3d-radar as

GeoScope™ User's Manual
Model Geoscope Mk4

Document Version 2.0

3d-radar as

Contact Details
3d-Radar AS
Klæbuveien 196B
NO-7037 Trondheim, Norway
(+47) 7289 3200 Phone
(+47) 7289 3201 Fax
www.3d-radar.com

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STATEMENT ACCORDING FCC
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Any changes or modifications not expressly approved by 3d-Radar may void the user's authority to operate the equipment.

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Per RSS-Gen, Section 7.1.3 This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

This Ground Penetrating Radar Device shall be operated only when in contact with or within 1 m of the ground. This Ground Penetrating Radar Device shall be operated only by law enforcement agencies, scientific research institutes, commercial mining companies, construction companies, and emergency rescue or firefighting organizations.

Selon RSS-Gen section 7.1.3, cet appareil est conforme aux normes "Industry Canada license-except RSS standards". Son fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne doit pas provoquer d'interférences, et (2) cet appareil doit accepter toute interférence, y compris les interférences pouvant provoquer un fonctionnement indésirable de l'appareil.

Ce dispositif de radar à pénétration du sol ne doit être utilisé que lorsqu'il est en contact avec ou à moins de 1 m du sol. Il ne doit être mis en œuvre que par les services officiels d'investigation, les instituts de recherche scientifique, les sociétés minières commerciales, les entreprises de construction et les organismes de secours d'urgence ou de lutte contre les incendies.

Safety
EXPOSURE TO RADIO FREQUENCY RADIATION
The radiated power of the radar antenna is approximately 10mW. This is a very low RF power. However, we recommend to maintain a minimum separation distance of 10 cm (approximately 4 in.) between yourself and the bottom side of the radiating GPR antenna to avoid any harmful radiation levels.

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Abbreviations

DMI	Distance Measurement Instrument (encoder wheel)
GPR	Ground Penetrating Radar
SFCW	Step-frequency Continuous Waves
TX	Transmitter
RX	Receiver

1 Introduction

This document contains the user manual for the GeoScope™ Mk4 ground penetrating radar system, designed and manufactured by 3d-Radar AS, see http://www.3d-radar.com. The purpose of this document is to explain how to assemble the hardware and use the GeoScope software. GPR and signal processing theory is not covered by this manual. Some guidelines for configuring the waveform will be provided.

1.1 3d-Radar Technology

The GeoScope is a three-dimensional step-frequency ground penetrating radar. The GPR transmits electromagnetic waves through an antenna array and measures the echo from layers and objects in the subsurface. The depth of the objects is found by measuring the travel time from the signal is transmitted until the echo is received. A depth estimate is obtained by multiplying this time with the wave velocity of the signal.

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 140 MHz up to 3 GHz. The step-frequency technique has a coherent receiver which means that the whole waveform length 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 with optional GPS system.

