OKM

GERMAN DETECTORS



OKM GEPARD GPR 3D

Ground Penetrating Radar

Model GPR-D01

USER'S MANUAL

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CHAPTER 1

Introduction

1.1 Preface

Dear Customer,

all our engineers, sales, training and support staff at OKM GmbH thank you for your purchase of the Gepard GPR.

The Gepard GPR detector works on the principle of Ground Penetrating Radar (GPR). The radar (RAdio Detection And Ranging) sends a signal into the ground and awaits the reflection of the electrical signal or in common terms an "echo" of the signal to detect sub-surface anomalies. Besides the detection of metallic objects, this device is also capable of detecting natural features of the earth like formations of strata, cavities, voids, faults, and other non-metallic objects. This equipment is best suited at detecting sub-surface anomalies like, sepulchers, buried treasure, buried utilities, tanks and the like.

The Gepard GPR is able to locate, document and analyze buried objects within various soil conditions, structures and vessels non-intrusively without having to excavate the area. Using the GPR is particularly useful in areas where detection is a must and excavation is not possible. The easy and flexible handling of the Gepard GPR can easily and quickly give reproducible results.

With our team of specialists we guarantee that our products are under recurrent control. Our specialists are constantly striving to improve the equipment, performance and understanding of the equipment.

By purchasing or using one of our products, we cannot guarantee that during your research you will be successful and have a find. The recognition of hidden and buried objects depends on a huge number of factors. As you well may know there are different soil types all over the world with different levels of natural attenuation. Variable soil properties can and will hamper and alter ultimate scan measurements. Areas where there is an extreme amount of ground water, varying clays, sands and wet soils making scanning more difficult and may reduce the maximum depth capabilities of any and all detection equipment, regardless of make or model.

For more information regarding where this equipment has been used, operated and tested, please visit our website or contact a sales representative. Our equipment is under constant testing and improvement. With this being mentioned, it is possible for material in this handbook to change without prior notice.

It is necessary for our company to protect our developments and all the information learned during the "Research and Development" phases in creating our technology. We strive to stay within the given framework of legislation, patents and trademark registration.

Please take the time to read this user manual and familiarize yourself with the operation, functionality and how to utilize the Gepard GPR. We also offer training for your equipment in our factory. We strive to maintain a worldwide dealer network for assistance and support. Please visit our web site for more information!

1.2 Important Notes

Prior to using the Gepard GPR and its accessories, please read these operating instructions carefully. These instructions give information on how to use the detector and potential sources where precautions should be taken.

The Gepard GPR and its accessories serve for the analysis, documentation and detection of sub-surface anomalies and ground disturbances. The recorded data of the ground structure will be transmitted to an electronic device like an Android Tablet to give a visual representation of the anomaly. Using our proprietary software program will assist in visualizing the object.

> The Gepard GPR utilizes an unshielded transmitting system to be as portable as possible. It is not approved for the usage in the EU. Please check the local regulations of your country!

1.2.1 General notes

Being an electronic device, the Gepard GPR has to be treated with caution and treated with care as with all other electronic devices. Any failure to observe safety precautions or use of the equipment for purposes other than its intended design may result in damage or destruction of the processing unit and/or its accessories or connected components.

There are no end user serviceable parts on the inside of the unit.

1.2.2 Possible health hazards

If used properly this device normally does not pose any health hazards. According to current scientific knowledge, the high-frequency signals are not harmful to the human body on account of their very low power.

1.2.3 Surrounding area

When moving this unit from a cold place to a warmer place, watch out for condensation. Do not immediately operate the unit until any possible condensation could have evaporated. The unit is not weather proof and water or condensation can destroy the unit.

Avoid strong magnetic fields, which may occur in places where there are large electric motors or unshielded loudspeakers. Try to avoid using this equipment within 50 meters (150 ft) of this type of equipment.

Metallic objects on the ground such as cans, tin, nails, screws or debris can influence your scan data and present negative results regarding your scan data. Also it is a good habit to remove any metallic objects off of your person like cellular telephones, keys, jewelry, etc... Do not wear steel toe boots.

1.2.4 Voltage

Please be aware that the unit is powered by an internal accumulator. Please use only approved chargers for this unit.

> Never connect or use a 110/230 Volt main AC power supply directly!

1.2.5 Data safety

Data errors can occur if:

- the range of the sender module has been exceeded,
- the power supply of the device or the batteries are too low,
- the unit is operating to close to devices which sends out or causes disturbances
- atmospheric conditions (electrical storms, lightning, etc...)

1.3 Maintenance and Services

In this section you will learn how to maintain your measuring instrument with all included accessories to keep it in good condition for a long time and to get receive measuring results.

The following list indicates what you absolutely should avoid:

- penetrating water
- strong dirt, sand and dust deposits

- hard impacts or drops
- strong magnetic fields
- operating within metal enclosures
- continued exposure to high heat

To clean your device please use a dry soft rag or cloth. To avoid any damage you should transport the device and accessories always in the appropriate carrying case.

Prior to using your Gepard GPR please be sure that all batteries and accumulators are fully charged.

> To charge external and internal batteries, use only the approved chargers which are part of the scope of delivery.

1.4 Danger of Explosion during excavation

Unfortunately, the last two world wars and other conflicts have also made the ground in many places of the world a potentially explosive scrap heap. A host of those lethal relics are still buried in the ground. Do not start digging and hacking for an object wildly when you receive a signal of a piece of metal from your device. Firstly, you might indeed cause irreparable damage to a truly rare find, and secondly, there is a chance that the object reacts in an insulted way and strikes back.

Note the color of the ground close to the surface. A red or reddish color of the ground is an indicator of rust traces. As regards the finds themselves, you should definitely pay attention to their shape. Curved or round objects should be a sign of alarm, especially if buttons, rings or little pegs can be identified or felt. The same applies to recognizable ammunition or bullets and shells. Leave that stuff where it is, do not touch anything and, most importantly, do not take any of it home with you. The killing machines of past wars have made use of diabolical inventions such as rocker fuses, acid fuses and ball fuses. Those components have been rusting away in the course of time, and the slightest movement may cause parts of them to break and be triggered. Even seemingly harmless objects such as cartridges or larger ammunition are anything but that. Explosives may have become crystalline over time, that is, sugar-like crystals have formed.

Moving such an object may cause those crystals to produce friction, leading to an explosion. If you come across such relics, mark the place and do not fail to report the find to the police. Such objects always pose a danger to the life of hikers, walkers, farmers, children and animals.

CHAPTER 2

Technical Specifications

The following technical indications are medial values. During measurements, variations are possible.

2.1 Control unit

Dimensions (H x W x D)	450 x 260 x 130 mm
Weight	approx. 1.60 kg
Input (max.)	8.4 V DC, 1.0 A
Protection class	IP 20
Operating Time	approx. 4 hours
Operating Temperature	-20 °C to +55 °C
Storage temperature	-25 °C to +60 °C
Air humidity	5 % – 70 %
Waterproof	No
Multiple Transmission Frequency Range	60 MHz to 300 MHz
Timing/Sampling Adjustments Send/Receive	4 Levels
Complete Cycle Measurements	9 per second
Samples	512
Data Transmission	USB-C

2.2 Telescopic shaft

Dimensions	70 x 60 x 590 – 1630 mm
Weight	0.80 kg
Built-in battery	7.26 V, 2600 mAh
Protection class	IP 20
Operating Temperature	-20 °C to +55 °C
Storage temperature	-25 °C to +60 °C
Air humidity	5 % – 70 %
Waterproof	No

2.3 Triangular antenna (unshielded)

Dimensions	1010 x 330 x 50 mm
Weight	1.50 kg
Protection class	IP 20
Operating Temperature	-20 °C to +55 °C
Storage temperature	-25 °C to +60 °C
Air humidity	5 % – 70 %
Waterproof	No

CHAPTER 3

Scope of Delivery



Description	Quantity
Control Unit	1
Charging Adapter with power supply and travel adapter	1
Android Tablet	1
USB-C Cable	1
Water and Shock Resistant Protector Case	1
Telescopic shaft	2
Transmitting antenna	1
Receiving antenna	1

CHAPTER 4

Control Elements

In this section you will learn more about the fundamental use of all control elements for the Gepard GPR measuring instrument. All connections, inputs and outputs are explained in detail.

4.1 Control Unit

The control unit is the processing center of the Gepard GPR. It collects data from the underground and sends it to an Android Tablet, where a graphical representation of underground anomalies is shown.

4.1.1 General overview



Figure 4.1: GPR Control Unit

Trigger button with LED: This button is the main control for turning on the unit, starting and stopping measurements as well as turning off the unit. To turn on the Gepard GPR, simply press the trigger button one time. The unit will turn on and as a test it will illuminate blue for approximately 3 seconds, then it will turn green. Do not press the trigger button during this startup period. The device is ready for operation as soon as the green LED is illuminated.

To turn off the Gepard GPR, press and hold the trigger button for at least 3 seconds. When the green LED turns off, you can release the trigger button. The meanings of the LED colors are as follows:

- **Green:** The green LED indicates that the Gepard GPR is powered on but no connection has been established so far.
- **Blue:** The blue LED indicates an active connection between control unit and Tablet. It also indicates the sampling status of the device. As soon as sampling starts the LED will start to blink. If sampling stops it will shine permanently.

Connectors for antennas: These connectors are used to connect the cables of the antennas. Always make sure to connect the receiving and transmitting antenna to the correct connector (see section 4.1.2 "Connector Panel" for more details).

Mounting socket for telescopic shaft: The mounting sockets are used to mount transmitter and receiver shafts. Each of the telescopic shafts contains an internal battery that powers the control unit of Gepard GPR. Furthermore you can adjust its length to adapt the distance of the antennas to the ground surface.

4.1.2 Connector Panel

Figure 4.2 shows where to connect the telescopic shafts as well as the cables for the transmitting and receiving antennas.

