Opening a new dimension for Ground Penetrating Radar

The GeoScope™ GPR is designed for high-resolution 3-dimensional subsurface mapping using innovative radar and antenna technology.

The fastest step-frequency system available
The GeoScope™ GPR is the fastest step-frequency radar on the market. By using a digital frequency source instead of traditional phase-locked loop technology, the GeoScope™ can generate waveforms from 100 MHz up to 3 GHz with as much as 1500 frequencies with waveform lengths of 0.5-10 milliseconds. The step-frequency radar has a coherent receiver which means that the whole waveform length (typically a few milliseconds) is used as 100% efficient integration time. By comparison impulse GPRs use stroboscopic sampling with significant loss of energy. Figure 1 shows an overview of the GeoScope system.

Figure 1. GeoScope GPR system overview.
What are the benefits using step-frequency?

- 100% efficient integration time.
- Fully programmable frequency source signature with full spectrum control.
- The frequency range can be programmed and optimized to each measurement problem. There is no need to waste energy at high frequencies if the soil attenuation is high and medium to low resolution is sufficient for the job.
- The raw measurement data can be stored as frequency domain data. This allows the user to reprocess data with different frequency weighting to enhance the features of interest. It is also possible to perform frequency domain absorption analysis of the data.
- The frequency domain data is perfectly suited for fast FK-migration for image focusing.
- The step-frequency signal is a low peak-power signal with low probability of interference with other radio systems. The 3d-Radar step-frequency system only transmits a burst of energy only when it is performing a scan.
- Due to the self-calibration of the system, there is no time-drift in the system eliminating the warm-up time.

The step-frequency waveform gives optimum source signature with a uniform frequency spectrum. The computer control allows the user to set the dwell time on each frequency as well as the start and stop frequencies as shown in Figure 2.

The radar system performs real-time time domain conversion through Fast Fourier Transform allowing the user to view B-scans from one antenna at a time. Raw data can be stored on 3DR data format either in time-domain or frequency-domain for post-processing. These data can be imported into either ReflexW from Sandmeier or RoadDoctor™ from Roadscanners OY.

![Figure 2. Step-frequency waveform.](image)

The radar is controlled from a laptop computer through an ethernet cable.
Collect up to 31 survey lines simultaneously
The GeoScope™ GPR is designed to operate with an electronically scanned antenna array containing up to 31 antennas. The antennas are scanned sequentially by the radar unit. The unique antenna system consists of air-coupled bow-tie monopole pairs as shown in Figure 3. This gives a quasi-monostatic antenna configuration with practically zero-offset distance. The air-coupled antenna array can be operated at elevations up to 30 cm off the ground allowing high-speed surveys.

![Ultra-wideband bow-tie antenna pair (cross section).](image)

Figure 3. Ultra-wideband bow-tie antenna pair (cross section).

In opposition to traditional octave-band GPR antennas the ultra-wideband bow-tie monopoles have continuous frequency coverage from the 100 MHz range up to 3 GHz as illustrated in Figure 4. This allows the user to collect data from 100 MHz to 3 GHz without changing antennas. By comparison, a similar survey using impulse GPR would require use of 200 MHz, 400 MHz, 800 MHz and 1600 MHz antennas.

![Wideband coverage of the antenna array compared with traditional GPR antennas.](image)

Figure 4. Wideband coverage of the antenna array compared with traditional GPR antennas.

The antenna elements are arranged in a linear array as shown in Figure 5 where the transmitting and receiving antennas are displaced to each other. During the survey, the radar combines the transmit/receive antennas sequentially to obtain a number of profiles (or channels) as shown in Figure 5. Depending on the application the system can be programmed to use all the antennas in the array for full 3-D imaging mode. For regular road survey, the system can be programmed to use fewer elements for depth sounding on a sparse spatial grid.
Figure 5. Antenna layout Model V1821.

Figure 6 illustrates the different survey modes ranging from high-speed surveys collecting 3 profiles to high-resolution surveys collecting data on all antennas for full 3-dimensional imaging.

Figure 6. Data Collection modes.
The standard range of antenna arrays includes the following models:

<table>
<thead>
<tr>
<th>Model</th>
<th>Width</th>
<th>Elements</th>
<th>Spacing</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>V0605</td>
<td>0.6m</td>
<td>5</td>
<td>7.5 cm</td>
<td>200 – 3000 MHz</td>
</tr>
<tr>
<td>V1821</td>
<td>1.8m</td>
<td>21</td>
<td>7.5 cm</td>
<td>200 – 3000 MHz</td>
</tr>
<tr>
<td>V2125</td>
<td>2.1m</td>
<td>25</td>
<td>7.5 cm</td>
<td>200 – 3000 MHz</td>
</tr>
<tr>
<td>V2429</td>
<td>2.4m</td>
<td>29</td>
<td>7.5 cm</td>
<td>200 – 3000 MHz</td>
</tr>
<tr>
<td>B3231</td>
<td>3.2m</td>
<td>31</td>
<td>10.0 cm</td>
<td>300 – 3000 MHz</td>
</tr>
</tbody>
</table>

Custom antenna models with other line spacing, frequency ranges, and array lengths are available on request.