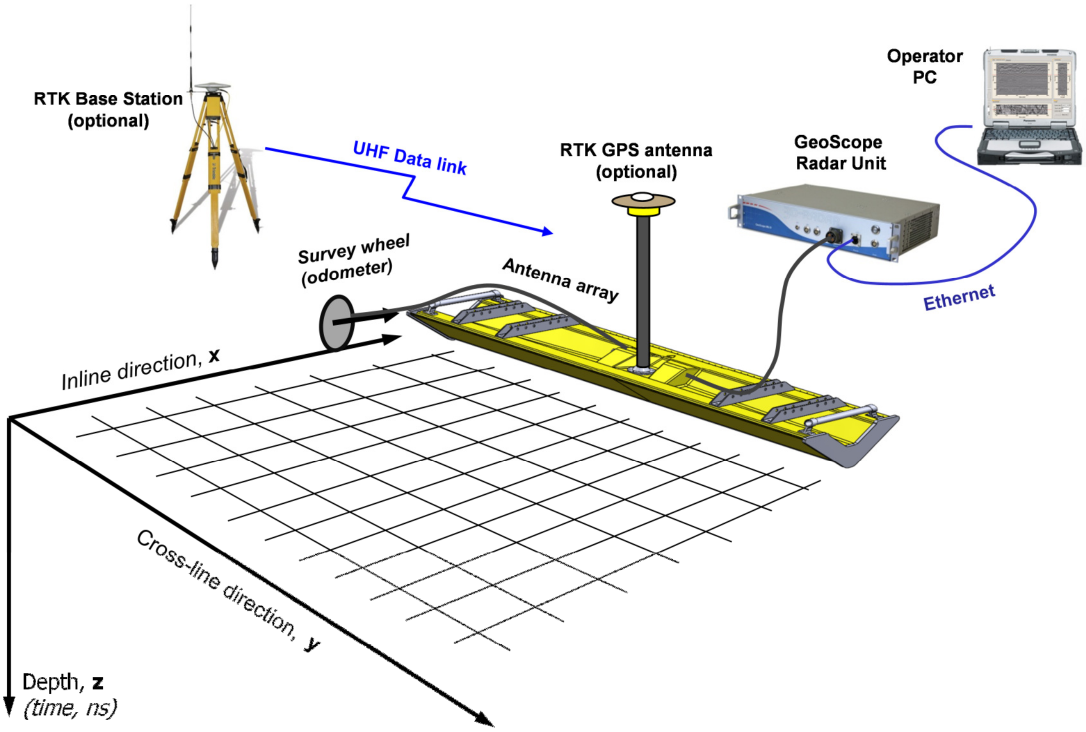


Figure 1 - GeoScope GPR system overview.

The step-frequency waveform gives optimum source signature with a uniform frequency spectrum. The computer control allows the user to set the dwell time per frequency as well as the start and stop frequencies as shown in Figure 2. The GeoScope sequentially transmits one complete waveform on each transmitting antenna while receiving on the corresponding receiving antenna. The transmission of one complete waveform on one transmitting element is called as scan. The recorded frequency domain data contain one complex value for each frequency in the waveform.

The radar system performs real-time time domain conversion through Fast Fourier Transform allowing the user to view radargrams from the antenna array. These data can be imported into either **3dR Examiner** software, or RoadDoctor™ from Roadscanners OY.

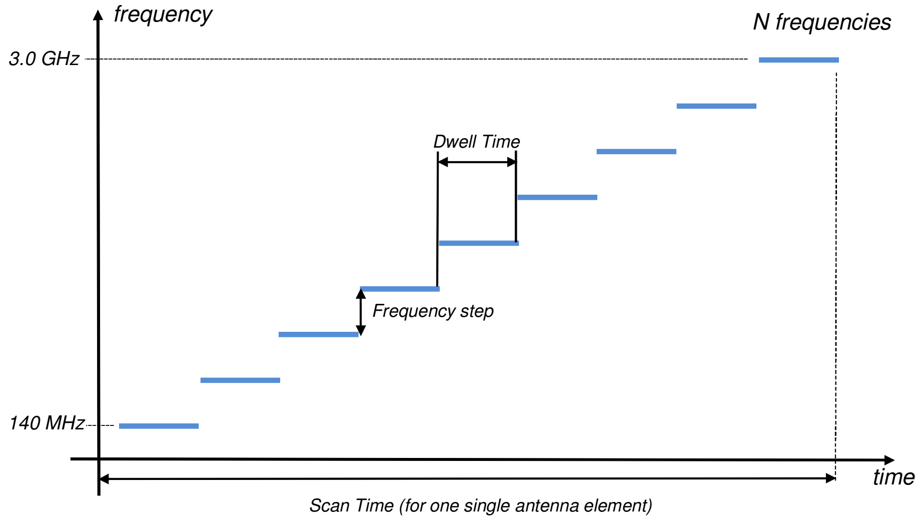


Figure 2 - Step-frequency waveform.

The radar is controlled from a laptop computer through an Ethernet cable. The system can also be configured with GPS/Total Station interface (option) to allow recording of position data through the serial port (RS-232).

1.2 Collect up to 41 survey lines simultaneously

The GeoScope™ GPR is designed to operate with an electronically scanned antenna array with up to 41 antennas. The antennas are scanned sequentially by the radar. 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 50cm off the ground allowing high-speed surveys.

Figure 1 shows the spatial sampling grid for a typical 3D radar survey. The Distance Measurement Instrument (DMI) outputs a trigger signal to the system every time the array has moved the specified interval along the x-axis. The horizontal sampling interval determines the Δx in the sampling grid. The array is aligned along the y-axis. The spacing between the antenna elements in the array gives the Δy in the sampling grid.