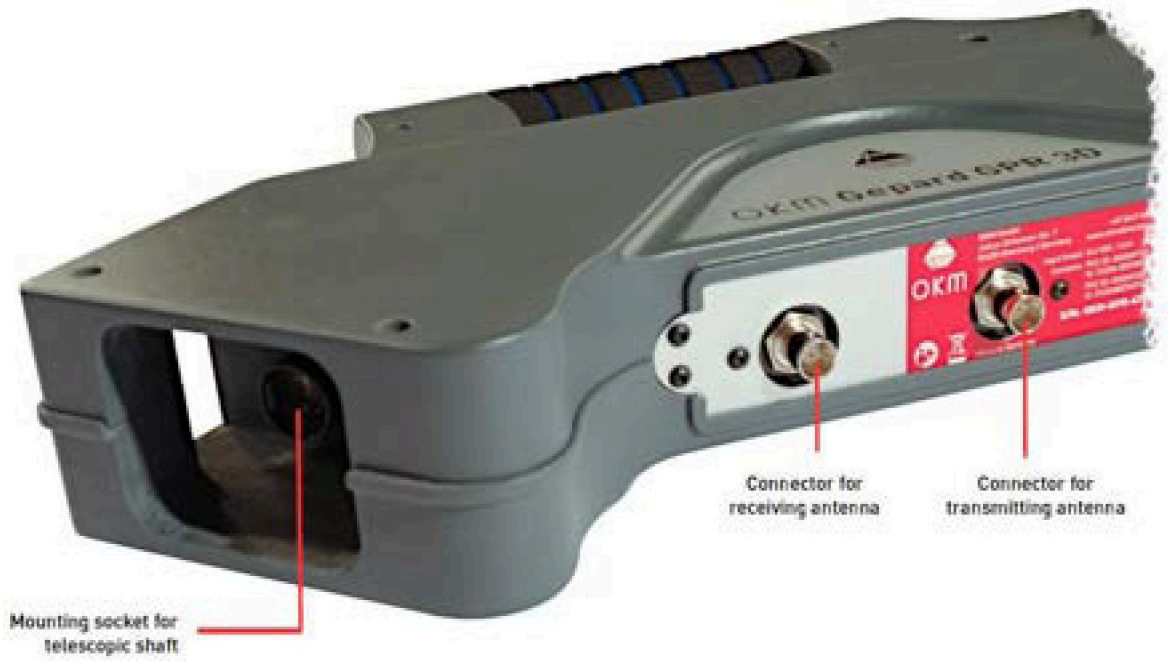


Figure 4.2: Connector panel of the control unit

Mounting socket for telescopic shaft: Here you can mount the telescopic shaft by pushing it into the opening. The socket that is located on the shaft must fit the mounting socket. At the end it will snap in perfectly. Please read chapter 5 "Assembly" on page 16 to learn more about mounting the telescopic shafts properly!

Connector for receiving antenna: The connector, that is situated on the silver side of the connector panel, is used to attach the cable of the receiving antenna. Please pay attention to not interchange the connectors.

Connector for transmitting antenna: The connector, that is situated on the red side of the connector panel, is used to attach the cable of the transmitting antenna. Please pay attention to not interchange the connectors.

4.2 Triangular Antennas with shafts

The Gepard GPR utilizes two triangular antennas: a transmitting antenna as well as a receiving antenna. Both antennas come with a telescopic shaft that contains a rechargeable battery that powers the control unit of the Gepard GPR.



Figure 4.3: Triangular antennas with transmitter, receiver and telescopic shafts

Transmitting antenna (red): The transmitting antenna is generating signals in the range of 60 MHz to 300 MHz that will be send into the underground.

Receiving antenna (silver): The receiving antenna collects all echos and reflections to calculate potential anomalies that might exist in the underground soil.

Telescopic shafts: The telescopic shafts will be used to mount the antennas to the Gepard GPR as well as supplying the power to the control unit.

4.3 Charging adapter

The charging adapter, as depicted in figure 4.4, is used to charge the internal batteries of the telescopic shafts. You can either charge only one of the batteries or two batteries at the same time.



Figure 4.4: Charging the internal batteries

Charging connectors: Each telescopic shaft has a socket that must be connected to one of the charging connectors of the charging adapter. Please make sure to place the connector tightly into the socket until it snaps in securely.

Input socket for power supply: Put the connector of the provided power supply into this input socket to start the charging process.

Charging LED: As long as the appropriate charging LED is illuminated, the charging process is still in progress. When the LED switches off, the battery is fully charged.

CHAPTER 5

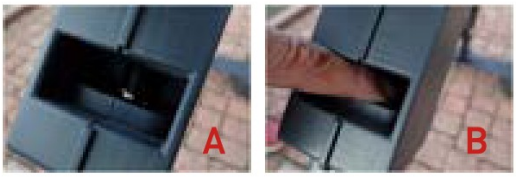
Assembly

Preparing the Gepard GPR for use is very simple. After inspecting all of the components and ensuring that all parts are present, assembly can begin.



Before mounting both antennas, we recommend to mount the telescopic shafts first. Therefor push one of the shafts into the **mounting socket for telescopic shaft** that is situated on the front part of the Gepard GPR (right beneath the Tablet holder).

Push the shaft firmly into the socket until you hear a clicking sound, that occurs when the little metallic hook snaps into the socket.



Please pay attention that the little metallic hook is pointing towards the second opening (see figure A). This hook must be pushed down to release the telescopic shaft while disassembling as shown in figure B.



Now connect the short end of the shaft's cable to the **connector for transmitting antenna** that is marked with a red label (transmitting port).

While pushing the plug of the cable over the connector, you have to make sure the little pins of the connector slide into the L-shaped trenches of the plug (Bayonet mount).

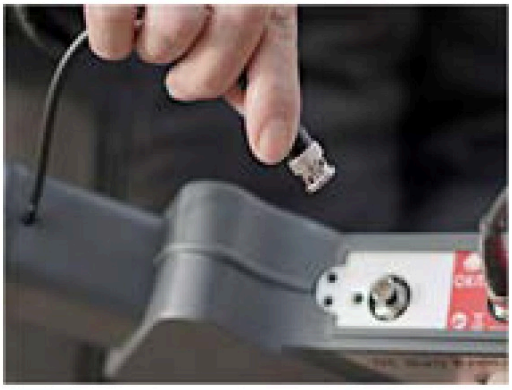


As soon as the plug of the cable is completely pushed over the connector, you have to turn the plug to fix its position.



Now you have to repeat the whole process for the second telescopic shaft as well.

First push the second shaft into the **mounting socket for telescopic shaft** that is situated on the back part of the Gepard GPR.



Next, connect the short end of the second shaft's cable to the **connector for receiving antenna** that is marked with a silver label (receiving port).



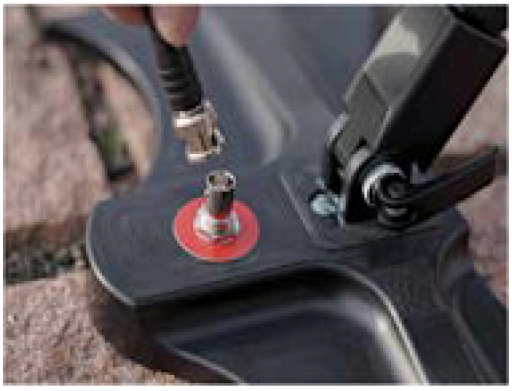
At the end of this process both cables are connected to the connector panel of the Gepard GPR.

Now you can continue to mount the antennas to the telescopic shafts.

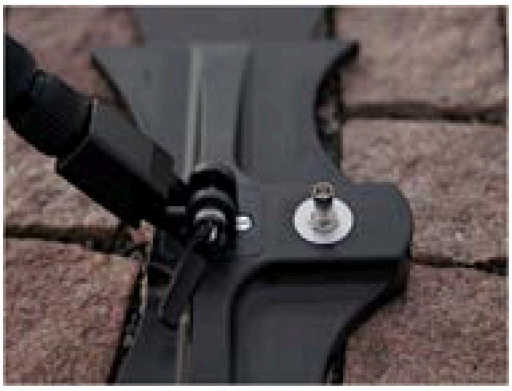


The lower part of the shafts have a small notch that is used to grab the antennas.

Push the notch of the first shaft, that has been connected with the transmitting port, right over the bolt of the transmitting antenna (red marking). Then close the eccentric strap (short lever at the side of the bolt) to tighten the grip.

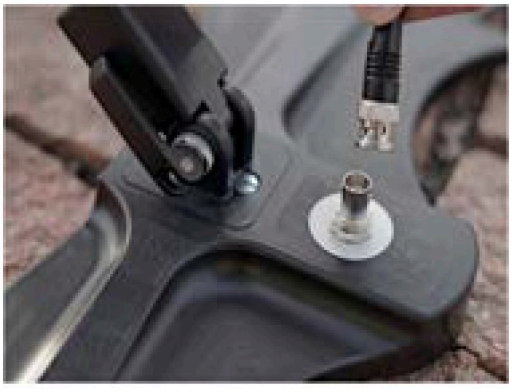


Now you have to connect the longer end of the cable, that has been connected with the transmitting port, to the connector of the transmitting antenna.



Like you did with the transmitting antenna, the receiving antenna is mounted in the same way.

First place the notch at the lower part of the telescopic shaft over the bolt and close the eccentric strap (short lever at the side of the bolt) to tighten the grip.



Then you connect the plug of the cable to the connector of the receiving antenna (silver marking).



Before using the Gepard GPR you might adjust the telescopic shafts according to your body height. Therefor unlock the locks by turning them loose, adjust your desired length and tighten them up again.



Now place your Android Tablet on the Tablet holder of the Gepard GPR.

Please make sure that the magnets of the Tablet holder match the metallic plates on the back of your Tablet.



Connect the Control Unit and the tablet using the USB-C cable.



Power on the Gepard GPR Control Unit and start your first measurement.

CHAPTER 6

Field Procedure

The Gepard GPR from the original conception has the design of ease and simplicity allowing for the use and operation of the unit without needing an extensive amount of training or schooling.

For the use and operation of the Gepard GPR, there are several factors to take into consideration. The operation of the unit is simple and using the following rules will give good consistent data:

1. During a measurement it is important to keep the transmitting antenna and the receiving antenna at the same height above the ground.
2. Do not change the height during a measurement. Usually the distance should be as close to the ground as possible but in case of obstacles you have to use a bigger distance which must be maintained during the complete scan.
3. Do not swing the GPR from the left to the right. Keep the unit steady and in the direction that you would like to scan.
4. Move the GPR at a consistent speed, even though it can scan using the GPS coordinates, moving the unit at the same speed helps in locating your target easier.
5. If a suspected target is detected, repeat the scan. With any detection device, repeating the detectable object will increase your accuracy.

The ground, this is going to be your biggest challenge. Though the unit can detect items to depths of approx. 40 meters, please consider the fact that with so many varying soil types and combinations, there are some locations where maximum depths will be considerably less.

In the Android Tablet, the software has been simplified requiring only a couple of steps prior to beginning a measurement. In chapter 7 “Software” starting on page 27, we will explain in detail how to begin a measurement.

Conducting measurements is quite simple. Knowing your starting position and stopping position of every scan and keeping the scan lines straight will help to localize sub-surface targets. Enabling the GPS in your Gepard GPR will aid in the localization and assist in retracing the path taken. The GPS does not transmit data, it only receives data and is available in most parts of the planet.

