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Subsurface Views

Sensors & Software Inc.

GPR tips

The beginning of GPR time...

Strong "dark" bands are normal at the top of the GPR cross-sections. The top of the section is the start of GPR recording time. (See Figure A - page 2). Customers invariably ask "Why are they there?" and "Why can't they be eliminated?" Answering these questions requires understanding what the bands represent and how they are created.

The transmitter in GPR systems emit an electromagnetic pulse. The pulse signal traverses many possible paths (Figure B) to the GPR receiver which detects the electromagnetic signal displayed in a GPR section. Increasing path length delays the signal arrival in time and greatly reduces the signal amplitude.

The bands at the top of the GPR section are the waves which travel the shortest distance and arrive at the receiver first. In most GPR systems, the receiving antenna is placed very close to the transmitter to create a compact system. The first arrival direct wave signals are large (since their path is short) and create strong bands in the cross-section.

GPR system developers strive to reduce the magnitude of direct signals since they can impact receiver electronics performance.

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Compiling Multiple Data Sets

See the Big Picture

When using GPR, building a coherent view of all the data is important. Real projects are rarely conducted on simple "rectangular shaped" sites. Further, surveys can extend over time as the scope of work changes. Examples best illustrate how compiling composite images makes the big picture visible.

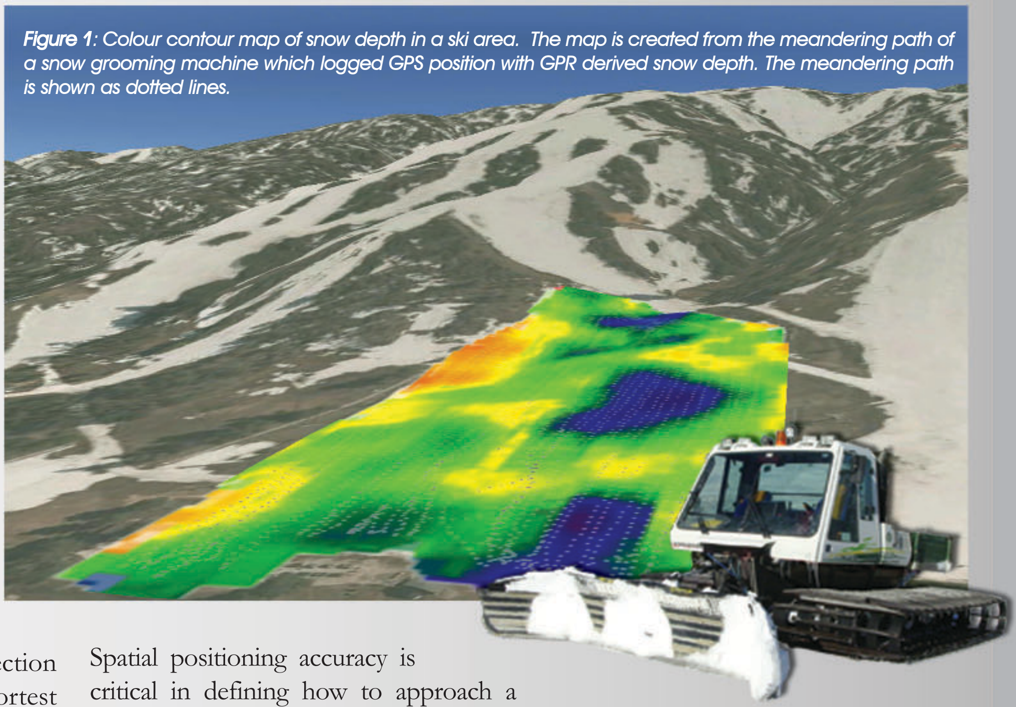

***Figure 1**: Colour contour map of snow depth in a ski area. The map is created from the meandering path of a snow grooming machine which logged GPS position with GPR derived snow depth. The meandering path is shown as dotted lines.*

Spatial positioning accuracy is critical in defining how to approach a project. Large scale mapping of slowly-varying responses can be accomplished by following one or more meandering paths while simultaneously recording position and GPR response. Detailed imaging of small scale structures is best achieved using regularized survey grids with accurately controlled positioning.

