Width: Vertical thickness of each slice. Slices can, but do not have to, overlap.

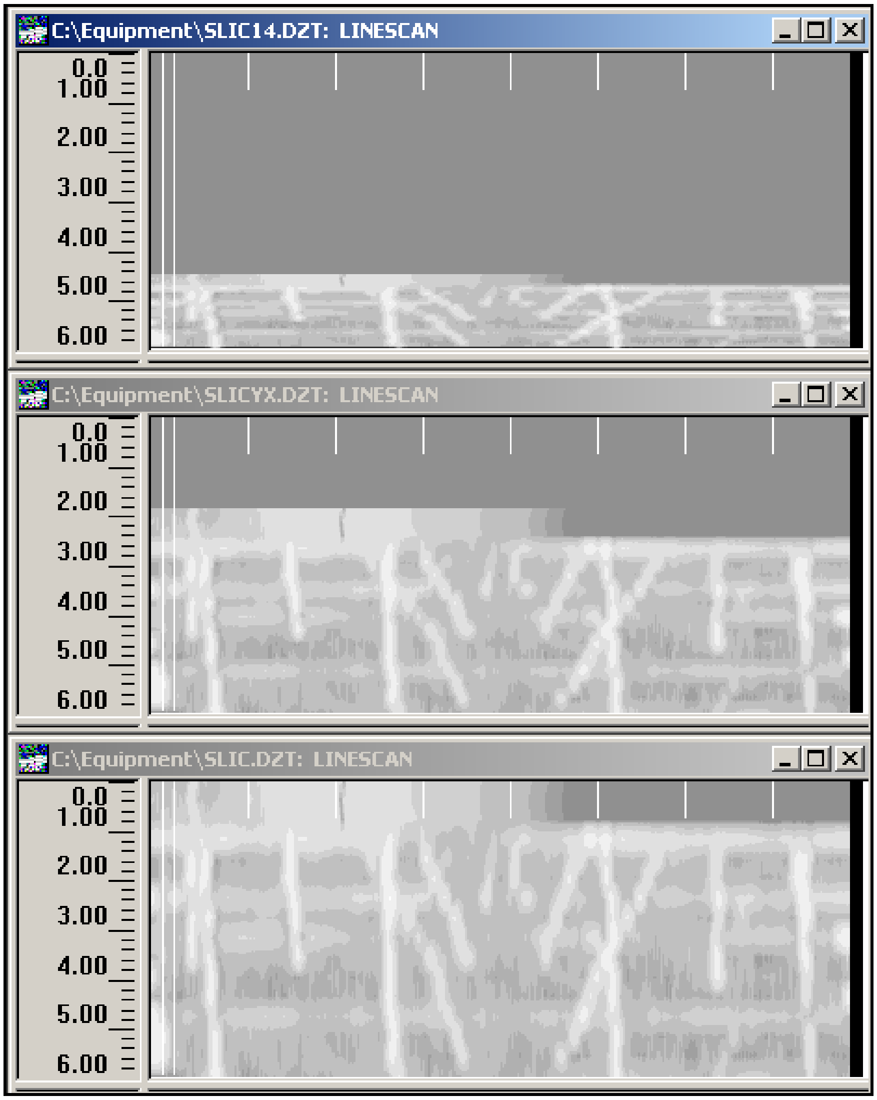
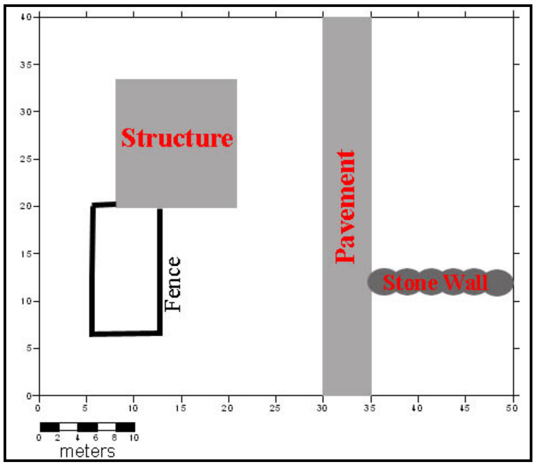


Figure 185: 3D Slices generated from the same dataset, with Stretching of ¼ (top), X/Y (middle) and FULL (bottom).

Chapter 13: Super 3D

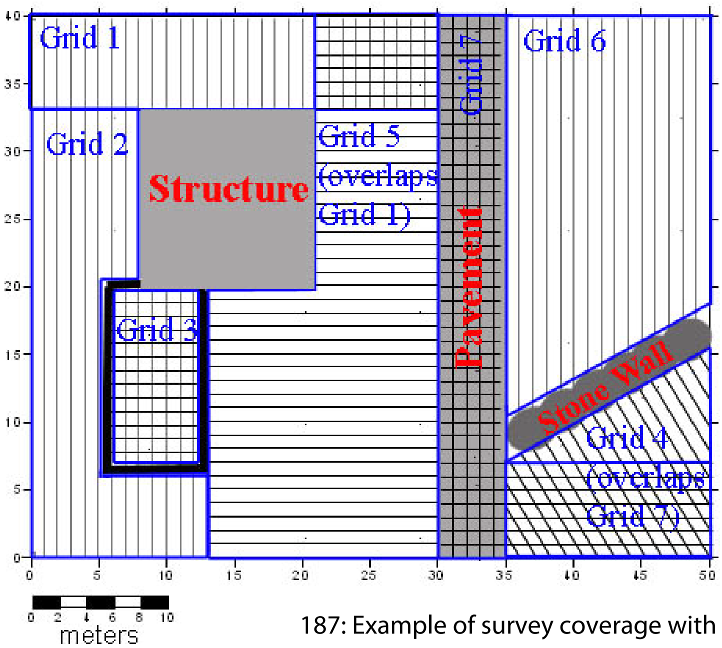
The Super 3D mode of 3D QuickDraw allows you to combine multiple grids into one survey area. Not only can you stitch together grids collected across your site, you can merge grids collected on the same survey area oriented at a 90-degree angle.

Super 3D files are made with fully processed 3D project files. Once positioned in the Super 3D file, the software reassigns grid coordinates to data so they reflect your designated survey area parameters.



A typical survey area may have standing structures and other surface obstacles. In this case, GPR data sets have to be collected in segments across a site.

Figure 186: Survey area with surface obstructions.



Multiple grids cover a single survey area. Note some grids are orthogonal, some grids overlap and grids have different transect orientation (NS, EW, diagonal to regular grid).

All of these data sets can be combined in Super 3D. Data collected orthogonally (at 90 degree angles) will be merged together and peak amplitude values drawn from the data sets will be displayed.

If 2 or more grids overlap with the same or different grid transect orientation – Grids can be layered to display the data layer of choice.

187: Example of survey coverage with multiple grids.

New File Setup

1 To create a Super 3D file, close all windows on your screen and select File > New.

2 Enter a new File name.

3 Change the file type from Project file (*.rpj) to S3D File (*.s3d).

4 Put a check in the "Create Super 3D File" box.

5 Save the new S3D file.

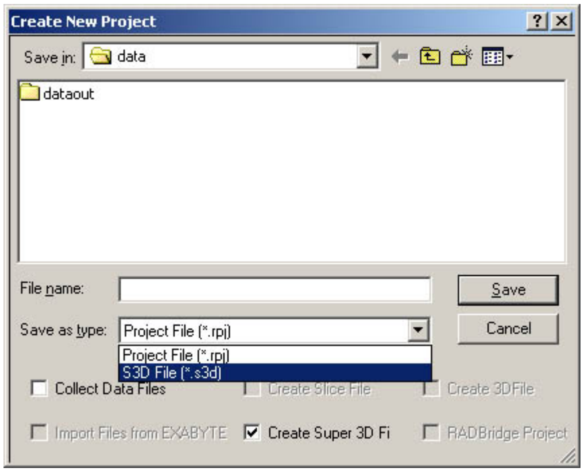


Figure 188: Create New Project File dialog.