Keeping notes of the measured area is very important. Notes can be written directly into the file (see section 7.4.5 “Changing project title and notes” on page 50).



Figure 6.1: Holding the Gepard GPR before starting the scan

6.1 Conducting a field measurement

While configuring your measurement with the Tablet's application you may choose between two different scan modes:

- **2D Scan:** This scan mode is used to scan just one straight single line over your scan field. So this is very useful to pre-check your area for potential anomalies like pipelines or tunnels. If the underground object is very large in horizontal dimension you will see an anomaly by just passing over it one time.
- **3D Scan:** While using the 3D scan mode you have to scan more than just one single line. You will scan your first straight line and then step to the left side to scan another line. Simply repeat this procedure several times to collect data of a complete scan area. In this way you will be able to determine several underground objects in just one measurement.

After setting up your software application go to the starting point of your first scan line and make sure the antennas have the same distance to the surface as shown in figure 6.1.

More information about preparing the measurement and how to start or stop your scan lines you will also learn in section 7.3 “New Scan” starting on page 30.

6.2 General scanning procedure

In general every 3D scan always starts on the bottom right corner of your scan area. Starting from this point, you should walk scanning path by scanning path, whereby every following path is situated on the left side of its previous path. While walking these lines, the measurement values will be recorded and at the same time displayed in the software of the Gepard GPR.

Figure 6.2 shows all 4 possible starting positions and the corresponding first scanning path. Depending on the composition of your terrain you can determine the optimal starting point for your measurement by yourself.

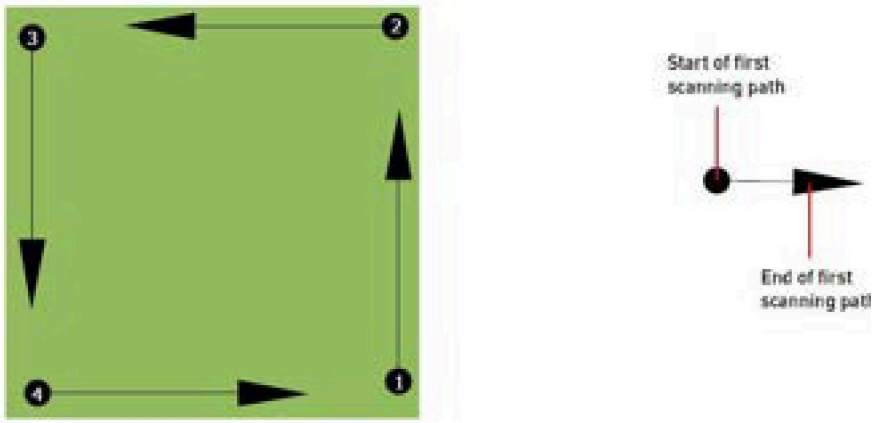


Figure 6.2: Starting position of a scan area

The scanning paths may be referred as "Zig-Zag" or "Parallel" traverses. Also the number of impulses (measure points), which are recorded during one scanning path can be adjusted individually depending on the size of your scan area (length of scanning path).

6.2.1 Scan mode

There are two general techniques to surveying an area with the Gepard GPR:

- **Zig-Zag:** The starting position of two scanning paths next to each other is on the opposite side of the measured area. You will record data on your scanning path and on the return path as well.
- **Parallel:** The starting position of two scanning paths is always on the same side of the measured area. You will only record data in one way and in one direction, while you should return and walk back to the starting position of the next scanning path without recording data.

Figure 6.3 represents both techniques schematically:

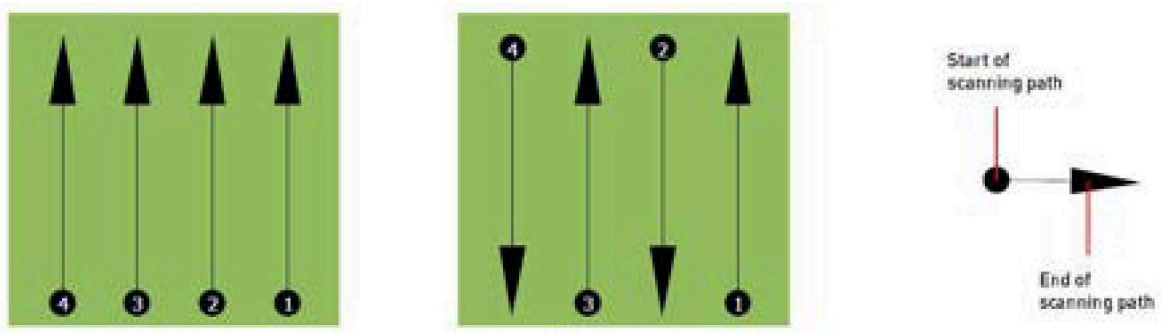


Figure 6.3: Scan modes to measure an area

Doing the scan in "Parallel" mode you will start on the bottom right corner of your measure area (point ❶) to walk and record a scan path towards the upper right corner of the area. After recording the first line, you should walk back to the starting point and move to the left of the first scan line to start the scan path 2 (point ❷), to start there the second scanning path. In this way all other paths will be scanned until you have reached the left side of your scan area.

Doing the scan in "Zig-Zag" mode you will start also from the bottom right side of your measure area (point ❶) to walk and record a scanning path towards the right upper corner of the measure area. Different from the parallel measurement, you should continue recording data while walking back the second scanning path. So you go to the starting point of the second scanning path (point ❷) and scan in the opposite direction. In this way, all other paths will be scanned in the scan mode "Zig-Zag" until you have reached the left side of your measure area.

The distance between the scanning paths should be consistent during one measurement but can vary from measure area to measure area. If you mostly look for smaller targets than you should also select a smaller distance between the lines. A standard rule is: The smaller the distance between the paths, the more accurate your scans will be. When you are conducting your first scans the lines should not be to close together to locate possible targets.

6.2.2 Regulation of the number of impulses per scanning path

The number of measure points per scan line is determined at the end of your first scanning path. You have to stop the measurement of the first scanning path by yourself, by pressing the trigger button of your Gepard GPR, as soon as you have reached the end of the first scanning path. This effective amount of measure points will be used for all further scanning paths of this measurement. Starting from the second scanning path, the device now stops automatically after the assumed number of impulses has been reached.

The number of impulses can be influenced by your walking speed. The slower you are walking the more impulses will be recorded per scanning path. There are different aspects which should be considered. These are some considerations

- the length of your measured area and
- the size of the objects you are searching for.

If you are looking for small objects you have to slow down, for big objects you can increase your walking speed.

Figure 6.4 shows the effects of the number of impulses per scanning path for some objects.

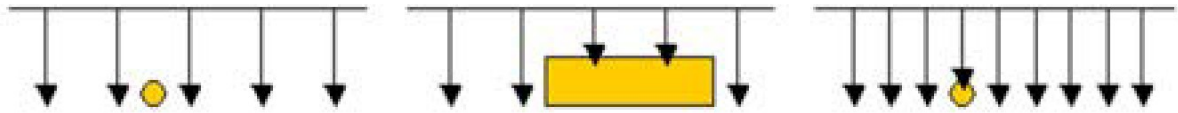


Figure 6.4: Effects of changing the number of impulses and their distance

Do not hesitate to record more measurements with different numbers of impulses. For example you can scan a large area before doing a second detailed precision measurement. Especially if searching for bigger objects you can proceed like this. With this manner you can measure a larger area very quickly and afterward you make new scans localizing the suspect targets.

When conducting a scan it is important to not only make note of how many impulses are being used but to get a clear picture of what you are scanning, it is very important to watch your speed. Every scan line should be measured at the same speed as the previous line.

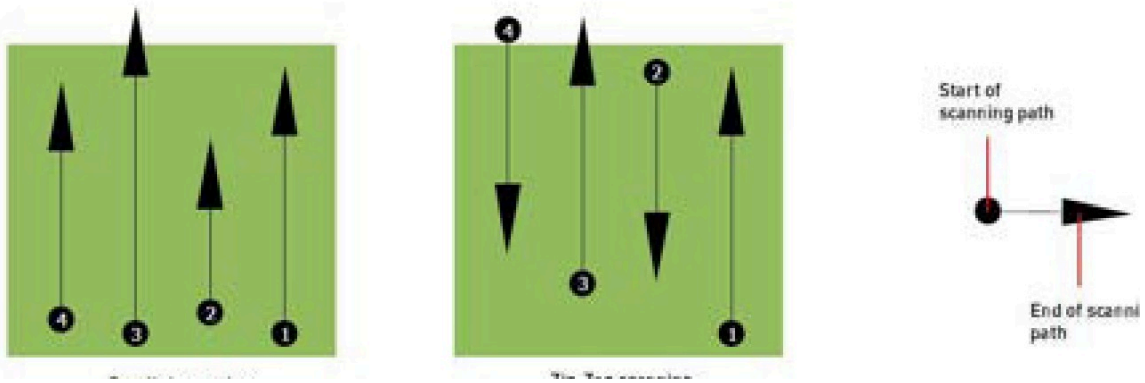


Figure 6.5: Different walking speeds during scanning

Using a different walking speed in the scanning paths, will cause displacements in the scanning path. As a matter of fact, a target can get cut into several smaller items or completely lost because it was missed. Later when the data is analyzed, speed errors can make a target completely unidentifiable and may be discarded.

In general, the following rule is valid: Keep scans at practical sizes where you can see the beginning and stop lines and can comfortably traverse an area to keep your speed and the distances reasonable.

6.3 Special advice for field procedure

There are some aspects which you should take note of when conducting scans. In principle, a scan is only as good as the path that was taken. Making errors while scanning will show up in the final graphical representation also as an error. This will cause frustration and lost time.

Before you start with a measurement in the field, you should think of what you are looking for and if the selected area is suitable. Measuring without a plan usually will produce unacceptable results. Please consider the following advice:

- What are you looking for (graves, tunnels, pipelines, buried objects, ...)? This question has direct effects on how a scan is conducted. If you are looking for larger targets, the distance between the single measure points and scanning paths can be larger, as if you are looking for small targets.
- Inform yourself about the area, where you are searching. Does it make sense to detect here? Are there historical references which confirms your speculation? What type of soil is on this area? Are there good conditions for data recording? Is it allowed to search at this place (e.g. private property)?
- Your first measurement in an unknown area has to be large enough to get representative values. All further control measurements should be adjusted individually.
- What is the shape and the dimensions of the object that you search? When looking for a long pipe, you should measure across the object to better "see" it in your scan.
- To get better values concerning depth measurements, the object has to be in the center of the graphic, which means it has to be framed by normal reference values (normal ground). If the object is on the side of the graphic and not totally visible an estimated depth measurement is not possible and also measurement of size and form are limited. In this case, repeat the scan and change the position of your scan area, to receive an optimal position of the anomaly inside of the graphic.
- You should do at least two control scans to be more sure about your results.