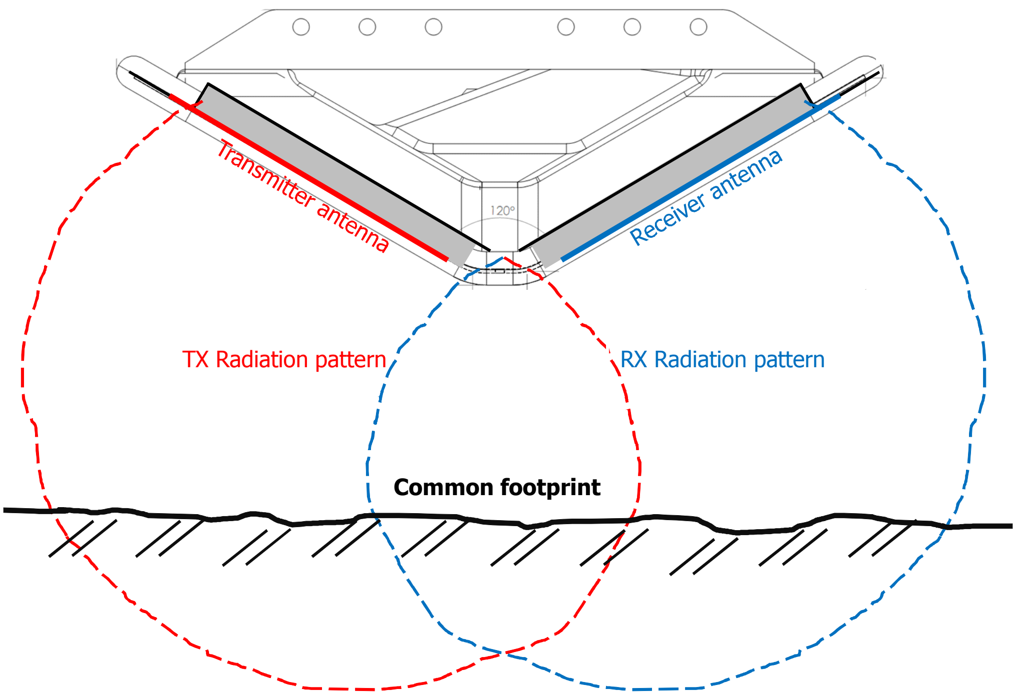


Figure 3 - Ultra-wideband bow-tie antenna pair (cross section).

As opposed to traditional octave-band GPR antennas, the ultra-wideband bow-tie monopoles have continuous frequency coverage from the 200 MHz range up to 3 GHz as illustrated in Figure 4. In practice this allows the user to collect data from 140 MHz to 3 GHz without changing antennas. By comparison, a similar survey using impulse GPR would require use of 200MHz, 400 MHz, 800 MHz and 1600 MHz antennas.

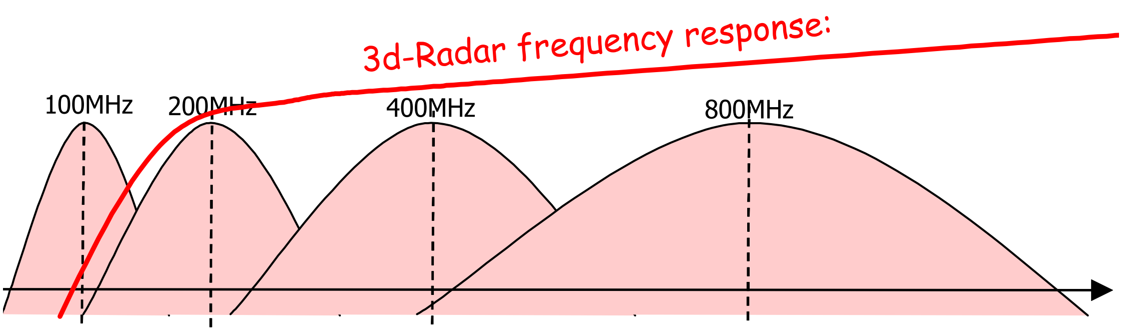
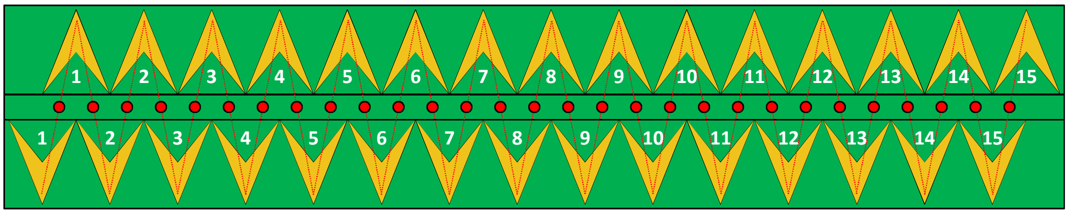


Figure 4 - Wideband coverage of the 3d-Radar antenna array.

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.



Ch#	1	2	3	4	5	...	25	26	27	28	29
Tx#	1	2	2	3	3	...	13	14	14	15	15
Rx#	1	1	2	2	3	...	13	13	14	14	15

Figure 5 – Antenna layout DX2429.