6 The Super 3D File page will open and can be resized to fit your screen by dragging on edge of window.

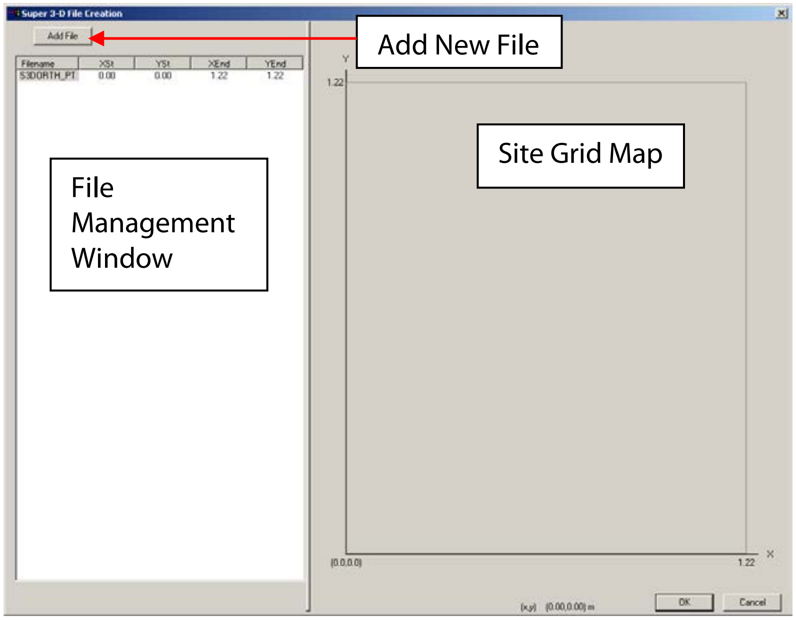


Figure 189: Super 3D File Creation dialog.

7 Once the Super 3D file is named, select each fully processed 3D grid file merge.

- Click the Add File button.
- The File Parameters dialog will open.
- Click the Filename button and select the file from the Specify RADAN File dialog to be inserted into the Super 3D file.

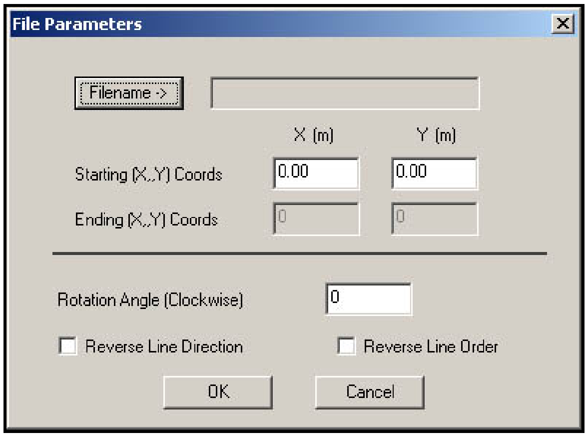


Figure 190: Super 3D File Parameter dialog.

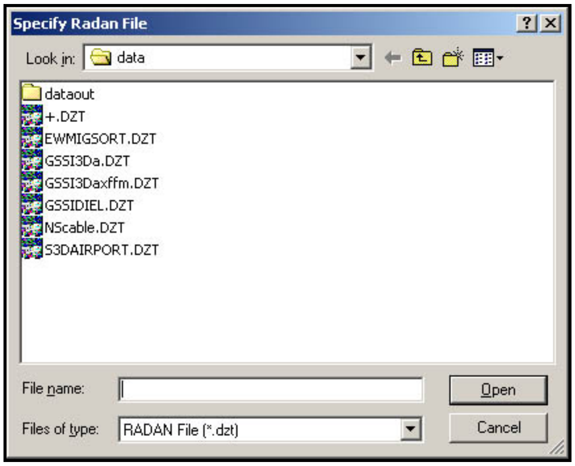


Figure 191: 3D file selection browser for Super 3D file.

8 Enter file parameters:

- Starting X & Y Coordinates
- Rotation Angle of grid
- Also available are the options to Reverse Line Direction or Reverse Line Order.

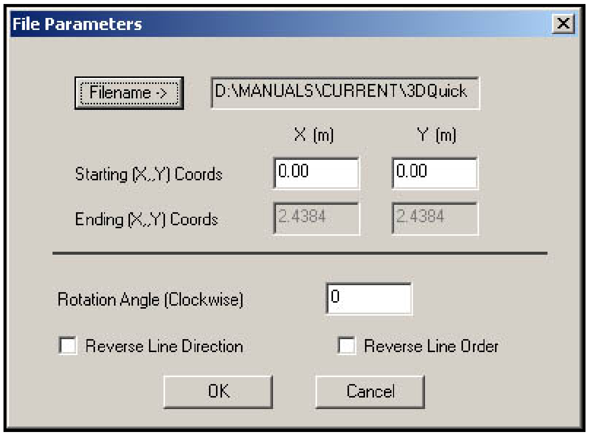


Figure 192: Super 3D File Parameter dialog.

9 Once the first file is selected, a block appears in the Site Grid Map window with an arrow showing the direction of the first profile collected. The Site Grid Map window will also reflect the dimensions of the selected file.

10 Continue adding files until all the grids in the survey area entered.

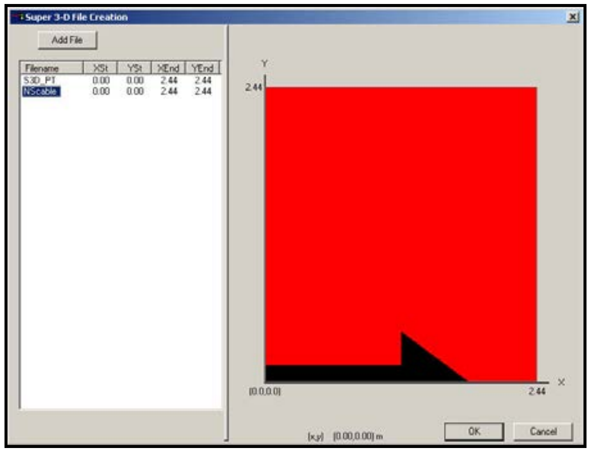


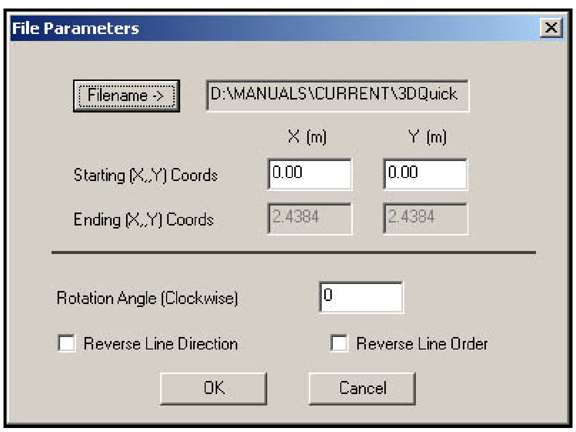
Figure 193: Super 3D File Creation Dialog with single grid.