SnowScan demonstrates the meandering path approach. Ski areas have irregular shapes and snow management only requires data footprints of several square meters. Inexpensive GPS devices provide positioning to meter level accuracy. GPR data combined with GPS using QuickMap software creates snow depth images (Figure 1). The meandering path of the snow grooming machine carrying the instruments is superimposed.

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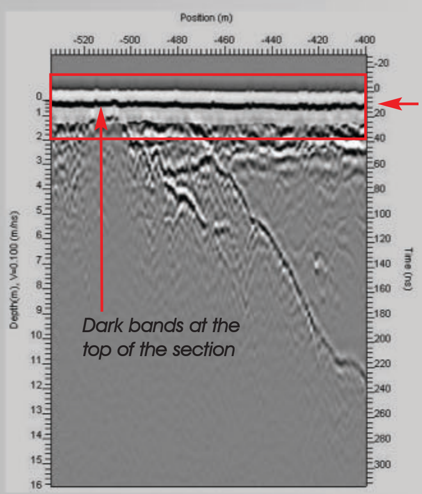

***Figure A:** An example of a typical GPR section with the dark bands indicated at the top of the section.*

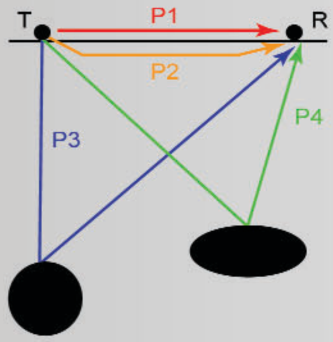

***Figure B:** The recorded GPR trace consists of the addition of signals that have travelled many paths from the transmitter to the receiver. Some paths are short, such as the direct wave paths P1 and P2, while some are longer like the reflection paths P3 and P4. Amplitude decreases rapidly and time increases linearly as path length increases.*

Some methods used to minimize the direct signal (and impacts) are:

- Increase the transmitter and receiver separation to increase the path length (increases the physical size of the system and reduces shallow target resolution).
- Shield the receiving antenna from direct waves (shields create other signal paths and do not reduce the direct ground wave signals).
- Use antenna polarization to minimize transmitter-receiver coupling (usually means all desired signals are equally reduced).
- Use non-linear electronic amplification to reduce or eliminate the initial signal (problem is hidden - not eliminated - with possibility of artifact creation).
- Apply the non-linear amplification (gain) to the recorded data (very easy to apply but just another form of hiding the issue). See Figure C.
- Estimate and subtract the direct wave signal using a digital processor, commonly used in post processing (effective but direct signals change with ground conditions making the subtraction imperfect). See Figure D.