The standard range of antenna arrays includes the following models:

Model	DX0909	DX1213	DX1821	DX2125	DX2429	DX3341
Length (mm)	900	1200	1800	2100	2400	3300
Channels	9	13	21	25	29	41

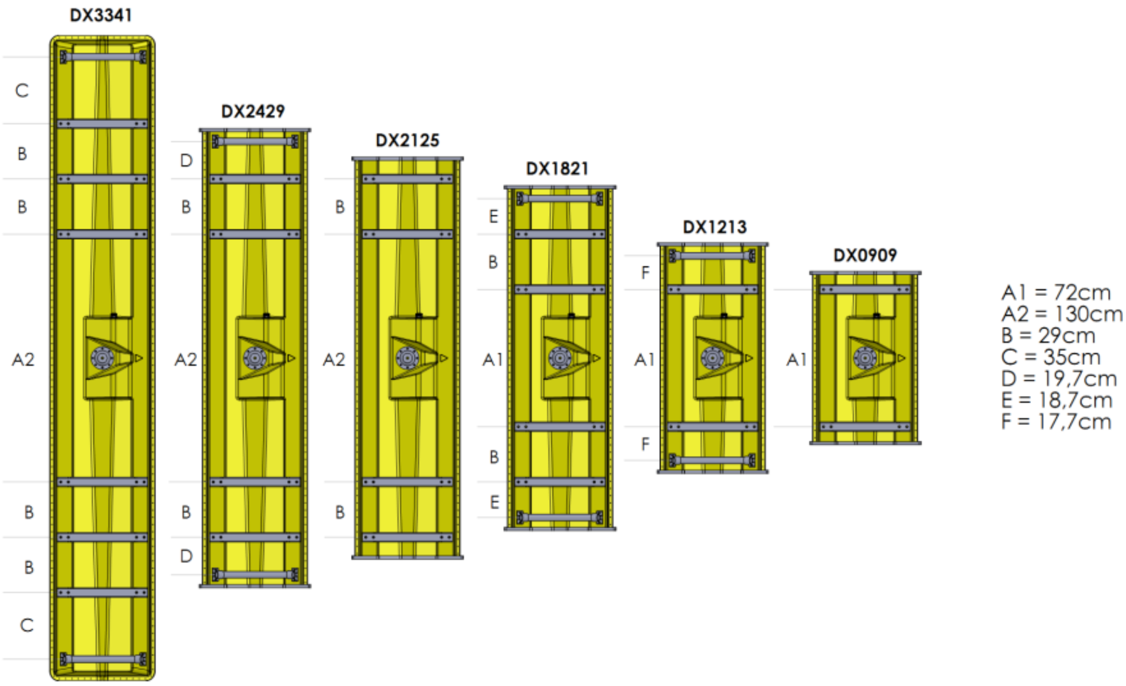


Figure 6 – Available antenna models.

1.3 Multi-offset recording (optional)

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

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.

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 7. 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.

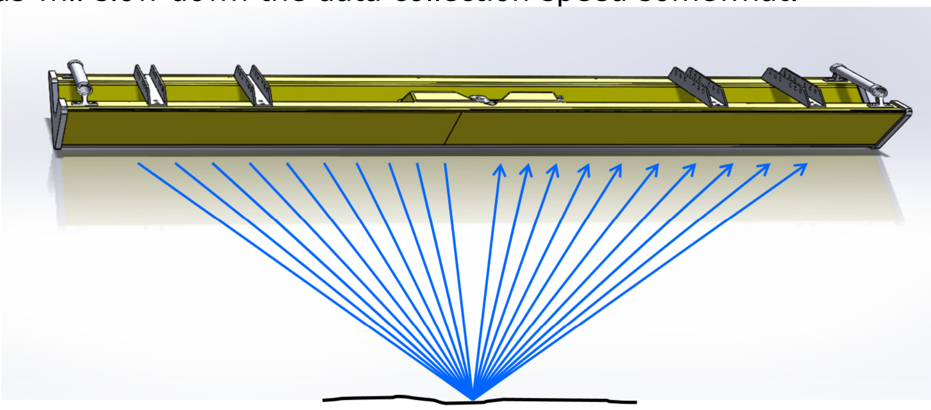


Figure 7 – Common-Mid-Point Gather.

1.4 Accessories/options

The GeoScopeTM can be used in combination with digital video camera, GPS and CamLinkTM software from RoadScanners for simultaneous recording of video, GPR data and GPS data.