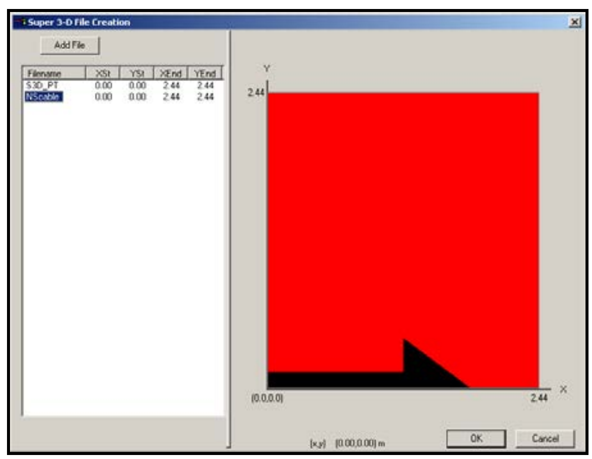
Orthogonal Super 3D Files

The following example shows 2 data sets collected at 90 degrees over the same survey area. Super 3D will merge the data sets and display peak amplitudes selected from the two data sets.

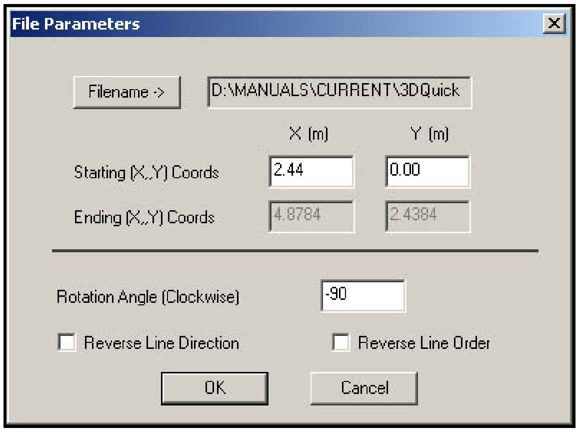
1 Create new Super 3D Project.

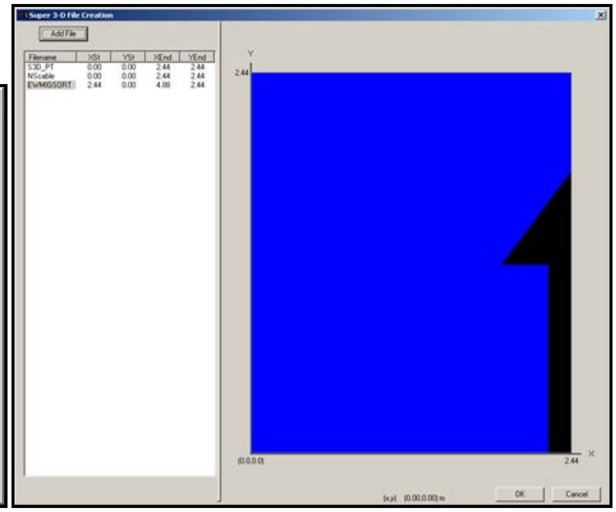
2 Add first file.





3 Add second file.

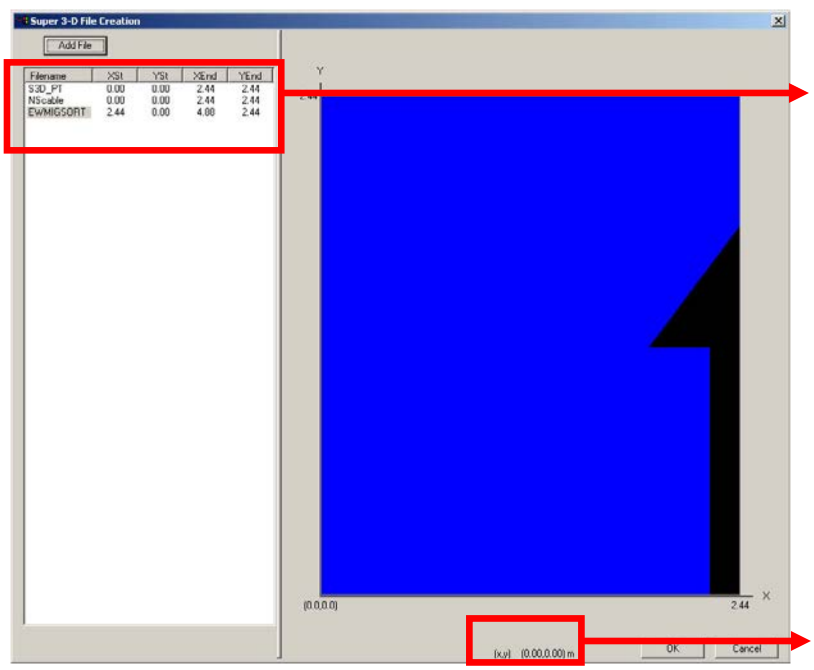




The above File Parameters dialog shows the second file, rotated counter clockwise 90 degrees starting at the lower right corner of the initial grid.

Note: The File Management dialog displays each file in the Site Grid Map, as the cursor passes over a file in the Site Grid Map window, the file will be highlighted in the File Management dialog.

The cursor in the Site Grid Map window is active showing X and Y coordinates.



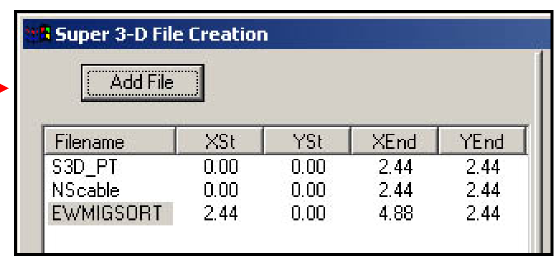


Figure 194: List of files with coordinates in Super 3D file.

4 When all grids are entered into the new Super 3D file, click OK.

5 The new Super 3D file will run, reassigning coordinates to the data in the new Super 3D file according to user input information.

6 When this process is finished, the new Super 3D file will be displayed on the screen as a regular 2D vertical profile with all transects connected.

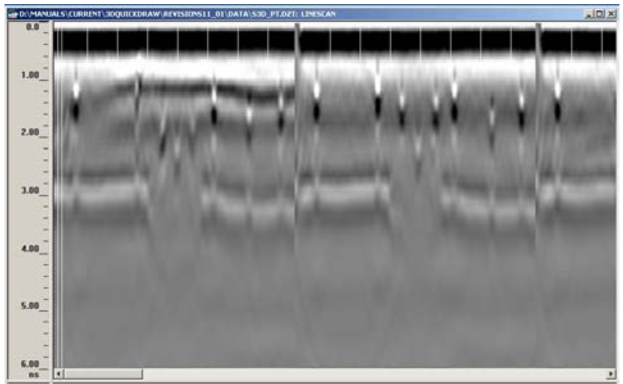


Figure 195: Super 3D *.dzt vertical profile. View Super 3D files using all the 3D cube display options.

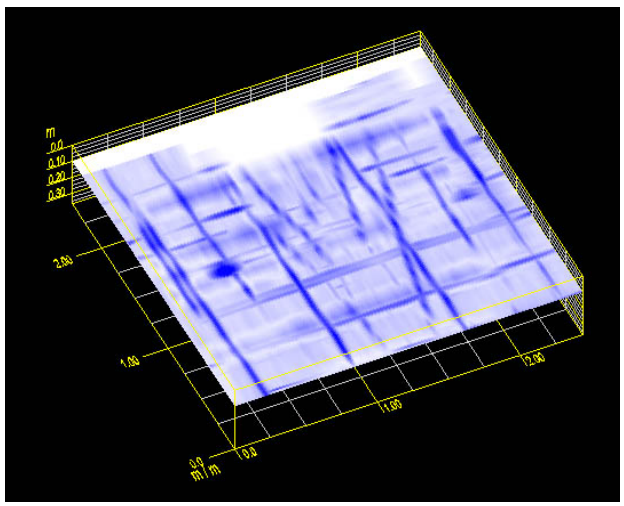


Figure 196: Super 3D file of combined survey grids collected with a 90 degree angle.