6.3.1 Orientation of the antennas

During one measurement the antennas should have always the same distance to the ground. Generally we recommend a height of about 10 cm (0.4 inches) from the surface of the ground if possible.

In the event that you are going to go over stones, wood or high grass that is higher, start your scan with the antennas higher right from the beginning. In circumstances like these, then perhaps you will need to start the scan with the antennas at a height of 30 cm (1 ft) and keep it at that level for the entire scan. It is important to maintain the height, this will eradicate many errors. As a rule, do not change the height during a scan for it may create unnecessary errors.

6.3.2 Parallel or Zig-Zag?

For skilled users of the Gepard GPR both scan modes are suitable. According to experience the best graphics has been received in the "Parallel" mode, because you are starting at the same point and traveling in the same direction. It is also easier to control your walking speed.

Especially in uneven territories like mountain sides, acclivities or other inclined layers the parallel mode is preferred. When it comes to speed, the experienced user will very often use the Zig-Zag mode for the initial scan to determine if there are anomalies in the area worth further research.

CHAPTER 7

Software

After starting the Gepard GPR software you will see the main menu as shown in figure 7.1.

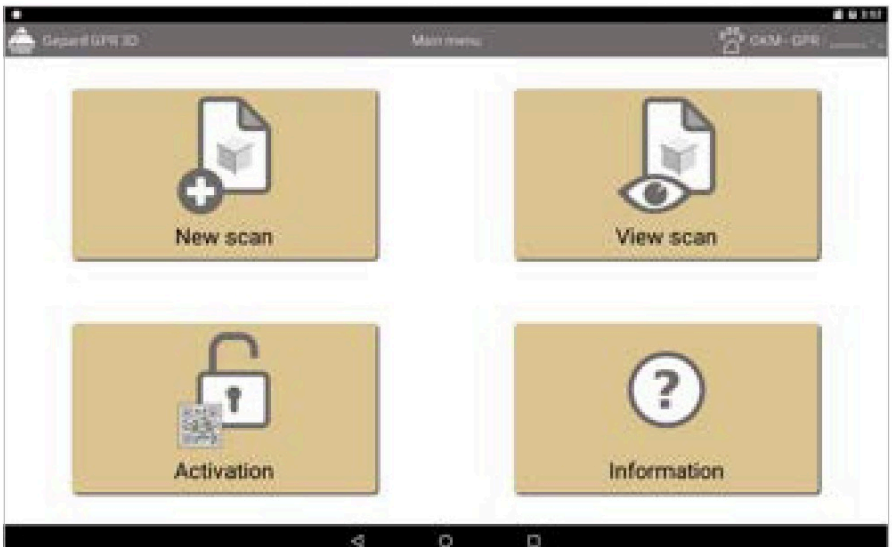


Figure 7.1: Main menu

In the main menu you can choose between following options:

- **New scan:** Select this option if you want to create a new measurement, whether in 2D or 3D.
- **View scan:** Use this option to open previously saved measurements for detailed evaluation.
- **Activation:** Before using the Gepard GPR application for the first time, you need to activate it. The process of activation starts by selecting this option.
- **Information:** If you need to contact the manufacturer for advanced support, you may use this option.

7.1 Setting up the Android application

If you have purchased the complete package of Gepard GPR, the Tablet was included and is already equipped with an activated software application. In that case you can skip section 7.1 and its subsections and continue reading with section 7.3 “New Scan” on page 30!

If you have not purchased any pre-configured Tablet along with your Gepard GPR, you have to

1. install the software application on your Tablet,
2. activate the application,

3. connect the tablet to the Gepard GPR Control Unit.

7.1.1 Download and install the application

If you want to install the application for the first time or reinstall the application after a factory reset, you first have to download the application from "Google Play".

Find the "Play Store" application on the Tablet - that you are using to install the Gepard GPR application - and open it. If you don't have any Google Account so far, you must create one to be able to download the Gepard GPR application. Simply follow the instructions on your Tablet to download and install the application.

7.1.2 Activate the application

After installation you have to activate the software application. Detailed information about this activation process you can find in section 7.2 "Activation" on page 28. In case of any troubles, please contact your local dealer for additional help!

7.1.3 Connect the Control Unit with the tablet

In order to conduct measurements with the Gepard GPR, the Control Unit and the Android tablet must be connected using the included USB-C cable. Please use the short cable provided for this purpose. Cables that are too long may cause interferences that negatively affect the measurement data.

Once you've plugged in the USB-C cable, a connection will be established automatically. You can now open the Gepard GPR app on your tablet and use it to control your control unit.

7.2 Activation

After running the Gepard GPR application for the first time, you have to pass through the activation process to be able to use all functions. In order to start the activation process, simply select "Activation" from the main menu.

If you received your Gepard GPR together with a pre-configured Android Tablet, your application should be activated already.

> You can find the software code for re-activation in the documentation that came with your device at the time of purchase. Keep it in a safe place.

There are two different ways to activate your Gepard GPR application:

- **Activation via QR code:** Simply scan a QR code with your Tablet to activate your application.

- **Manual activation:** Enter information like serial number and activation code manually.

7.2.1 Activation with QR code

One way of activating your application is using the enclosed QR code. After selecting the option “Use QR code”, you have to position your Android's camera to the QR code.

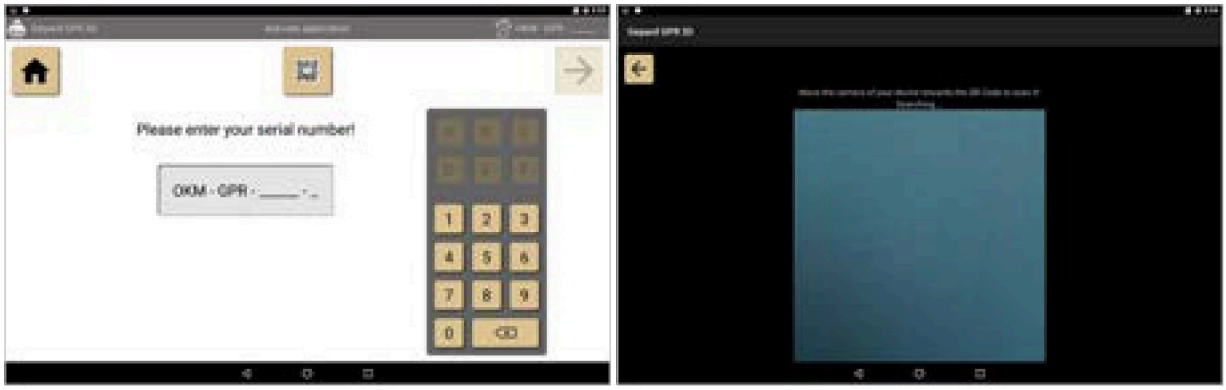


Figure 7.4: Scan QR code to activate the application

If the code gets recognized by your application correctly, the activation will succeed and you may use your Gepard GPR. In case you are using a different Gepard GPR with this application at a later time, you will have to change your activation accordingly and repeat the activation process.

7.2.2 Manual activation

The second way of activating your application is by entering all necessary information manually. You will find all of the activation information attached to the printout on this manual. Safeguard this information for future use.

First, enter the unit's serial number, as shown in figure 7.5. You will find your serial number on the notice in front of your user's manual as well as on your device itself.

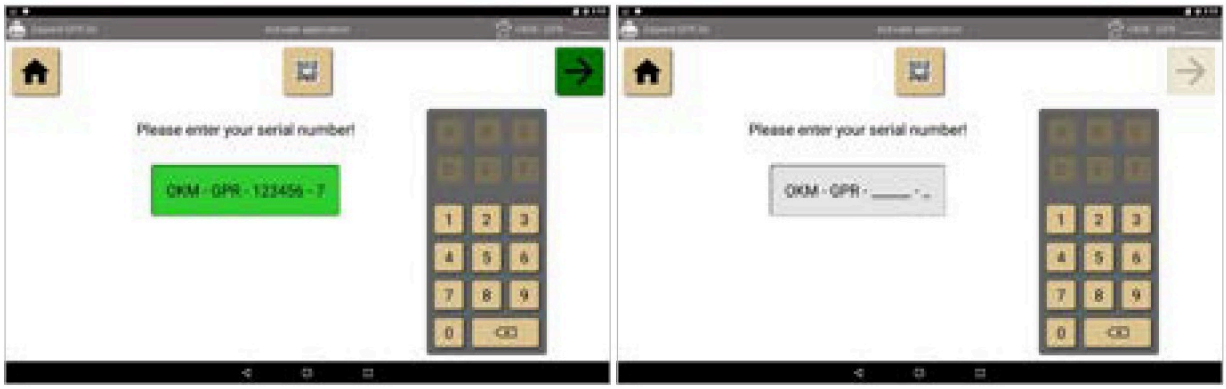


Figure 7.5: Activation - Entering the serial number

After entering the right serial number click the → button to continue.

In the next step you will be asked to enter the activation code as shown in figure 7.6. This information is also printed in the small leaflet in front of your manual. After entering the activation code tap the → button again.

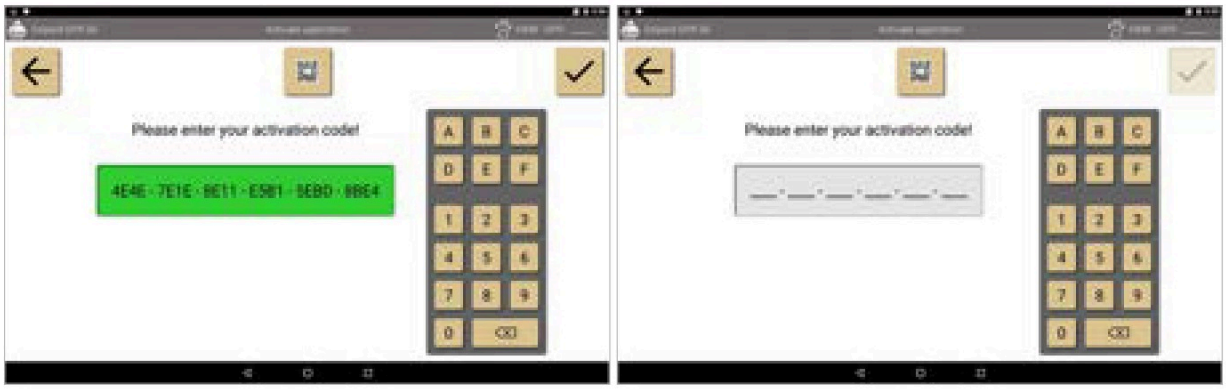


Figure 7.6: Activation - Entering the activation code

Once that is completed and all information are valid, your software application is ready to use.