The antenna array can be equipped with a 2-wheel lightweight trailer assembly (Figure 8). The trailer connects to a standard ISO 50mm ball hitch used on cars. For railway operation 3d-Radar can provide railway wheels with adjustable track width. For high-speed surveys we recommend to mount the array directly to the vehicle

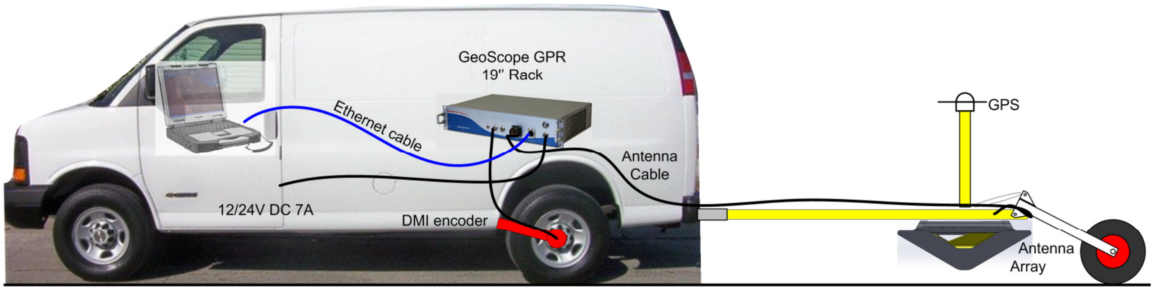


Figure 8 - Typical GPR setup with a 2-wheel trailer.

2 Hardware Components

The GeoScope system consists of four main parts:

1. GeoScope unit
2. Antenna Array
3. Distance Measurement Instrument (DMI)
4. Control computer

2.1 GeoScope Unit

The GeoScope unit is the heart of the GPR system. It contains the RF hardware including the digital signal generator and the ADC system which stores the collected data. The GeoScope runs off 12V or 24V DC. Figure 9 shows the GeoScope front panel with connectors.

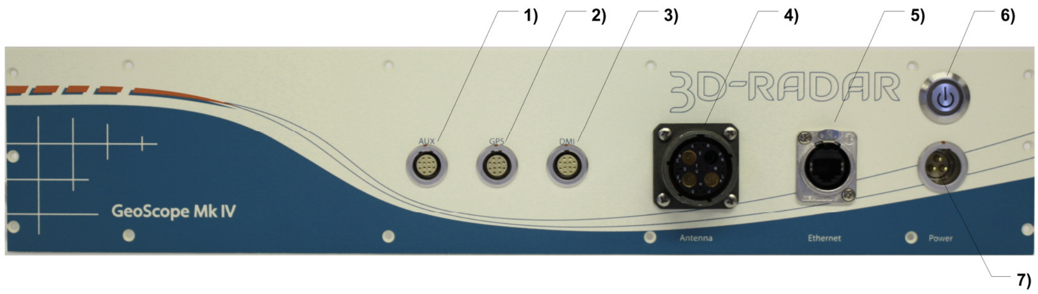


Figure 9 - GeoScope front panel.

The front panel contains the following elements:

Item	Name	Description
1	AUX	Aux Ethernet for service + I/O (Section 2.2)
2	GPS	RS232 port for recording NMEA0183 messages from GPS, + Additional RS232 port, + Trig I/O (Section 2.3)
3	DMI	DMI encoder input. (Section 2.4)
4	Antenna	Antenna & Control cable
5	Ethernet	Ethernet connector to Operator Computer
6	Power Switch	Push to turn on. LED ring is red when system is up and running. Push again to turn off. LED ring goes dark when system is turned off.
7	Power Input	Connector for 12/24V DC Input (Section 2.5)

To turn on the GeoScope, press the power button briefly and wait for the startup procedure to finish. This takes a few seconds.

When the GeoScope is started with an Ethernet cable connected directly to the control computer, it will have the following TCP/IP address: 192.168.8.2.

To stop the GeoScope, press the power button briefly and wait for the shutdown procedure to finishWhen the shutdown procedure is finished the power button LED goes dark and fans stop.

Make sure that the side air inlet and outlet are not covered to ensure proper cooling. The air inlet filter should be cleaned regularly when operating in dusty environments. Insufficient cooling might lead to system malfunction and potential loss of data. Make sure that the GeoScope is not overheated by direct sunlight.