The two regular 3D files that were combined to create the above image are:

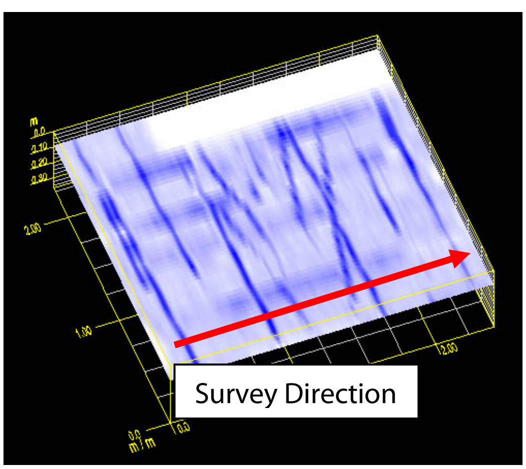


Figure 197: Grid 1

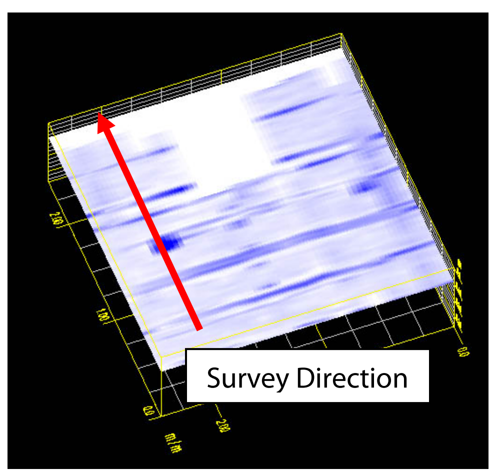


Figure 198: Grid 2 (collected with a 90° orientation to Grid 1).

Multiple-Grid Sites

Super 3D will create a single Super 3D file for your project area by combining multiple 3D files into one Super 3D file.

1. Follow the same steps above for creating a new Super 3D file (*.s3d).
2. Enter each fully processed regular 3D file making sure to enter X & Y min coordinates and any rotation angle that will correctly position each grid. (Line order and direction can be reversed if necessary.)
3. There may be some overlap with multiple files. To correctly layer each file, place cursor on top of file to be moved, right click and select where the file should be positioned (On Top, On bottom, Down One Layer, Up One Layer).
4. When all files are added, click OK.
5. The new *.dzt file will appear after the S3d function runs. View the 3D cube using all display options.

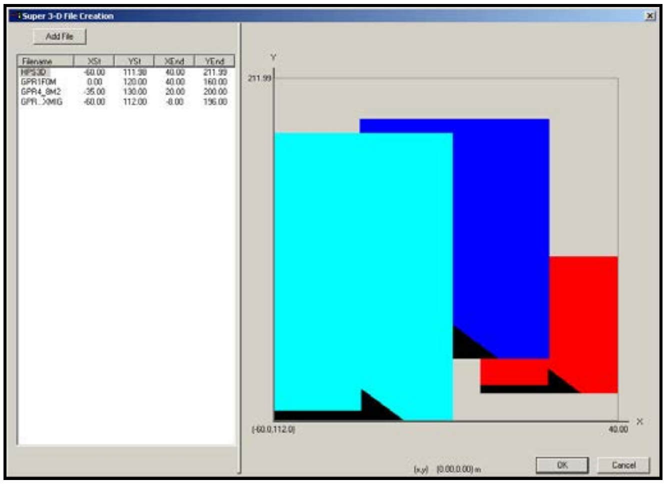


Figure 199: Super 3D file Creation dialog with multiple grid files

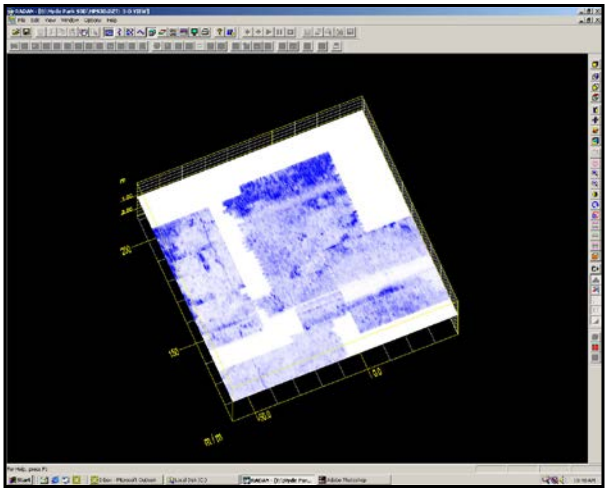


Figure 200: Super 3D file showing 3 combined grids.

Appendix D: Installation

This section is for users who purchased the 3D QuickDraw separately, at a later date than the main module. Users who purchased the 3D QuickDraw module at the same time as the main module, should skip this section.

Additional modules can be purchased and added to RADAN at any time. Contact GSSI for details. To activate the 3D QuickDraw module after purchase:

1. Activate the RADAN program.
2. Press the F5 key to open the Activation dialog box. You will see two sets of numbers:

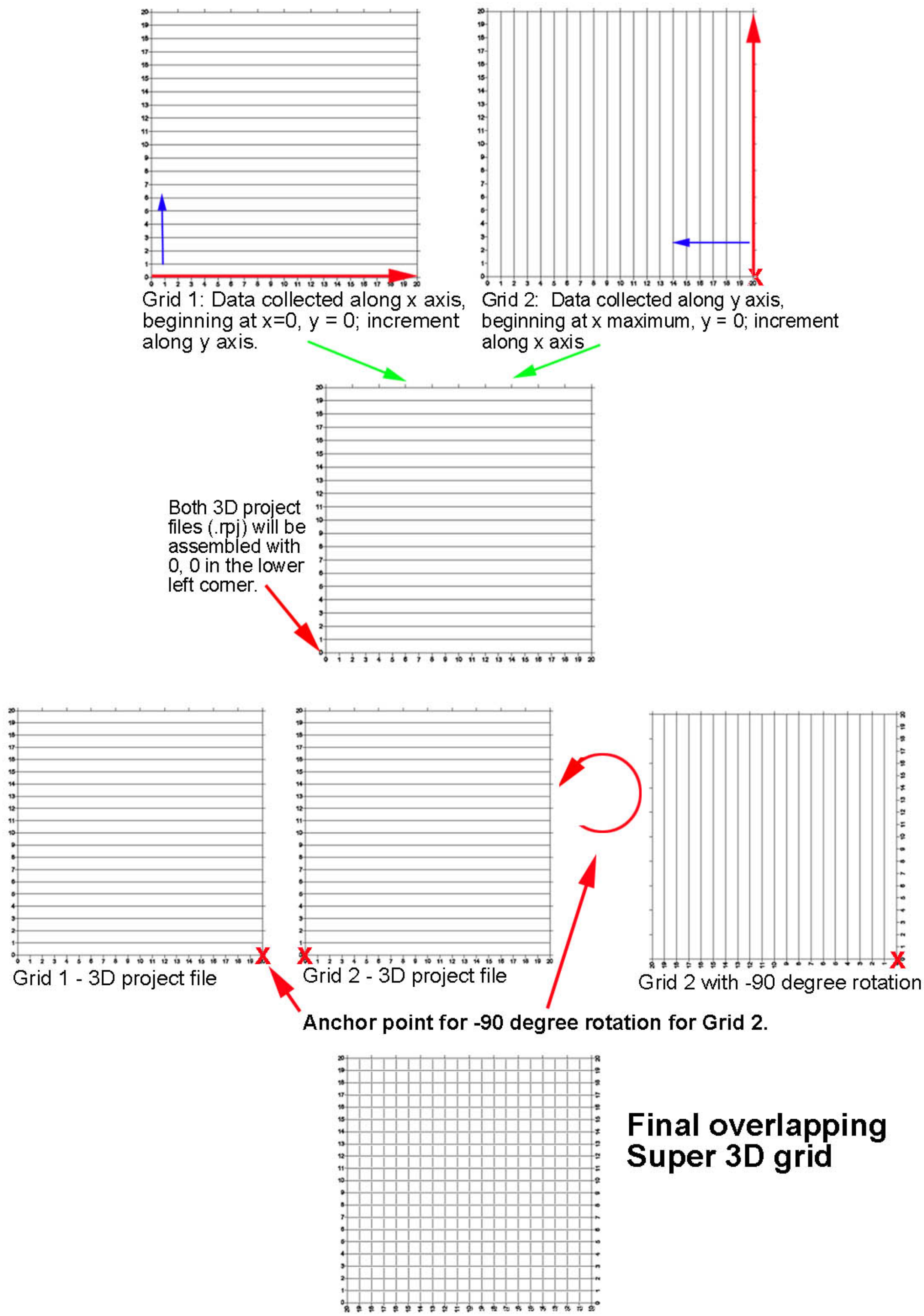
   User code 1
   User code 2

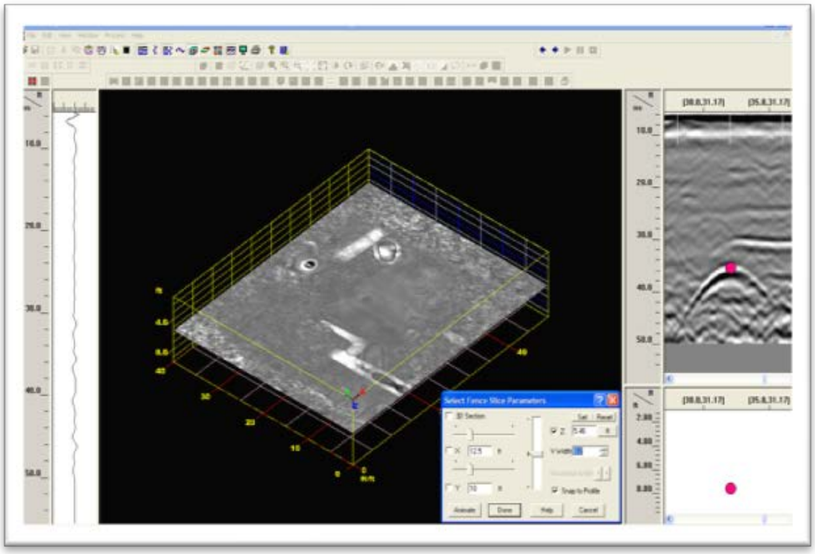
3. Record these numbers and visit the GSSI support site at support.geophysical.com (you do not need a www at the beginning of this web address).
4. Follow the instructions to register for a username and password and then follow the instructions for software activation. You will receive the following:

   Key number 1
   Key number 2

5. Once you receive these numbers, open the Activation dialog box in RADAN by pressing F5. Record these two numbers in the appropriate fields.

Appendix E: Super 3D Rotation Guide





RADAN

Interactive 3D Module

Geophysical Survey Systems, Inc.
www.geophysical.com

August 6, 2009

Table Of Contents

Introduction

The I^{3D} module in RADAN Version 6 helps you interpret your GPR data. You can view (a) the O-scope display, (b) 3D display (c) Linescan display, and (d) depth pane display of 3D data files in one window.

In addition, you can interactively interpret the data in the 3D and Linescan views by drawing in points and pipes (and soon layers) right on the data. These added targets show up in all four views at the same time. The 2D and 3D panes are interactive and editable. All targets added can be saved in a binary file or ASCII file for later viewing and editing.

To help data interpretation, an auto-target function has been developed that looks for and marks hyperbolas in the data. Not only can this give you a leg up on subtle utility interpretations, but in some cases, weeks of time analyzing large data-sets can be cut dramatically. Gigabytes of data can be analyzed in well under an hour, automatically performing the first 80-90 percent of the time-consuming task of data interpretation.

With the I^{3D} module, designed especially for the UtilityScan and StructureScan users, you can create clean accurate data for presentations in record time.

Note: I^{3D} requires both RADAN 6.6 and 3D QuickDraw to run.

Getting Started 

For users of RADAN with this module activated, the I^{3D} module is opened when you select the Interactive Interpretation button. If you do not see this button, go to View > Toolbars and make sure that the Toolbar is opened. If the file is not 3D format, then the normal Interactive Interpretation window opens with an O-scope view on the left side. For 3D files a 3D view is also opened.

Navigating

1 After you click on the I^{3D}, the window shown in Figure Figure 201 will pop up.

- If you are starting a new session, then check the box for "Generate New Pick File."
- If you are continuing a session, then click on the "Pick File" button and browse for the saved pick file that you last worked on.
- Pick files will have the root name of the DZT file that they were generated from and they will have the extension .LAY or .BII.

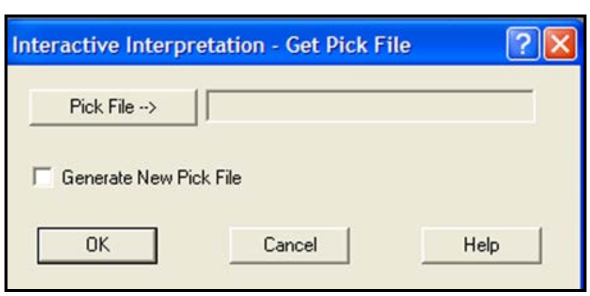


Figure 201: Interactive Interpretation Pick File.

2 Once you open a 3D file in I^{3D}, four windows pop up.

- By clicking and dragging the gray frames that separate the views, you can resize them as you like.
- Notice that clicking in the 3D window activates all the buttons you use in 3D QuickDraw.
- Clicking in the Linescan window changes the focus by activating the Interactive Interpretation options and graying out the 3D buttons.
- Each window pane can act independently in this way.

But I^{3D}'s power is that the views are also interactive. If you create or edit a point or a pipe in the 2D window, it shows up in 3D and vice versa. If you click on the 2D window, the actual scan shows up on the wiggle trace along with a circle where your point is located.

At the same time, a 3D "cross-hair" appears on the 3D cube, showing you exactly where you are in the data. If you look at the bottom right corner of the RADAN window you will see the X, Y, Z information in real-time. This lets you move around your data intuitively and accurately. All the information is right there.

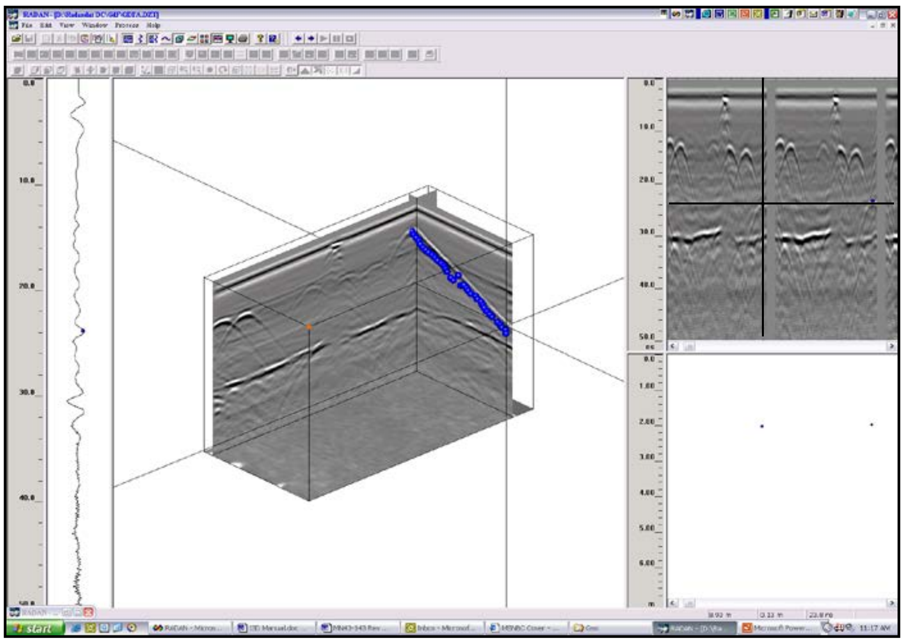


Figure 202: Moving around the data with the cursors.