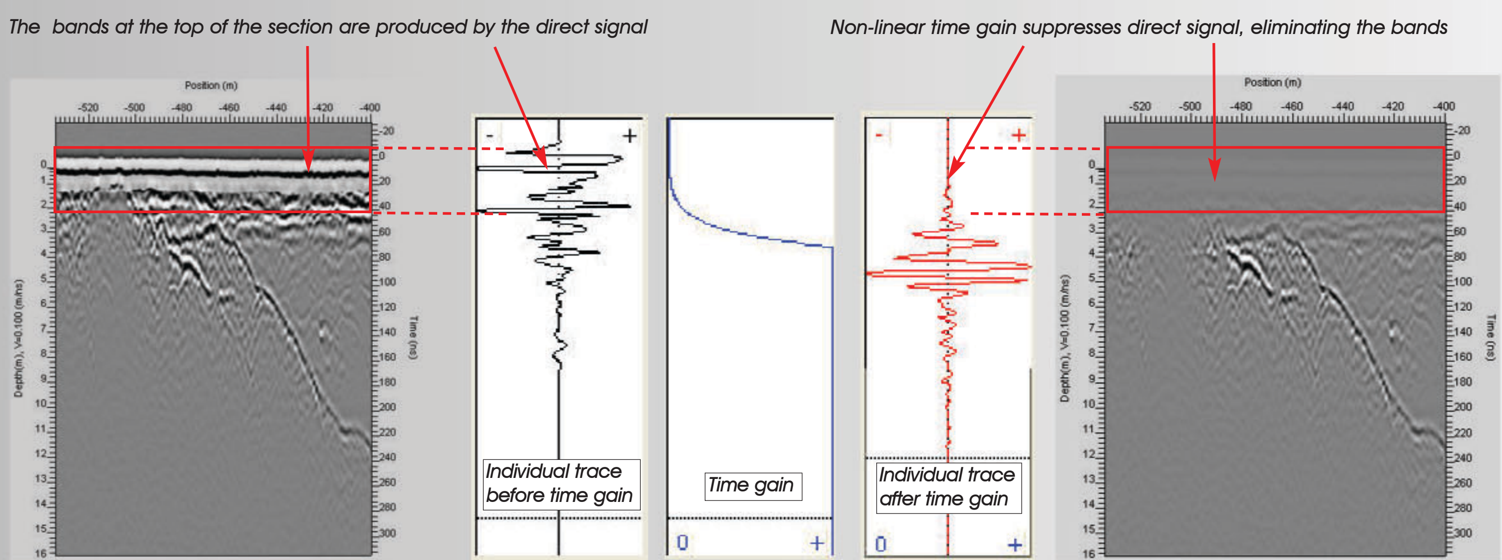

***Figure C:** A non-linear time gain was applied to the data from Figure A to suppress the direct signal.*

In all cases there are trade offs. The best philosophy is to record all signals with linear fidelity and maximize transmitter-receiver separation where possible to reduce signal dynamic range.

The first arrival direct wave signals have beneficial aspects:

- The first arrival provides a great zero time reference.
- The signal presence or absence provides operators with a quick operational indicator.
- Consistency of the direct signal amplitude at controlled sites provides a quality assurance measure.
- The first arrival contains useful information about the ground's electrical properties.

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See the Big Picture

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Buried utility mapping and concrete imaging illustrate controlled grid acquisition. Targets are normally small, requiring footprints much less then 1 square meter. The spatial positioning accuracy desired cannot be obtained using inexpensive positioning systems. A further benefit of accurate positioned grid data is that it enables use of advanced processing such as migration that substantially enhances images.

Noggin SmartCart data grids acquired over the span of 3 years are displayed together in Figure 2. The image clearly defines the locations of buried utilities leading to a remote building. The target has responses that vary rapidly in less than a meter and are enhanced using migration processing. The application required a footprint of about 0.25 m. Inexpensive GPS with 1 m accuracy augmented the grid controlled positioning. The georeferenced composite image was created using EKKO_Mapper software.

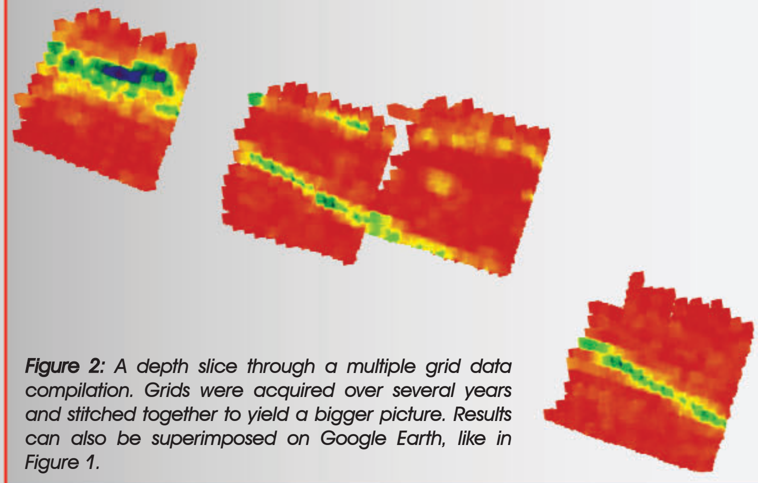

***Figure 2:** A depth slice through a multiple grid data compilation. Grids were acquired over several years and stitched together to yield a bigger picture. Results can also be superimposed on Google Earth, like in Figure 1.*