2.2 Aux connector

The AUX connector (Lemo EGB.2B.312.CLL) has the following pin configuration:

Pin	Signal
1	*Reserved*
2	*Reserved*
3	GND
4	Ethernet
5	Ethernet
6	Ethernet
7	Ethernet
8	Ethernet
9	Ethernet
10	Ethernet
11	Ethernet
12	N/C

2.3 GPS input

The GPS input connector (Lemo EGA.2B.312.CLL) has the following pin configuration:

Pin	Signal
1	GPS RS-232 TX (output)
2	GPS RS-232 RX
3	GND
4	*Reserved*
5	*Reserved*
6	GND
7	Trig out (TTL)
8	Trig in (TTL)
9	GND
10	N/C
11	N/C
12	N/C

The Geoscope reads serial data on NMEA0183 format from any GPS or GNSS receiver. Recommended settings for the GPS NMEA output is:

Parameter	Recommended settings
Position data	$GPGGA (1Hz output rate)
Velocity data	$GPVTG (1Hz output rate)
Baud rate	115,200
Data bits	8
Parity	None
Stop bit	1

2.4 Distance Measurement Instrument (DMI)

The DMI consists of an optical encoder that measures the distance of movement and generates trigger pulses to the GeoScope. The DMI outputs quadrature TTL pulses to allow detection of forward or reverse travel direction. The DMI should be recalibrated at least each time you change its mounting.

The DMI input connector (Lemo EGG.2B.312.CLL) has the following pin configuration:

Pin	Signal
1	+5V DC to DMI-1, max 50mA
2	DMI-1: Quadrature A (TTL)
3	DMI-1: Quadrature B (TTL)
4	*Reserved*
5	*Reserved*
6	GND
7	GND
8	DMI-2: Quadrature A (TTL)
9	DMI-2: Quadrature B (TTL)
10	*Reserved*
11	*Reserved*
12	+5V DC to DMI-2, max 50mA

The relationship between DMI Tick count and the quadrature pulses is shown in Figure 10. One tick is counted for each rising or falling edge of pulse trains A and B.

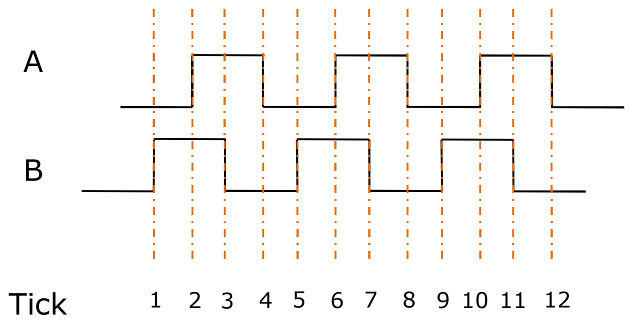


Figure 10 - DMI pulses.

The supplied DMI encoder has 1000 pulses/rev.

2.5 Power Supply

The GeoScope runs off 12/24V DC (10.5 – 36V). At maximum load, the GeoScope power consumption is about 80W (7A @ 12V DC). During startup the inrush current might be as high as 10A.

⚠ **Never unplug the power cable from the GeoScope when the system is running. This may cause loss of data and insufficient system shutdown.**

The Power connector (Lemo EGJ.3B.303.CLA) has the following pin configuration:

Pin	Signal
1	Pos
2	Neg
3	Chassis GND

The GeoScope may be connected to the 12V DC system of a car, but special care should be noted to voltage stability. Always use a separate 12V accumulator or a DC/DC converter with galvanic isolation between the GeoScope and the car 12V outlet to stabilize the voltage. Avoid starting the car engine when the GeoScope is connected since the starter motor might cause severe voltage surge.

When running the GeoScope on battery power, it is very important to use a high quality battery. Old batteries may often appear to be fully charged when measured without load, but when connected to load, like the GeoScope, voltage can drop quickly.

Under normal operation, a fully charged 50Ah lead-acid accumulator with good health, will last for approximately 5 hours. A gel-type deep-cycle accumulator is recommended both for safety, i.e. reduced risk for acid leakage, and for endurance. Gel accumulators are designed for supplying power over a long period of time with repeated deep discharging. Ordinary car accumulators on the other hand, are constructed for supplying high currents over a short period of time during starting. They are not constructed for being completely discharged repeatedly.

2.6 Control Computer

The control computer is usually a laptop with the GeoScope user software installed. The control computer is used to configure the radar waveform, calibrate the DMI, control data acquisition and manage the collected data stored on the GeoScope. The system performance will be affected by the speed of the client laptop. A workstation grade CPU, gigabit Ethernet and a fast SSD is recommended.

As of 2013-05-04, the client software runs on Java 1.6 while 3drExaminer requires Windows 7.

If the computer runs Windows XP with Service Pack 2 or newer, the Windows firewall should be disabled when connecting to the GeoScope; otherwise you will have problems connecting to the GeoScope. If you use other firewall software, and experience connection problems, please turn off this as well.

An alternative to disabling the firewall completely is to enable the outgoing ports 19005 and 19003.

3 Antenna Array

3d-Radar AS provides different antenna array solutions for the GeoScope. Current arrays range from widths of 90 – 330 cm with number of channels ranging from 9 to 41Figure 11 shows the DX2429 antenna array which covers a width of 240 cm using 29 channels.