Adding and Modifying Targets in Linescan View

Once the I^{3D} view is opened from a 3D file, you can add picks from either the 3D view or the Linescan view.

The addition and deletion of picks in the Linescan portion of Interactive Interpretation works the same as Interactive Interpretation in earlier versions of RADAN. There are several differences in the pick properties, however. These differences are listed below.

Main Menu

The new Main menu, accessed by pressing the right mouse button with the mouse cursor in the data pane is shown in Figure 203.

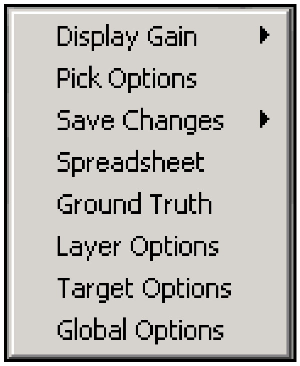


Figure 203: New Main Menu in Interactive Interpretation.

The new Main menu has divided the Other Options menu item that existed in previous versions of RADAN into 3 categories: (1) Layer Options, (2) Target Options, and (3) Global Options.

The layer options have not changed from previous versions of RADAN; and, currently, no layer picks will appear in 3D. Layer picks will be viewed in 3D in a *future* version of RADAN.

The Target Options Menu item opens up a target list as shown in Figure 204.

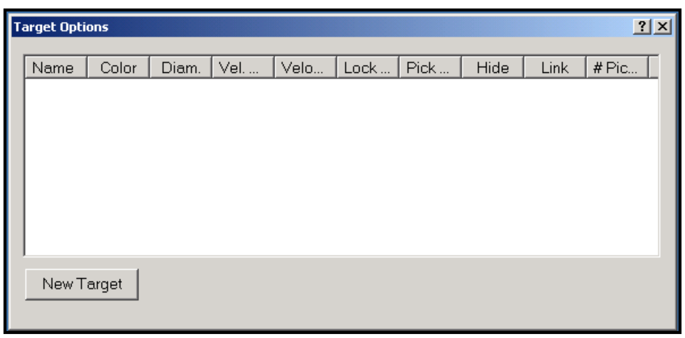


Figure 204: Initial Target Options Menu.

Click 

to add a new target to the target list. A new target is shown in Figure 205.

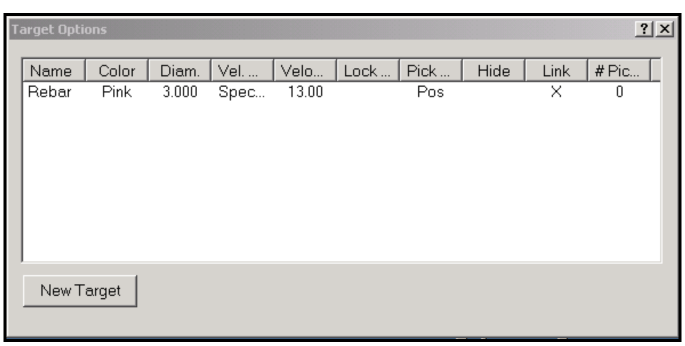
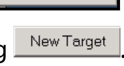


Figure 205: Default new target added after pressing 

.

The target properties can be edited by moving the mouse over the target name, which in this case is Rebar and double-clicking. This opens up the target parameters dialog, shown in Figure 206, which allows you to change target parameters.

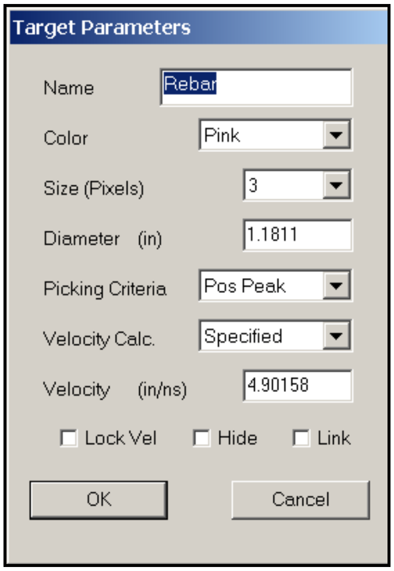


Figure 206: Target parameters dialog.

There are a number of target parameters that can be modified. These include the target name, color, diameter, picking criteria, velocity calculation method, and the velocity value if you choose to specify the velocity. In contrast to Version 4, the target size (diameter) is in physical units instead of the previously used pixel values. If no diameter is specified, the pixel size will be used.

The options new to Version 5.0 include three check-boxes:

Lock Vel – if this box is checked, all targets with the same name are forced to have the same velocity.

Hide – the target is hidden from view when this box is checked.

Link – when this box is checked all of the targets with the same name are physically linked in the 3D view. This basically allows you to visualize pipes and elongated targets.

When adding targets in the Linescan portion of I^{3D}, you have the option of selecting the desired target to add. First, imagine you add 3 targets to the Target Option list, as shown in Figure 207.

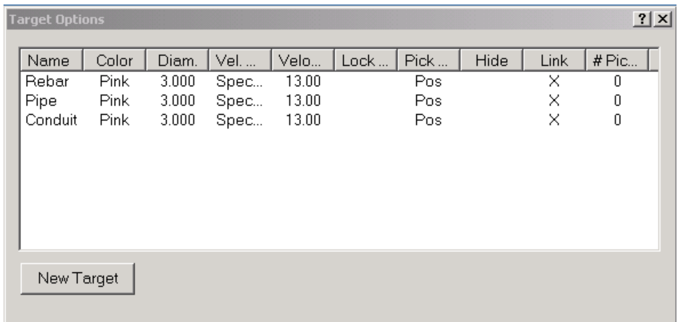


Figure 207: Target Options list after adding 3 new targets.

Next, you open the Main menu and select Targets as the Current Focus. You then have the option of selecting the current target, as shown in Figure 208.

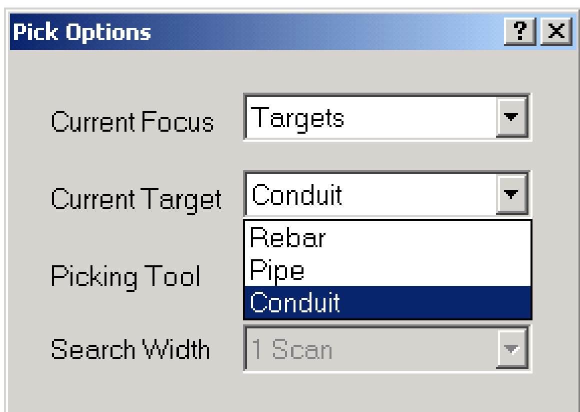


Figure 208: The user has the option of selecting which target to add when adding picks to the Linescan portion of I^{3D}.

All other operations in the Linescan portion of Interactive Interpretation are essentially the same as in RADAN NT version 4.x.