Figure 3 shows Conquest grids spanning two rooms that have been pieced together using EKKO_Mapper. The footprint required to define the reinforcing structure and the location of a buried power cable is a few square centimeters. No inexpensive indoor positioning system was available, making controlled grid acquisition critical. Further, the in-building location required working around walls and furnishings using patchwork grid acquisition.

These examples illustrate the critical issues when faced with surveying a complex site. For meandering path surveys:

- get clarity on the application objective;
- determine what footprint will be acceptable;
- determine whether GPR responses vary slowly over the footprint;
- confirm if the positioning uncertainty is smaller than the desired footprint; and
- have software such as QuickMap that melds multiple meandering paths into one image.

For detailed imaging, use controlled grids. To be effective:

- subdivide the site into suitable patches;
- visualize the area as a set of small survey grids;
- define a local site coordinate system;
- locate each patch in local coordinates;
- if georeferencing is needed, establish the translation from local to global coordinates;
- establish rectilinear survey grids on each patch for GPR data acquisition;
- use any positioning system - it can help even if accuracy is limited;
- have a flexible compilation tool such as EKKO_Mapper software to stitch the individual grids into a composite image.

Plan ahead using these suggestions and you will definitely be able to see the big picture. ■

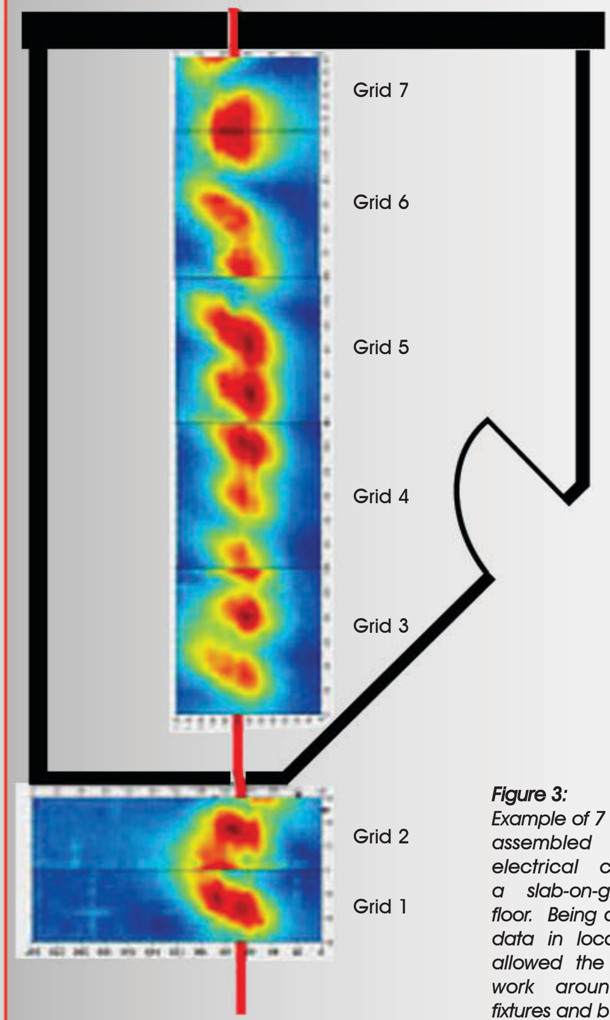

***Figure 3:** Example of 7 Conquest grids assembled to track an electrical conduit under a slab-on-grade concrete floor. Being able to acquire data in localized patches allowed the field crew to work around furnishings, fixtures and building walls.*