Figure 11 - Antenna Array Model DX2429.

3.1 Antenna Trailer

The antenna trailer is a lightweight assembly which allows the array to be towed behind a vehicle. Figure 12 shows a drawing (top view) of the trailer assembly.

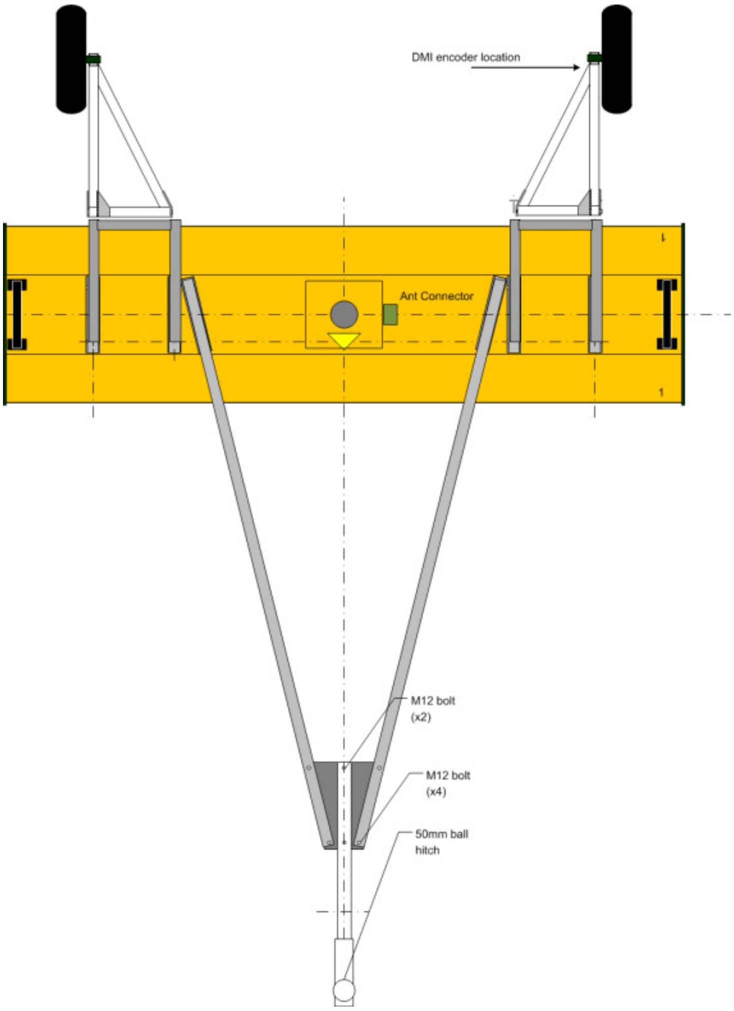


Figure 12 - Antenna trailer.

The antenna trailer is assembled by mounting the wheel brackets to the top of the antenna array as shown in Figure 13. Mount the wheel containing the DMI close to Antenna #1. Use the rigging screw to adjust the elevation.

Figure 13 - Wheel bracket with DMI.

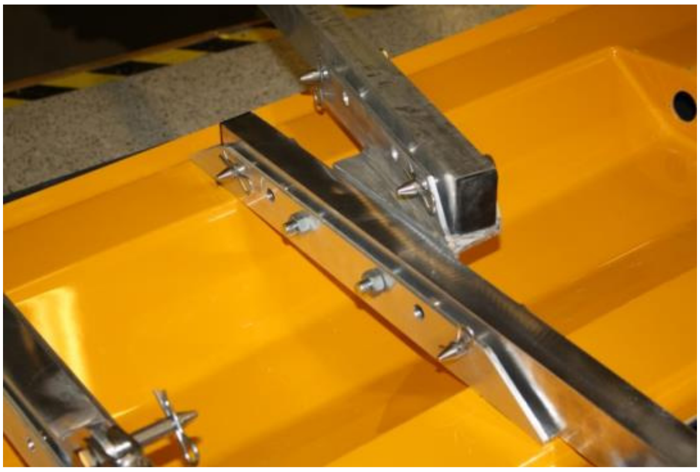


Figure 14 – Installation of tow bars.

Mount the tow bar to the top brackets on the antenna array as shown in Figure 14.

Connect the RF cable to the main antenna connector of the array. Connect the DMI cable to the DMI connector on the wheel bracket containing the DMI.