Saving Targets

There are now two options for saving targets identified in I^{3D}. These save options are accessed in the same manner as previous Interactive Interpretation versions. You must go to the Main menu from the Linescan view of Interactive Interpretation and select Save Changes then Current File or New FileName. The Save File Dialog shown in Figure 209 now has two options:
(1) ASCII File and (2) BII file.

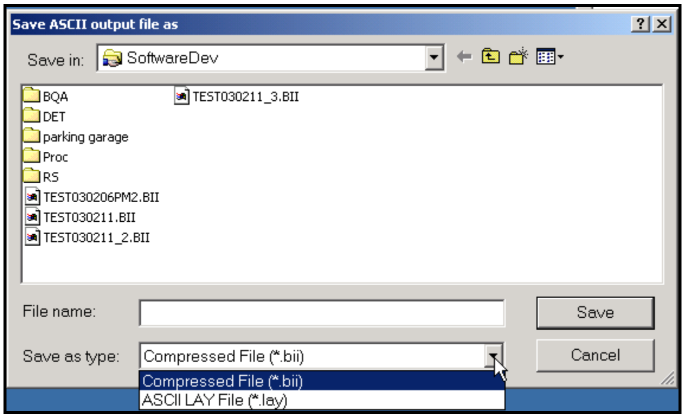


Figure 209: Two different file formats that I^{3D} files can be saved in.

The .BII extension is an acronym for Binary Interactive Interpretation. The BII file is a binary file that is efficiently written and read into RADAN. It is recommended that during intermediate processing steps you save the work as a BII file, then only at the completion of the project write the output as an ASCII file.

RADAN 6.6 has the capability of reading all RADAN NT ASCII .lay files generated in previous versions of RADAN. However, there is no backward compatibility between ASCII files created in RADAN 6.6 and previous versions of RADAN. In other words, .lay files created in RADAN 6.6 cannot be read in RADAN 4.x.

Adding and Modifying Targets in 3D View

Before proceeding, familiarize yourself with the 3D QuickDraw manual, since this description assumes a basic understanding of our 3D functions. Please note that several important improvements have been made to 3D QuickDraw in Version 6.6. Two “Target” shapes are available in I^{3D}, Points and Pipes. Pipe targets are nothing more than multiple “linked” points. With these you can perform most of the data analysis required for GPR interpretations.

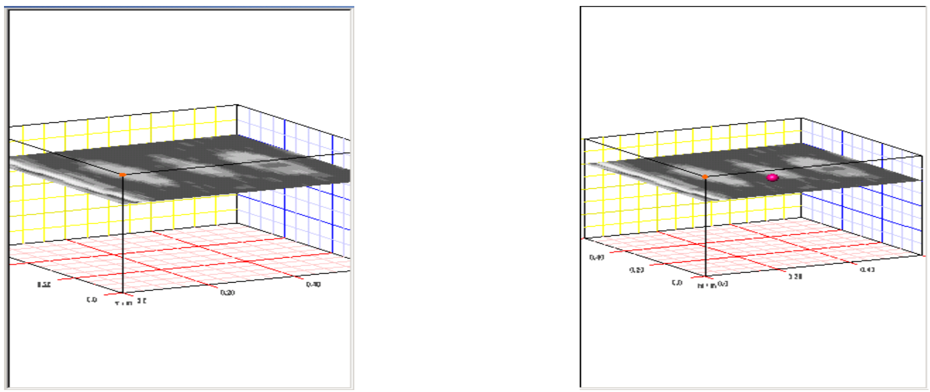
Adding Targets

To add new points in the 3D view, simply put the mouse cursor in the desired location anywhere on the data slices and double-click (this is the same as with 3D QuickDraw). A target will appear on the data and a unique Name will be created in the I^{3D} Target Options List described earlier.

The target will be picked using the picking criteria of the current target selected in the Linescan view. This means that if Pos Peak is the picking criteria, the target will be located at the nearest positive peak in the data. If you clicked on a Z-slice the target may be above or below Z-slice depending on the Z-Slice Thickness selected.

If you don't see your dot, then (1) check that all four corners of the slice are visible, (2) rotate the cube to see if the positive peak was located *underneath* your slice. If you want a dot right ON your slice, change your Z-slice thickness to a minimum, and try again. Now the dot will be drawn right on the surface of your slice (with the diameter set to zero). More on this later.

Helpful Hint on "all four corners." Before adding targets in the 3D view portion of I^{3D}, it is important to remember that the *entire slice* of data must be showing in the view. We use each corner to calculate your cursor position. Figure 210 (a) shows a slice with the edges clipped. No targets can be added to this slice. Figure 210 (b) shows a slice that will permit the addition of targets.



Clipped view – no targets can be added.

(b) Data with no clipping – targets can be added.

Figure 210: Two different magnifications of 3D view: (a) clipped view that prevents addition of picks, and (b) view that is not clipped.

Adding "Pipes"

Linking points together creates tubes, useful for mapping rebar and pipes in 3D. To create a pipe double-click with your left mouse button at one end, then press the Spacebar and double-click on the other end of your pipe. These two targets will then be linked together. Continuing to hold down the Spacebar while adding additional targets creates a snake of linked points. These new points keep getting added to the same Target Name until you double-click without pressing the Spacebar.

What if you want to join (or link) two points together? Two separate targets (points or pipes) can be grouped together to create a new single linked target by right-clicking your mouse and selecting Group Target(s). But first you need to select them.

Selecting Targets

Once you have points and targets in your data, you may modify them only if they are selected. You know a target is selected when a yellow border blinks around it. There are three ways to select targets:

1. Simply right-clicking it.
2. Holding down the Ctrl key lets you left-click to select multiple targets.
3. Holding down the Shift key lets you left-click and drag a square border around targets you want to include in selection.

Once several targets are selected, you can modify them by right-clicking on any one of the selected targets. You can unselect and start over by right-clicking elsewhere.

Helpful Hint: Since small targets are sometimes hard to select, you can continue to press Ctrl or Shift and right-click anywhere within 3D to modify the selected targets. That way the targets won't become unselected by mistake.

Helpful Hint: Once you link targets to form pipes, the targets will be connected in the order that you selected them. Be sure to keep this in mind when selecting targets.

Modifying Targets

Right-clicking permits three options for modifying: Edit, Delete, Group (Figure 211).

Figure 211: Modifying selected targets.

- Group Targets combines targets, creating a new entry in the Target Options List on the 2D side. A numerical extension is added to the new target name.
- Delete deletes targets from the Target List.
- Editing lets you change target properties. (Also accessible on the 2D side)

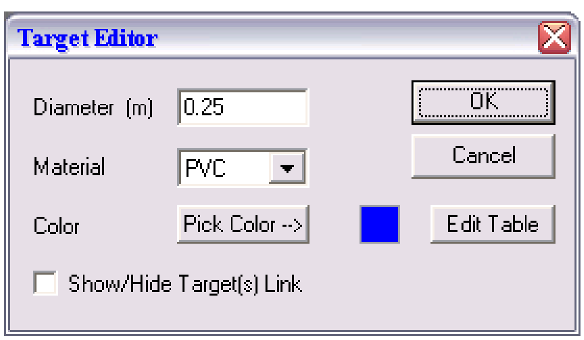


Figure 212: Editing target properties.

You can check Show/Hide Target Link to change the state of the selected targets.

If targets already appear linked, checking Show/Hide Target Link reverts them to individual points again and vice versa. Internally, they are still part of the same Target Name and therefore can be re-Linked again.

Helpful Hint: If you would like to break the link, you can select point(s) in the chain and click Group. This breaks the selected object(s) out of the chain and creates a new Target Name. The remaining targets remain grouped together.

You can also change the material type (metal, PVC, PE), the color and the diameter.