7.3 New Scan

Please make sure that your Gepard GPR is powered on and you have connected the tablet to the Control Unit using the included USB-C cable. If so, you can start to set up your measurement now.

7.3.1 Setting up a GPR measurement

After selecting the operating mode "New scan" from the main menu, you have to follow several steps to set up your application according to your specific task.

7.3.1.1 Establishing Connection

In the first screen from figure 7.7 the application connects to your Gepard GPR. At the same time it checks for a valid software activation.

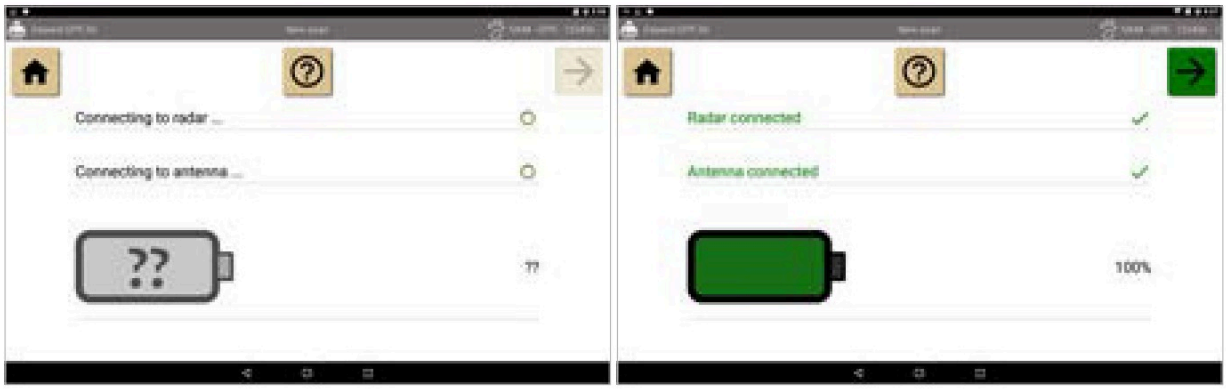


Figure 7.7: New Scan - Establish connection

If the antennas are indicating any problem, check all connections and cables. As soon as the connection is established successfully, push the → button to continue with step 2.

7.3.1.2 General settings

In the second step, shown in figure 7.8, you can adjust general settings that improve or assist your scan procedure.



Figure 7.8: New Scan - General settings

You can adjust the following settings:

- **GPS:** You can enable or disable the recording of GPS coordinates along to the actual scan data. After activating GPS, the device determines the quality of available GPS data. This may take a short moment. When a stable reception is provided the switch state changes to green automatically.
- **Headphones:** You can enable or disable the internal Bluetooth module for usage with wireless headphones. After activating this option, you should start the Bluetooth pairing process of your headphones. As soon as the Gepard GPR and your Bluetooth headphones are paired the switch state changes to green automatically.
- **Speaker:** You can enable or disable the internal speaker. When using the device without headphones you can activate the internal speaker to hear the sound output while conducting the measurement.
- **Color schema:** You can decide which color schema you want to use for the visual representation of the scan data while conducting a measurement. This color schema can be changed afterwards when analyzing your measurement results.

After you have changed all settings according to your personal preferences, you can push the → button to continue with step 3.

7.3.1.3 Project title and description

In the next step you must enter a project title, which is later on used to find your measurement from the list of all recorded files (see section 7.4 “View scan” on page 40). You may also add some additional notes in the description field (e.g. place of measurement, environment conditions, etc.).

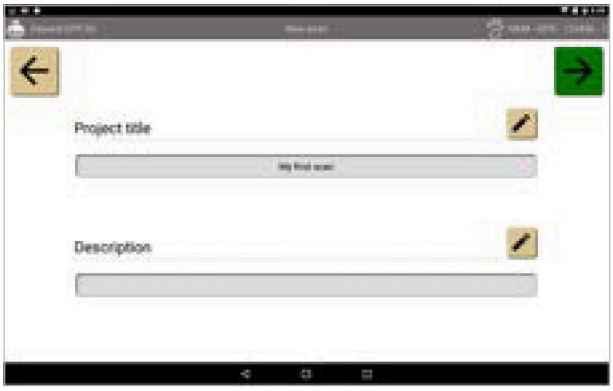


Figure 7.9: New Scan - Project title and description

You can change the value of each input by pushing the button. All these information can also be changed afterwards as described in section 7.4.5 “Changing project title and notes” on page 50.

After you have entered all information, you can push the button to continue with step 4.

7.3.1.4 Choosing a scan type

During the next step you have to decide if you are going to conduct a 2D measurement (mainly one single scan line) or a 3D measurement (several scan lines next to each other).

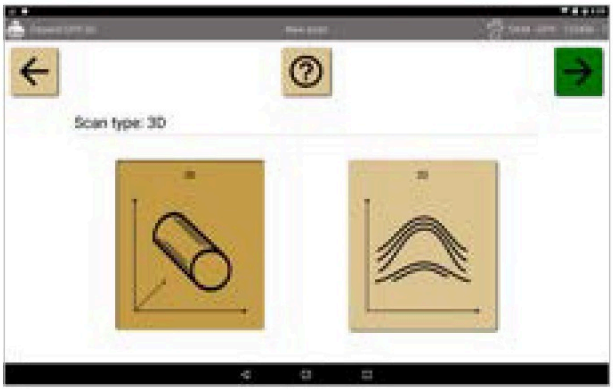


Figure 7.10: New Scan - Choosing a scan type

You have two choices:

- **2D:** The 2D scan is used to scan a single line only. You will just see the reflections of underground objects in simple 2D graphics.
- **3D:** The 3D scan is used to scan many parallel lines to get a real 3D image of the underground objects. After finishing the measurement you can also switch between 2D and 3D view.

If you select 2D the next step, which is only available for 3D measurements, will be skipped automatically.

7.3.1.5 Choosing the scan mode

This step is only processed when you selected to conduct a 3D measurement.

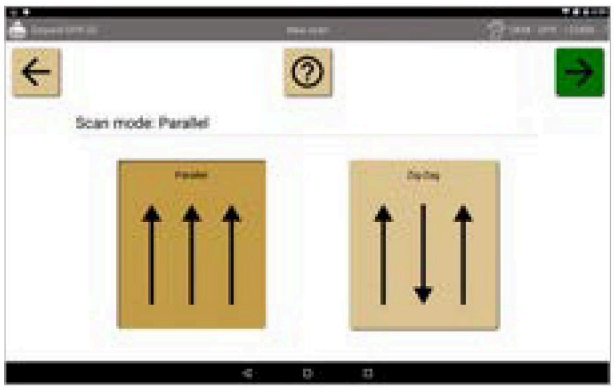


Figure 7.11: New Scan - Selecting the scan mode

If you have selected 3D as scan type, you now have to decide in which scan mode you would like to work:

- **Parallel:** In the parallel mode you walk several scan lines but always starting at on side of your scan area.
- **Zig-Zag:** In the Zig-Zag mode you also walk several scan lines but this time each following line starts at the side of the scan area where the previous line ended.

After selecting your preferred scan mode, you can push the → button to continue with step 6.

7.3.1.6 Maximum depth and soil type

During the next step, shown in figure 7.12, you will adjust some settings concerning the scan field itself.

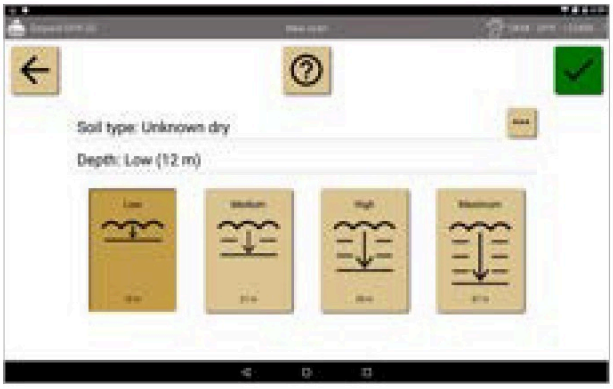


Figure 7.12: New Scan - Maximum depth and soil type

You have to adjust the following settings:

- **Soil type:** Selecting the correct soil type will make the depth measurement of the Gepard GPR very close to actual. Due to the fact that there are literally millions of various combinations of soils, getting the exact one will not always be possible. Various soil types will have different attenuation factors. Soil magnetic permeability (detailed table in figure 8.1 on page 55) is the ability for electrical signals to travel through different media. As a geological note, allows the radar wave to travel through the earth and return with an echo. One of the best ways to determine the proper soil type in an area is to conduct a measurement over a known buried object at a known depth. Conduct the scan and then compare the soil type to the depth of the object. This is a quick and easy method to determine the best soil for the area.
- **Depth:** The indicated depth will be the maximum depth to which the Gepard GPR is measuring into the underground (according to your selected soil type). The smaller the depth the better the resolution of objects that are closer to the surface. For greater depths the resolution will decrease. It is essential that the proper soil type has been selected before.

According to the selected scan mode you can conduct your measurement by pushing the  button.

7.3.2 Conducting a GPR measurement

After all the setup steps from section 7.3.1 “Setting up a GPR measurement” on page 31 have been processed successfully, you can start your actual measurement. Depending on the selected scan type the procedure is different. The next two subsections explain 2D and 3D measurements in more detail.

7.3.2.1 Measuring in 2D

For a simple 2D scan you just have to walk a single but straight line. After preparing your device for measurement, you will end up with the screen from figure 7.13.



Figure 7.13: Ready for 2D measurement

Now, go to your starting point, the antennas should be 10 cm (0.33 ft) above the ground, and push the trigger button of your Gepard GPR. Then keep walking slowly and continuously to the endpoint of your scan line. As soon as you reach the end point push the button again to stop the scan.

During this process you should see the data appearing on the screen of your Tablet as indicated in figure 7.14.



Figure 7.14: Incoming scan data during 2D measurement

You can extend your scan data, starting and stopping the measurement over and over again. To do so, simply push the trigger button of your Gepard GPR.

If you recorded all your data, push the ✕ button on the screen of your Tablet to finish the measurement. Now you have to decide whether you want to save ✓ or discard ✕ your scan (see figure 7.17 on page 39).