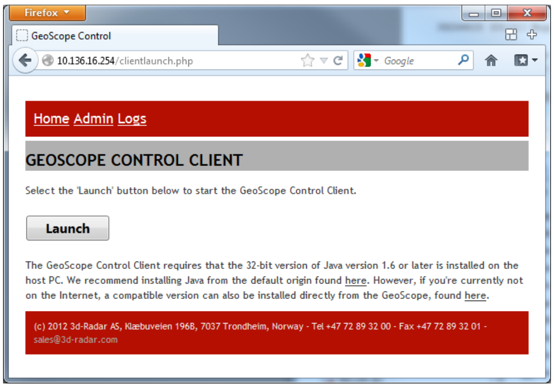
Note that the 2.4 and the 3.3 meter arrays (DX2429 and DX3341) are wider than the vehicle. Use flashlights and visible markers to the edge of the antenna array when operating at roads with traffic. Always wear visible reflex safety west when working at roads and railways.

Make sure that the elevation of antenna array is sufficient to avoid that the array hits the surface during data acquisition. Recommended elevation is 10 – 50 cm above the ground surface.

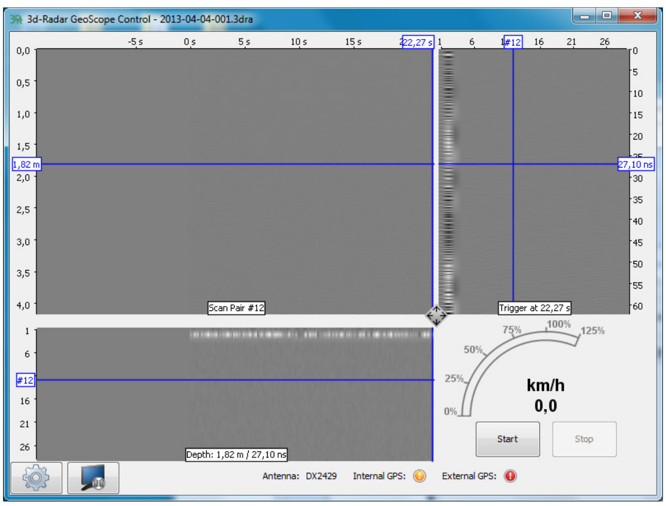
4 Operation

By following the steps below, you are ready to collect data with the Geoscope:

1. Connect the Antenna array, the DMI encoder and DC power to the GeoScope. Optionally, connect the External GPS.
2. Power up the GeoScope by pushing the button at the top right of the front panel.
3. Connect the client computer to the Ethernet interface using a standard CAT5E twisted pair cable. Please make sure that:
    a. The Local Area Network adapter on the client computer is configured with a fixed IP address in the 192.168.8.x range, where x is different from 2 (192.168.8.5 for example) and with a Subnet Max value of 255.255.255.0
    b. Power options of the client PC are set to "High performance" (Win7) or "Always on" (XP).
    c. There is available hard-disk space for your .3dra files which are stored on the client computer.
4. Open a web browser window and enter *http://192.168.8.2* in the URL field.



5. Push the "Launch" button, and the client GUI will appear:



6. Select survey settings by clicking the cog-wheel icon and selecting "Survey Settings".
   a. Adjust the sliders. Note that the max speed changes according to your slider settings. Depending on the "time window" setting, you may or may not get the full depth in the quick view. The full range is always recorded to file.
   b. Select your "File Location" for storage of 3dra files.
   c. Press "OK" to close the dialog.
7. Push "Start" button in the main window. Notice file name and location in window title bar. If you are driving too fast, some scans will be lost and vertical red stripes will be shown in the data view. When the acquisition is done, press "Stop". The 3dra file is now available in your specified location.
8. Make sure the DMI Calibration values, the General DMI Settings and the External GPS Settings are updated in the "System Settings" tab before performing a survey task.
9. 3dR Examiner software version 2.61 or newer is required for post-processing the .3dra files.

5 Maintenance

5.1 Cleaning air filter

Remove the air filter inlet cover at the rear right side. Open the cover and use a vacuum cleaner or compressed air to blow dust from the filter. Mount the filter in the same manner as opened.

5.2 Cleaning of connectors

The RF and control cables may be cleaned either using compressed air from a can or Isopropanol based electronic cleaning spray. Never use water to clean connectors. During field work, avoid putting connectors on the ground or in water in order to minimize the probability of getting sand or dust inside the connectors. Inspect connectors for corrosion at regular intervals.

5.3 Cleaning the antenna array

The antenna array top cover can be cleaned with a wet cloth with ordinary cleaner. Never use high-pressure jet water washer on the antenna. The bottom side can be cleaned firmly with a humid rag. Do not store the antenna array inside the container if it is wet or humid.