In the standard (zero-offset) antenna scanning sequence, the GeoScope transmits/receives sequentially on each antenna pair. Data is collected in the transverse direction by firing the antenna pairs in a linear sequence from Antenna Pair #1 to the highest antenna pair.

**Multi-offset recording (option)**
The Multi-offset recording allows the user to set up antenna scanning sequences with independent transmitter and receiver antenna locations.

With the Multi-offset feature, the system offers a higher degree of freedom to build more advanced scan patterns. It is for example possible to transmit at Antenna #1 and receive at Antenna #8, (i.e. with an offset distance along the cross-line direction). The automatic Common-Mid-Point (CMP) gather collects traces centered at the antenna in the center of the array with increasing offsets (normal move-out) as shown in Figure 1. This feature is used to estimate the wave velocity using standard methods (semblance analysis) used in seismic processing. Other scan sequences can be programmed as well. Note that this mode of operation works in a sequential manner, hence using all possible combinations of transmitter and receiver antennas will slow down the data collection speed somewhat.

![Figure 1. Common-Mid-Point Gather.](image)

**User friendly data acquisition and control**
The GeoScope™ is controlled by a laptop or flat panel Windows XP PC using standard 1Gbit/s Ethernet connection. The user software allows you to configure the frequency range, integration time, number of active antennas, and sampling interval for each survey. You can also create arbitrary scan
sequences with arbitrary offsets, as well as using pre-defined Common Mid-Point sequences. During data acquisition, the users can view data from one channel at the time and define their own range of markers to be introduced into the data. DMI (Distance Measurement Instrument) calibration is also easy conducted using the step-by-step guidance. Figures 8 and 9 contain screenshots of the user interface.

Figure 8. GPR Data Acquisition with Real-Time 3D view.

![GPR Data Acquisition with Real-Time 3D view](image)

Figure 9. Step-frequency waveform setup.

![Step-frequency waveform setup](image)
Real-Time 3D View (option)

The Real-Time 3D (RT3D) option of the GeoScope™ GPR gives the user an instant view of data from every channel from a 3d-Radar antenna array while collecting data in the field.

By displaying simultaneous views of in-line profile (radargram), cross-line profile and a horizontal time slice at a selected depth, RT3D makes field work much easier and enables the user to view and recognize targets while surveying as the objects are showed in Real-Time. This unique feature allows the user to track an object like a pipe while surveying. When coupling the RT3D equipped GeoScope with a GPS, operators can mark directly over the object’s location and have an exact position of the object.

Real-Time performance is achieved by using the built in capabilities of the Field Programmable Gate Array inside the GeoScope. This FPGA converts frequency domain data into time domain data by performing inverse fast Fourier transforms, or iFFTs. The resultant data, when converted into the time domain, truly exploits the multi-channel, step-frequency capabilities of the antenna and GeoScope.

The GeoScope™ stores the GPR data on its internal hard drive, and the user can select between storing frequency or time domain data for further post processing. Frequency domain data are useful for special processing prior to conversion to time domain.

The RT3D view opens many new applications such as real-time landmine, UXO and IED detection, fast and efficient utility mapping and real-time road and bridge inspection. It is even possible to use the RT3D GPR for tracking and guidance when mapping large structures like pipelines and cables.

Accessories/ options

The GeoScope™ GPR unit (19” rack) can be integrated in a rock solid flight case with wheels and telescopic handle for easy shipping and travelling.

The GeoScope™ can be used in combination with Digital Video Camera using RoadCam™ software from RoadScanners for simultaneous recording of video, GPR data and GPS data. Each video frame is tagged with GPS position and GPR scan number.

For easy surveying of large areas the Programmable Spray Painting Device (Figure 10) is very useful for marking the survey swaths during acquisition. This device can be programmed to paint a dashed line on the surface when it is mounted on the edge of the antenna array.
The antenna array can be equipped with a 4-wheel lightweight trailer assembly (Figure 11) that fits into the antenna container during transportation. The trailer connects to a standard 50mm ball hitch used on cars. For railway operation we can provide railway wheels with adjustable gauge.

For high-speed surveys we recommend to mount the array directly to the vehicle’s front or rear bumper as shown in Figure 12.