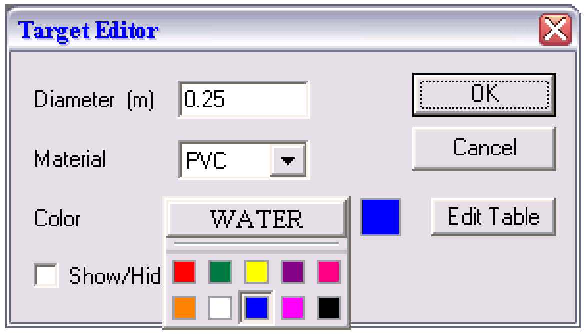


Figure 213: Editing color.

The colors (Figure 213) are linked to names consistent with the U.S. color code standard for marking underground utility lines. In the future these names may be changed to match your choice (or language) using the Shape Manager  or the Edit Table button.

Pipe Diameter

Since determining diameter from GPR data is still very much a matter of research, we set it initially to Zero (0) to make it clear that we don't know the diameter. In this case the center of the point is located in the center of the positive peak simply for the purposes of marking that position. This is useful for tracing regions of interest: building foundations: grave sites, soil boundaries etc.

However, changing diameter contains some design subtleties that can be confusing initially. If you make the diameter non-zero, we assume you have some prior information about the pipe, and that you now mean to position it relative to the diameter you have chosen. Therefore we need to shift its location down by its radius so that the positive peak of the hyperbola coincides with the **top** of the pipe. If you are not aware of this, the pipe will appear to shift down mysteriously, once a diameter is selected.

Helpful Hint: Because we now have the ability to stretch and compress the data in X, Y, or Z, pipes may not stay round. If you want to keep them round, then check Fix Pipe Aspect Ratio in the Shape Manager .

Auto Target Recognition

In most cases Auto Target Recognition saves time on data analysis and presentation. It is included in the I^{3D} module as an aid to data interpretation. Functionally it is designed to be simple and fast, offering an interpretation of data that might otherwise take too long to produce. On a 2GHz computer it can process about 1000 data scans per second, (about 16Mbytes a minute). This speed now makes it possible to do preliminary data interpretation on-site, without migration. It is especially useful for collections of large 3D files where finding pipes in data can be quite labor-intensive. Although target recognition will never be as good as the human eye, nevertheless, even a poor recognition accuracy of 50% would still reveal a shape in the data, something that might take quite a while to determine otherwise.

Actually, the function has two parts: 1) Hyperbola locating and 2) Linear Feature Extraction. First, hyperbolas are marked as points in the 3D data-space. Second, these targets points are searched for linear patterns. Of course, ATR is intended for unmigrated (usually raw) data files. Operation on Super3D files is soon to be available.

Hyperbola Locating Limitations

First and most importantly, ATR is intended as an advisor, not a substitute for intelligent analysis. The advice it offers is sometimes wrong and sometimes incomplete. The danger is that it's pretty good at finding most of the targets in the data. But don't rely on it to give the complete answer. Here are some things it's bad at so far.

1. Hyperbolas close together can be hard to untangle.
2. Extremely irregular hyperbolic shapes may not look hyperbolic enough!
3. One hyperbola under another can get misdiagnosed as multiples and ignored.
4. Hyperbolas that rest just under strong layers can be overlooked.
5. Parallel pipes, those aligned along the data path, don't produce hyperbolas, and therefore cannot be recognized with this method.

Linear Feature Extraction Limitations

Feature extraction through 3D space is an interesting challenge. The method we use is strongly biased toward perpendicular crossing pipes. Since hyperbolas in GPR data often indicate crossing pipes, this method works well in these applications. Increasingly oblique angles make it increasingly difficult for the software to follow the pipe through the data. Of course pipes parallel to the survey line are missed completely.

Operation:

1 Select Process > Auto Target, or click the Auto Target button on the process bar. 

2 Click OK.

At the end we 1) save results to a binary data file (*.BII), 2) overwrite the dielectric in the Header based on a weighted average of the velocities found and 3) automatically open the results in I^{3D}.

The user selects auto-target and hits OK to run it. The algorithm will rip through the data, marking on the screen what it finds.

Helpful Hint: shrinking (not minimizing!) the window avoids the slow-down caused by video updating. However, the data view must be visible during processing, i.e., unobstructed by other programs.

The dots (Figure 214) that appear on the screen are color-coded based on the initial recognition confidence: gray (threshold), green (good), blue (better), red (best). At the end, these initial estimates get completely changed as points get combined and sorted.

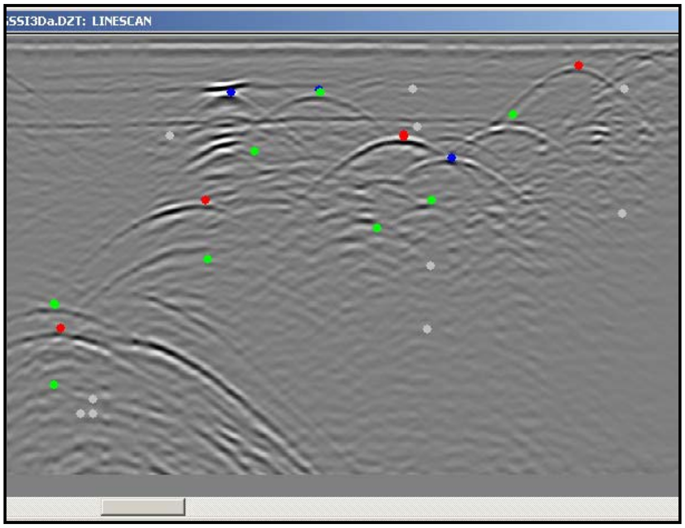


Figure 214: Auto Target running on screen.

When finished, the algorithm saves the output to a binary (*.BII) file and opens into Interactive 3D automatically. It also overwrites the Dielectric value in the header with a best guess number.

Helpful Hint: If there are only weak targets, then a nonsensical dielectric value may be produced which will need to be corrected and saved in the header. This will become immediately apparent in the 3D pane of I^{3D}.

The output is displayed in the four I^{3D} data panes, with the pipes automatically shown in 3D as in Figure 215. These are the long linear features shown in red. Weak isolated targets get dropped altogether, while the strong ones as well as points that show up in two or more passes get represented as black dots. Recognition confidence is mapped to transparency. So if the algorithm is unconfident about a target, it displays it as semi-transparent. This can be helpful information. Objects become completely solid once you hit OK inside edit, although any “grouping” causes the confidence values to reappear.

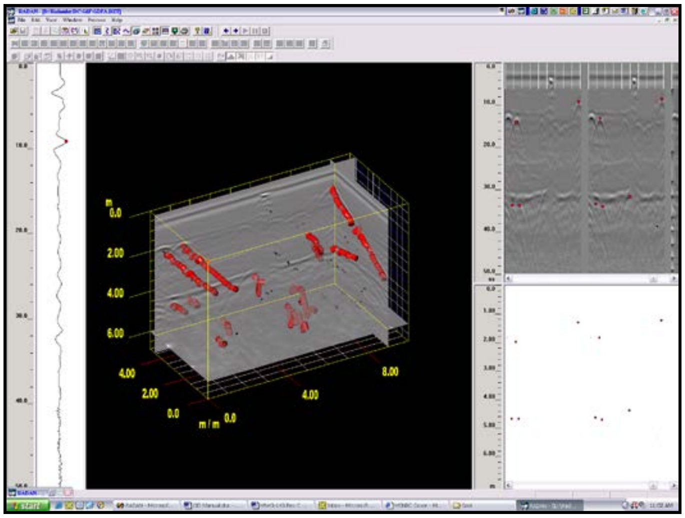


Figure 215: Unedited Auto Target output in I^{3D}.