7.3.2.2 Measuring in 3D

For a 3D scan you have to walk multiple straight lines while starting on the right side of your scan field. Each additional scan line is made left to the previous one. After preparing your device for measurement, you will end up with the screen from figure 7.15.

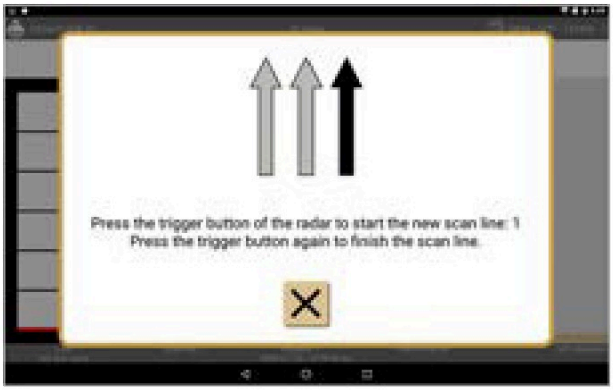


Figure 7.15: Ready for 3D measurement

Go to your starting point, the antennas should be 10 cm (0.33 ft) above the ground, and push the trigger button of your Gepard GPR. Then keep walking slowly and continuously to the endpoint of your scan line. While walking the lines, the scan data is visualized on the Tablet as shown in figure 7.16. As soon as you reach the endpoint of the first scan line push the trigger button again to stop recording. The amount of scanning points is now stored and will be used for all upcoming scan lines. Thus, you don't have to push the trigger button at the end of any following scan line anymore.



Figure 7.16: Incoming scan data during 3D measurement

Depending on your selection of the scan mode, one of the following actions is necessary after scanning the first line:

Scan mode = Parallel	Scan mode = Zig-Zag
Go back to the starting point of the previous scan line and step approx. 50 cm to the left. Now push the trigger button again to start measuring the new scan line. This time the device will stop automatically at the end of the scan line.	Step approx. 50 cm to the left and turn around by 180° (half turn). Now push the trigger button again to start measuring the new scan line. This time the device will stop automatically at the end of the scan line. Turn around by 180° (half turn) and step approx. 50 cm to the left before scanning the next line.

Repeat the preceding process for as many lines as necessary to complete your whole scan. If you have recorded all your data, push the button on the screen of your Tablet to finish the measurement. Now you have to decide whether you want to save or discard your scan. If you are going to save your data, the screen from figure 7.17 appears.

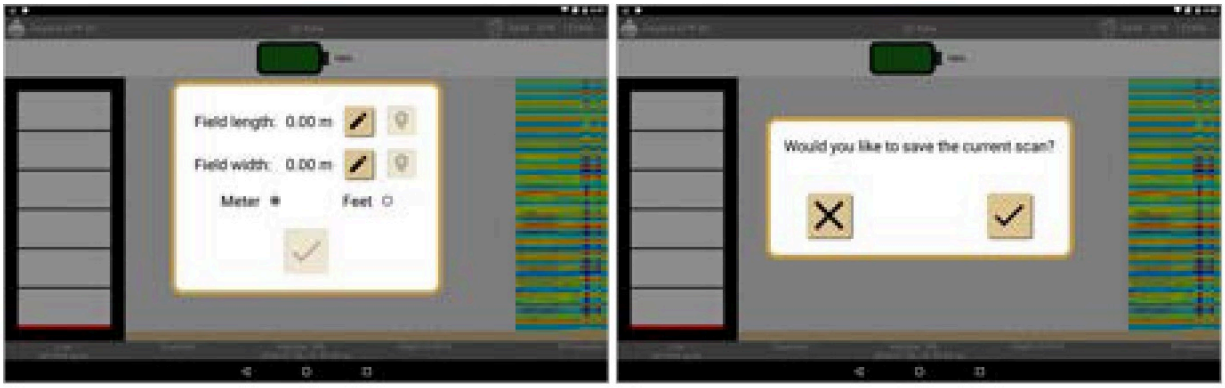


Figure 7.17: Applying field dimensions

You now have to enter the length and the width of your scan area. This is important to get correct distance measurements when analyzing your scan data. Please read section 7.4.6 “Setting field dimensions” on page 50 to learn how to set the field dimensions.

7.4 View scan

After conducting several measurements you can open, view and analyze your scans in more detail. Therefor you select the option “View scan” from the main menu. Now you can see a list of available measurements as shown in figure 7.18.



Figure 7.18: View Scan - List of measurements

Tapping on one of the file entries (inside of the “click sensitive area”) will just open the measurement. There are some additional buttons in the toolbar and directly on the screen with following meanings:

Home
Tap this button to go back to the main menu.

Scan files (*.nx)
If this button is pushed down, the list will show all measurements. The number in brackets indicates the total number of files available.

Display favorites only
Push this button down to display all files marked as favorite.

Sort order
Push one of these buttons to change the sort order of the files within the list.

Create new map file
When you checked one or more Map checkboxes, you can use the create new map file button to build a new Google Map file containing all GPS coordinates and scan areas.

Map files (*.kmz)
If this button is pushed down, the list will show all map files (a collection of one or more measurements). The number in brackets indicates the total number of files available.

Delete
Use this button to delete the corresponding file. After confirming the deletion, the measurement is gone and not recoverable.

According to the scan mode that was used to conduct the measurement, the selected file will be opened in 2D or 3D view. Any 3D file can switch to its appropriate 2D representation later on, whereas a 2D scan cannot be viewed in a 3D representation at all.



Figure 7.19: 2D and 3D representation of a measurement

At the top of each screen in figure 7.19 there is a toolbar with some special buttons that will be explained in the following table.

Home — 2D, 3D
Tap this button to go back to the main menu.

Toggle 2D / 3D — 2D, 3D
This button is only functional if the measurement has been conducted in 3D and allows easy switching between 2D and 3D representation.

Toggle filtering — 2D
If this button is pushed down the current filter configuration is applied to the measurement's data (see section 7.4.4 "Applying filters" on page 47).



Place markers 2D

After placing the cross-hairs over a specific target in your scan, you can push this button to place a color marker on that exact position. Thus you can mark several points of interest (POI).



Resize 2D

Push this button to resize the 2D representation of the measurement. After pushing the button a scrollbar appears beneath the toolbar that can be used to zoom in and out accordingly.



3D cross-hairs 3D

Push this button to enable or disable the 3D cross-hairs. When enabled, you can hold down your finger onto one of the three axis in the graphical 3d representation (see figure 7.22 on page 45) and drag the cross-hairs accordingly.



Color adjustment / Contrast 2D, 3D

After pushing this button, two scrollbars appear to adjust the current color schema. That can be used to increase the contrast of the selected colors.

Select color schema 2D, 3D

Tapping the current color schema opens up a dialog where you can choose from many other color schema. Switching between different color schemata can sometimes reveal hidden structures because of different contrast and brightness settings. So there is no recommended color schema to use, you always have to find the best solution by yourself.



Threshold 3D

After pushing this button a scrollbar appears that can be used to adjust the threshold of the graphical representation. By increasing the threshold you can remove as many noise as necessary to make potential targets stand out.

Select soil type 2D, 3D

Tapping the current soil type button opens a dialog where you can choose from many different soil types. Select the one that fits your scan area the best. Depending on the selected soil type, the calculated depth of potential objects is adapted. It does not change any visual representation of your graphics.

Toolbar menu 2D, 3D

If you tap this button a popup menu opens with additional functionalities as described in section 7.4.3 “Toolbar menu”.

At the bottom of the screens from figure 7.19 there is a statusbar, that contains information like scan line, impulse, depth and GPS. In figure 7.20 the statusbar and its information is depicted.

Depth setting: This value indicates the selected penetration depth that was used to conduct the scan.

Scan line: This is the number of the current scan line at which the cross-hairs are placed. If you entered valid field dimensions, you will also see the corresponding distance to the starting point in meter or feet.

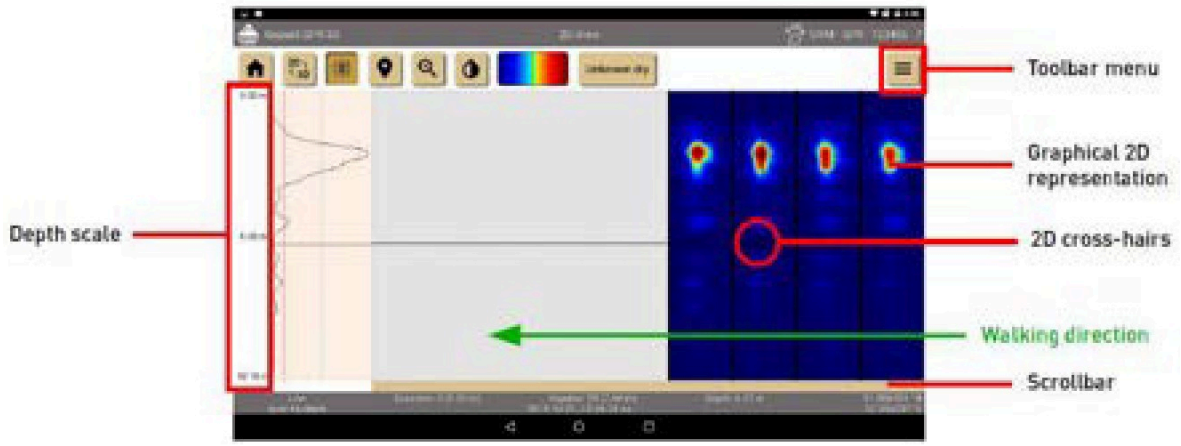


Figure 7.20: Statusbar of the view screens

Impulse: This is the number of the current impulse at which the cross-hairs are placed. If you entered valid field dimensions, you will also see the corresponding distance to the starting point in meter or feet.

Depth: According to the current soil type, this value represents the calculated depth.

Project title: Here you can see the title that you have entered while preparing a new scan.

Filename: This is the current filename under which the scan data has been saved.

GPS coordinates: If GPS was enabled while conducting the scan, the longitude and latitude are placed in the lower right corner of the screen.

7.4.1 2D view screen

The 2D view screen displays all measured data next to each other, starting from the right side. So if you view a 3D measurement in 2D the first scan line is located on the right side of the screen, followed by the second, then third, and so on.

type).

Figure 7.21: 2D view screen

Toolbar menu: Push the  button to open the toolbar menu (see section 7.4.3 “Toolbar menu” on page 46).

Depth scale: The depth scale indicates the depth of your measurement (according to the selected soil type).