Technical Papers & Notes

1. **Electromagnetic Principles of Ground Penetrating Radar,**
Ground Penetrating Radar: Theory and Applications, p. 3-40
By: A.P. Annan
2009 **ref 397**

2. **Environmental site assessment of an oil field and detection and imaging of sinkholes using a novel geophysical method,**
Special Section: Near-Surface Geophysics - The Leading Edge, p. 1480-1486
By: L. M.Gochioco, M. Zhang, M. Zhao,
2008 **ref 398**

Upcoming GPR courses

One Day Noggin® Short Course
July 7, 2010
September 13, 2010

Our Noggin® short courses are offered throughout the year to anyone interested in learning more about GPR and subsurface imaging.

One Day Conquest™ Course
July 8, 2010
September 14, 2010

Our Conquest™ courses are offered to anyone interested in learning more about our concrete imaging instrument.

Imaging Concrete with GPR - May 20, 2010 - Vancouver, BC
- June 8, 2010 - Pittsburgh, PA

See us at ...

PTI 2010
Fort Worth, TX
May 2 - 4, 2010
http://www.post-tensioning.org

Trenchless Roadshow Toronto
Mississauga, ON
June 9 - 10, 2010
http://www.trenchlessonline.com/trs

GPR 2010
Lecce, Italy
June 21 - 25, 2010
http://www.ibam.cnr.it/gpr2010/

3 Day GPR short course

July 14 - 16, 2010, Mississauga, ON

Sensors & Software gives you the basics

Our annual 3-day course is an intensive course covering GPR theory, case studies, survey techniques, data processing and interpretation. A practical day in the field is part of the course.

Interested? Contact us early as space is limited.

training@sensoft.ca

The beginning of GPR time...

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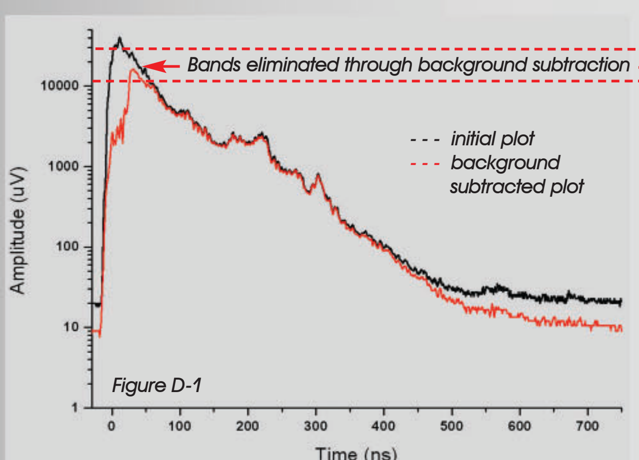

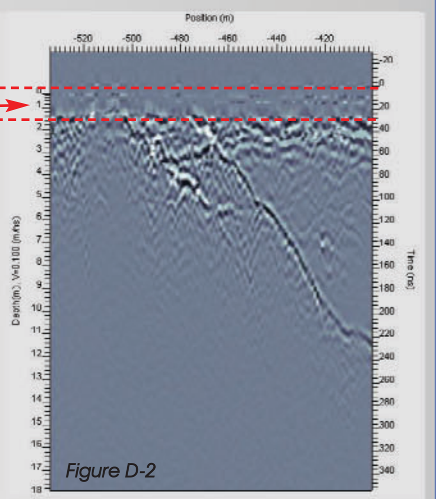

Figure D -1: *Signal amplitudes decrease rapidly with time which is approximately equivalent to path length. This common GPR display plot indicates the almost exponential decrease in amplitude versus time (or path length).*

Figure D -2: *Another way to remove the strong first arrivals is to estimate the signals and subtract the estimate from the data. These data show the use of average trace background subtraction processing on the data in Figure A.*

In summary, the "dark" bands at the beginning of GPR time are:

- a fundamental physical aspect of any GPR measurement,
- caused by large signals but can be reduced by several methods, and
- carriers of useful information. ■

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