Graphical 2D representation: This is the area where the visualized scan data is displayed. If you tap into this area and move your finger around, the cross-hairs can be positioned over a potential target. Thus the information like scan line, impulse and depth get recalculated in the statusbar.

2D cross-hairs: To read the depth as well as the position of detected objects you just need to move your finger over the main viewing area (graphical 2D representation) to place the cross-hairs directly over the potential object. Then you can read the depth and position value in the statusbar of the screen.

Scrollbar: If the visual representation of your measurement is too large to fit on your screen, you may use the scrollbar to move the graphic left or right.

7.4.2 3D view screen

The 3D view is calculated from all single scan lines. Depending on the amount of data this process can take a moment. You can switch back to a 2D view at any time.

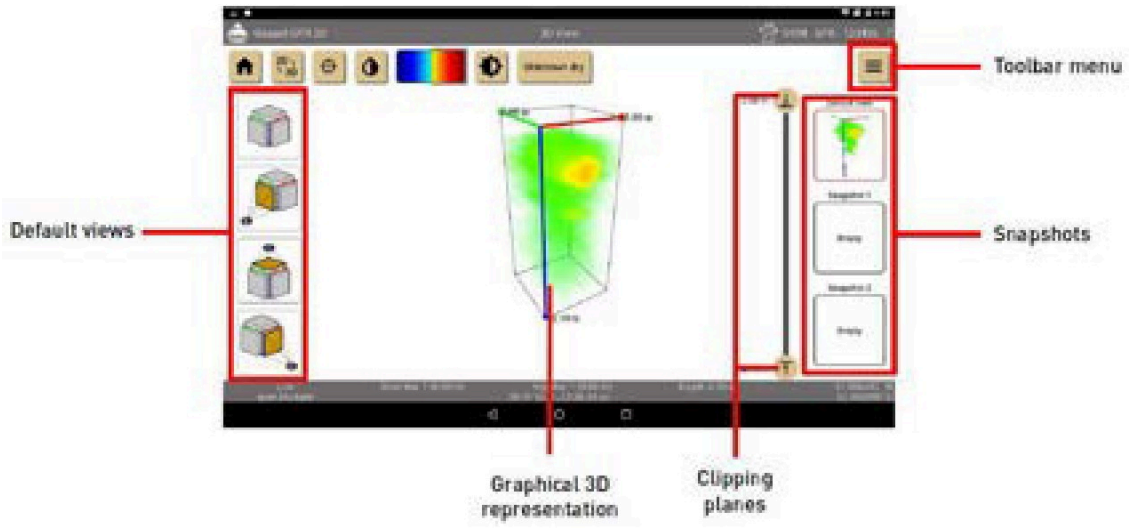


Figure 7.22: 3D view screen

Toolbar menu: Push the button to open the toolbar menu (see section 7.4.3 “Toolbar menu” on page 46).

Default views: Push one of the default view buttons to change the current perspective of the graphical 3D representation using predefined rotations.

Graphical 3D representation: This is the area where your 3D scan is shown. If you like to rotate the graphic you simply have to swipe left, right, up or down. For scaling and moving you have to use 2 fingers on the screen.

Snapshots: You can save your current 3D view (scale and rotation) as snapshot. Therefor adjust your graphical representation according to your needs and push either Snapshot 1 or Snapshot 2. After that a dialog, as shown in figure 7.23, will appear.

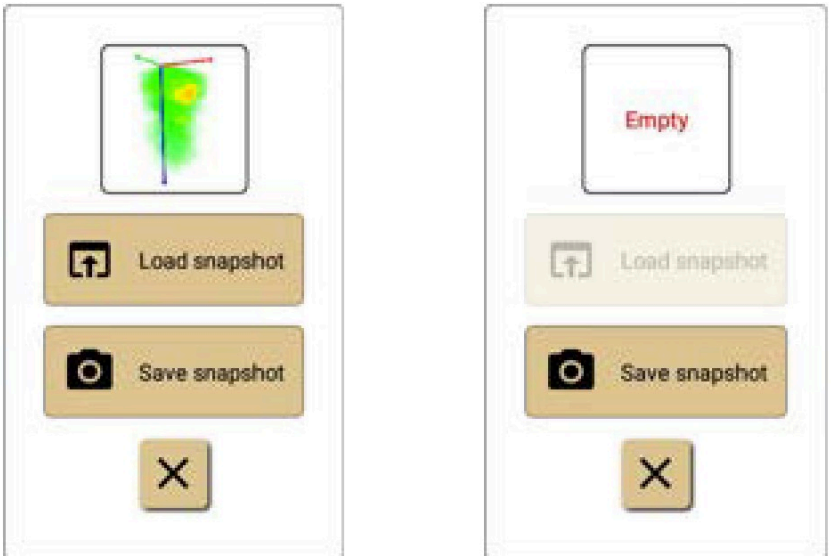


Figure 7.23: Snapshot dialog

If there was no previous snapshot saved before, you can just save this one now. Otherwise you can reopen the previously saved one into the graphical 3D representation or overwrite it with the current status.

Clipping planes: Move the upper or lower clipping plane button to remove scan data from the top or the bottom layers of your display. This helps to get rid of unwanted disturbances close to the surface or subfloor.

7.4.3 Toolbar menu

If you push the button, that is located in the toolbar of the 2D and 3D view screen, the toolbar menu opens up. Each toolbar menu consists of the following items:

- **Favorite:** Push this button to switch the current scan file from a non-favorite scan to a favorite scan. Doing so, you can filter out all favorites later on while browsing your scan files. Pushing this button several times simply toggles between both states.

- **3D / 2D filter ...:** This option can be used to change the applied filter configuration. This is only recommended for professional users. Changing the settings can result in wrong data display. Detailed information about filters is available in section 7.4.4 “Applying filters” on page 47.
- **Notes ...:** Use this option to change the project title and add additional remarks to your measurement. See section 7.4.5 “Changing project title and notes” on page 50 for further details!
- **Scan dimensions ...:** This option is used to enter the correct field dimensions of your measurement. That is very important to measure distances or positions of potential targets. Check out section 7.4.6 “Setting field dimensions” on page 50 for additional information!
- **Show map:** This function generates a Google Map containing the current measurement. Detailed information about maps are presented in section 7.4.7 “Showing map files” on page 52.
- **Export:** Select this option to export the current measurement into different formats like:
  - **PDF:** Generates a PDF document with the current graphical representation and additional scan information.
  - **PNG:** Generates a PNG image of the current graphical representation.
  - **CSV:** Generates a CSV file with all measured values along with its GPS data (if available) for usage in other software products.
  - **DZT:** Generates a DZT file that is common for general GPR software products.

Tap on the  button to close the toolbar menu.

7.4.4 Applying filters

After opening a 3D measurement the default filter is applied automatically to improve the visual representation of your recorded data. For all 2D measurements another filter combination is applied at the beginning, but you can change both filter configurations manually if necessary.

To apply the filters or change its settings accordingly, you need to open the toolbar menu as described in section 7.4.3 “Toolbar menu” on page 46. Then you select the option “Filter ...”. If you do so, the screen from figure 7.24 appears.

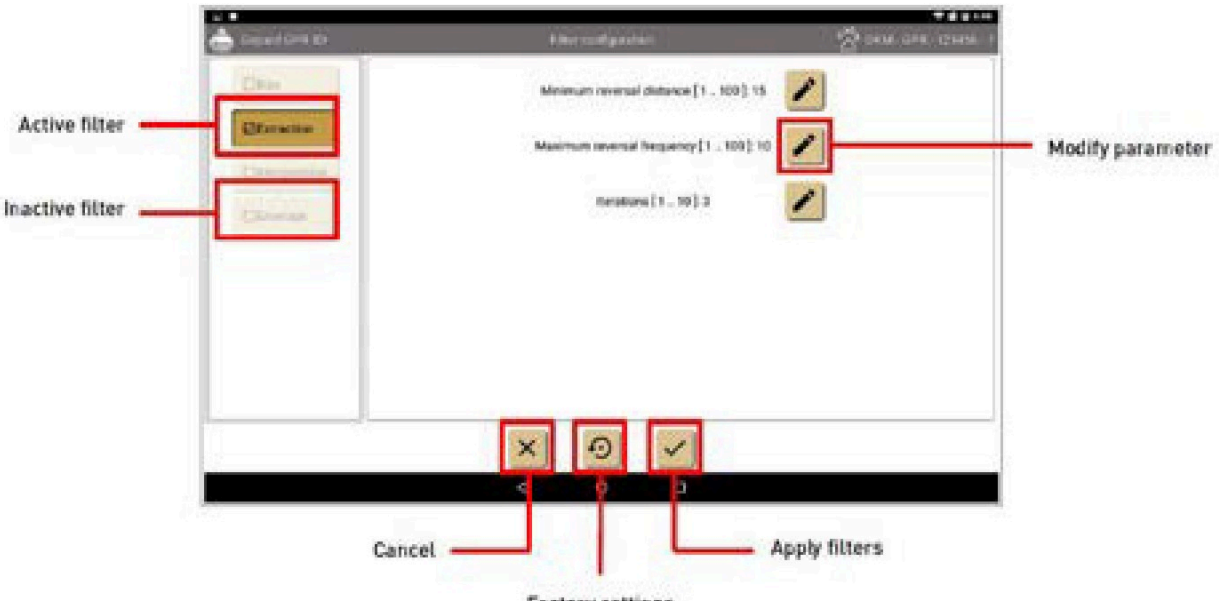


Figure 7.24: Filter dialog

On the left side of the screen there are all available filters listed. You can enable or disable filters by tapping the little checkbox left to the name. If you push the button itself, the right side of the screen changes to show the parameters associated with the selected filter.

Modify parameter: Select this option to change the value of the corresponding parameter. All parameters and its meanings are described in the following subsections.

Cancel: Use this button to cancel configuring the filters and close the filter dialog.

Factory settings: Push this button to set all parameters back to factory settings.

Apply filters: Push this button to apply the current filter settings to the current measurement.

The filters and its parameters will be explained in the subsequent sections.

7.4.4.1 Bias

The bias filter rearranges the values to remove noise and unwanted signals. You may change the intensity of the filter by setting the Range value. If this value equals 0 (zero) all measured values will be considered for the final calculation. Otherwise only the specified number of neighboring values will be used for the final calculation.

7.4.4.2 Extraction

The extraction filter has been developed to extract any kind of interference from the measured data. This is especially useful to create much cleaner 3D representations. Following parameters can be adjusted:

- **Minimum reversal distance:** This value defines for how long a valid signal must be present within a single scan line to be a valid object. This value represents a number of scan values.
- **Maximum reversal frequency:** This value defines how many signal changes are allowed within a single scan line. This value represents a percentage.
- **Iterations:** Enter a value from 1 to 10 to define how often the extraction process should be executed over the measurement. The more cycles you run the more signals will be taken away.

7.4.4.3 Interpolation

The interpolation collects nearby data to form groups of potential structures. Therefor several values can be adjusted:

- **Use absolute values:** If this value equals 1 (one), all scan values will be made absolute before any further calculation is applied.
- **Normalization:** If this value equals 1 (one), all calculated scan values will be normalized before executing the next iteration.
- **Mode:** The are two calculation modes: Simple and Advanced. The latter mode uses more values for its calculation which results in smoother results.
- **Maximum impulse distance:** Enter a value from 1 to 10 to set the range or distance of neighbor values that should be part of the interpolation process (only for current scan line members).
- **Maximum scan line distance:** Enter a value from 1 to 10 to set the range or distance of neighbor values that should be part of the interpolation process (for all scan line members).
- **Iterations:** Enter a value from 1 to 7 to define how often the interpolation process should be executed over the measurement. The more cycles you run the smoother the result but you may lose small single objects.

7.4.4.4 Envelope

The envelope filter takes a high-frequency signal as input and provides an output which is the envelope of the original signal. Therefor two values can be adjusted:

- **Raise Time:** Enter a value from 0.00 to 1.00 to set the increasing speed of the envelope.
- **Falloff Time:** Enter a value from 0.00 to 1.00 to set the decreasing speed of the envelope.

7.4.5 Changing project title and notes

Before you create a new measurement you have to enter a meaningful project title. Without entering a title you cannot conduct a measurement. You may change this project title and your additional remarks afterwards, e.g. to add some more important information or to precise the current title or description.



Figure 7.25: Notes dialog

To open the notes dialog from figure 7.25 you have to select the option “Notes ...” from the toolbar menu as explained in section 7.4.3 “Toolbar menu” on page 46. Use the buttons to change the content of title and description.

7.4.6 Setting field dimensions

If you want to measure the position of potential targets you must enter the correct field dimensions of your scan area. In the toolbar menu (see section 7.4.3 “Toolbar menu” on page 46) you have to select the option “Scan dimensions ...”. Then the dimensions dialog from figure 7.26 appears on the screen.



Figure 7.26: Field dimensions dialog

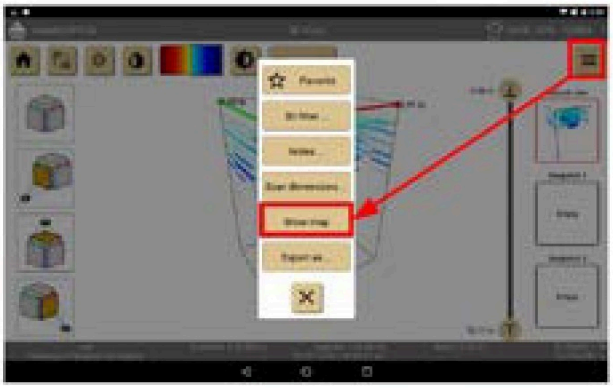
In the dialog you can enter the following information:

- **Meter / Feet:** Select either Meter or Feet as your unit of length and width.
- **Field Length:** This is the length of a single scan line, no matter if you have conducted a scan in 2D or 3D. Simply tap the button to change the length value. If the button is enabled, you can tap on it to get the calculated length value according to the recorded GPS data.
- **Field Width:** This is only useful for 3D scans and indicates the distance between first and last scan line. Simply tap the button to change the width value. If the button is enabled, you can tap on it to get the calculated width value according to the recorded GPS data.

Push the button to apply all changes and close the dialog.

7.4.7 Showing map files

Within the software application you can create Google map files that contain one or more scan files. There are two possible ways to create a map with your measurement.



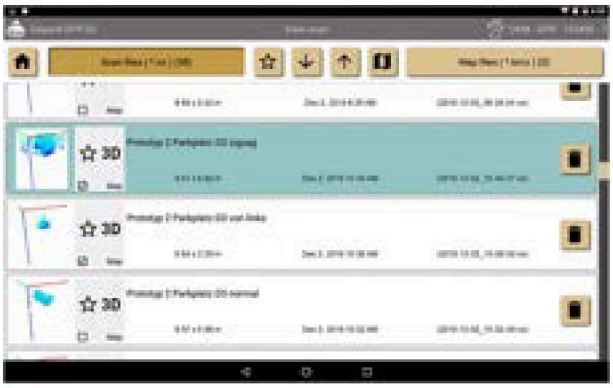


Figure 7.27: Create a map file - Alternative 1 / Figure 7.28: Create a map file - Alternative 2

Alternative 1	Alternative 2
1. In the main menu you select “View scan” and open the desired scan image. 2. Then you open up the toolbar menu ... 3. ... and select “Show map”.	1. In the main menu you select “View scan” and tick the small Map checkbox of all desired scan images. 2. Then you tap on the button within the toolbar. 3. Now enter an individual filename for the new map file.

Depending on the size of your measurements the map calculation may take a while. As soon as the map file has been created the screen from figure 7.29 appears.

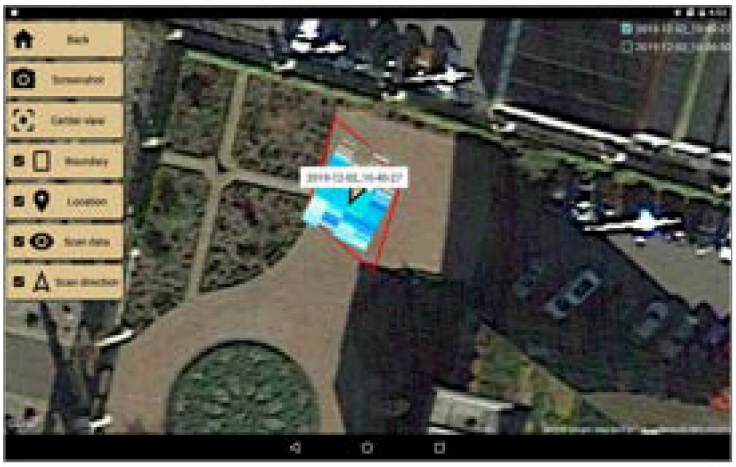


Figure 7.29: Map view

In the right upper corner of the screen you will see all included measurements. You can untick any of those measurements to hide it in the map view.

Use the buttons on the left side of the screen to overlay different kind of information:

	**Back** Use this button to leave the current map screen and get back to the previous screen.
	**Screenshot** Push this button to create a screenshot of the current map screen. The final image is stored at *Internal Storage > Documents > OKM > Gepard GPR 3D* If you push this button a second time you will overwrite the previous screenshot.
	**Center view** Pushing this button aligns your map with the scan centered in the screen.
	**Boundary** This button toggles the visibility of the bounding box of the scan area.
	**Location** Pushing this button toggles the visibility of the scan label. This is useful if there are more scans in the map.
	**Scan data** This button toggles the visibility of the recorded scan data. The display will use the current color schema and threshold to render the scan data.
	**Scan direction** This button toggles the scan direction indicator, that shows in which direction the scan was conducted.

CHAPTER 8

Appendix & References

8.1 Depth Table Calculations

With varying soil attenuation, the Gepard GPR was calculated with a median frequency value of 100 MHz.[1] Reference material used from DJ Daniels, Institution of Electrical Engineers, Ground Penetrating Radar, 2nd Edition, 1996.

Some Typical Dielectric Characteristics of Materials Measured at 100 MHz

Material	Conductivity, σ (S-m)	Relative Permeability ($\mu_r = \mu/\mu_0$)	Relative Permittivity ($\varepsilon_r = \varepsilon/\varepsilon_0$)	Attenuation, α(dB-m^{-1})
Air	0	1	1	0
Asphalt—dry	10^{-2} – 10^{-1}	2–4	2–4	2–15
Asphalt—wet	10^{-2} – 10^{-1}	6–12	6–12	2–20
Clay—dry	10^{-1} – 10^{-3}	2–6	2–6	10–50
Clay—wet	10^{-1} – 10^{-2}	5–40	5–40	20–100
Coal—dry	10^{-2} – 10^{-3}	3.5	3.5	1–10
Coal—wet	10^{-2} – 10^{-1}	8	8	2–20
Concrete—dry	10^{-2} – 10^{-3}	4–10	4–10	2–12
Concrete—wet	10^{-1} – 10^{-2}	10–20	10–20	10–25
Freshwater	10^{-2} – 10^{-3}	81	81	0.01
Freshwater ice	10^{-2} – 10^{-3}	4	4	0.1–2
Granite—dry	10^{-3} – 10^{-4}	5	5	0.5–3
Granite—wet	10^{-4} – 10^{-5}	7	7	2–5
Limestone—dry	10^{-4} – 10^{-6}	7	7	0.5–10
Limestone—wet	10^{-2} – 10^{-3}	8	8	1–20
Permafrost	10^{-3} – 10^{-4}	4–8	4–8	0.1–5
Rock salt—dry	10^{-5} – 10^{-7}	4–7	4–7	0.01–1
Sand—dry	10^{-5} – 10^{-7}	2–6	10–30	0.01–1
Sand—wet	10^{-3} – 10^{-4}	10–30	2–5	0.5–5
Sandstone—dry	10^{-6} – 10^{-8}	2–5	5–10	2–10
Sandstone—wet	10^{-4} – 10^{-5}	5–10	5–10	4–20
Sea water	10^{0}	81	81	100
Sea water ice	10^{-1} – 10^{-2}	4–8	4–8	1–30
Shale—dry	10^{-1} – 10^{-2}	4–9	4–9	1–10
Shale—saturated	10^{-1} – 10^{-2}	9–16	10–30	5–30
Snow—firn	10^{-5} – 10^{-6}	6–12	6–12	0.1–2
Soil clay—dry	10^{-1} – 10^{-2}	4–10	4–10	0.3–3
Soil clay—wet	10^{-1} – 10^{-2}	10–30	10–30	5–50
Soil loamy—dry	10^{-2} – 10^{-3}	4–10	4–10	0.5–3
Soil loamy—wet	10^{-2} – 10^{-3}	10–30	4–10	1–6
Soil sandy—dry	10^{-4} – 10^{-5}	4–10	4–10	0.1–2
Soil sandy—wet	10^{-2} – 10^{-3}	10–30	10–30	1–5

Source: Daniels, D.J., *Ground Penetrating Radar*, 2nd ed., Institute of Engineering and Technology, London, UK, 2004.

Figure 8.1: Dielectric reference for various soil attenuation

[1] DJ Daniels, Ground Penetrating Radar, 2004

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