

**OKM**

# **Gepard - GPR**

**Ground Penetrating Radar**



**User's Manual**

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# CHAPTER 1

## **Introduction**

## 1.1 Preface

Dear Customer,

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

The Gepard - GPR detector works on the principle of Ground Penetrating Radar (GPR). The radar (**RA**dio **D**etection **A**nd **R**anging) 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 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 and on-site. 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 PC to give a visual representation of the anomaly. Using our proprietary software program will assist in visualizing the object.

### **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.

The device has a built in anti-tampering module which will destroy the unit if it is improperly opened. 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 battery powered. Please use only approved batteries and power supplies for this unit.

**Never connect or use a 115/230 Volt main AC power supply!**

### 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 antenna is not extended far enough or extended too far,
- the unit is operating too close to devices which send out or cause 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 reliable 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(s).

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

**To charge the external and internal batteries, use only the approved chargers which are part of our 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 munitions 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

## **Equipment Introduction**

In this chapter we will show all the various parts of the Gepard - GPR. Please verify the contents to ensure that the package is complete.

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.

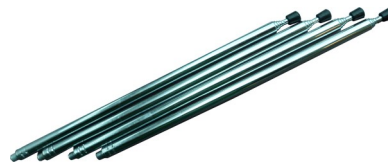
The unit comprises mainly of three different parts.



*Illustration 2.1: Control Unit - side view*



*Illustration 2.2: Shafts with the Transmitter and Receiver*



*Illustration 2.3: Extendable Antennas*

When all parts are assembled the unit is complete.

For the use and operation of the Gepard - GPR, there are several factors to take into consideration. Many are very simple some are more complicated.

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.
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 35 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 PC, the software has been simplified requiring only a couple of steps prior to beginning a measurement. In the software section, we will explain in detail as to how to begin a measurement.





# CHAPTER 3

## **Technical Specifications**

The following technical indications are medial values. During operation small variations are quite possible.

### 3.1 Control Unit

Dimensions (H x W x D) .....	350 x 182 x 60 mm
Weight (without batteries).....	about 1700 g
Voltage .....	9.6 – 13.2 VDC, 18 W
Operating Time (alkaline batteries, 25 °C) .....	about 6 hours
Operating Time (accumulator batteries, 25 °C) .....	about 3 hours
Operating Time (OKM Power Pack 25 °C) .....	about 10 hours
Operating Temperature .....	-20 °C to +55 °C
Storage temperature .....	-25 °C to +60 °C
Air humidity .....	5 % – 70 %
Battery Charger Module .....	Internal
External Power Supply .....	Yes (optional)
Waterproof .....	No
Multiple Transmission Frequency Range .....	60 MHz to 300 MHz
Control Display .....	LED
Multi-Function Control .....	Yes
Timing/Sampling Adjustments Send/Receive .....	16 Levels
Complete Cycle Measurements .....	9 per second

### 3.2 Data Transmission

Technology .....	Bluetooth
Transmission Frequency .....	ISM band from 2400–2480 MHz

# CHAPTER 4

## **Scope of Delivery**

In the following section is a detailed list of all standard equipment shipped with the Gepard - GPR. In some instances the contents may vary depending on custom configurations from the customer.

Description	Quantity	Image
Control Unit	1	
Battery Housing (4 x AA (LR6) Battery)	2	
Extendable Antenna + Spare Antenna	4 2	
Shaft with Transmitter (Red bands on BNC connector)  Shaft with Receiver (Black bands on BNC connector)	2	
Charger and travel adapter	1	
Android Tablet	1	
Android Tablet Holder	1	
User Manual	1	This Book
Water and Shock Resistant Peli Case	1	

Table 1: Gepard Packing List

# CHAPTER 5

## Assembly

This section explains how to assemble the Gepard - GPR and to prepare the unit for operation.

## 5.1 Assembly

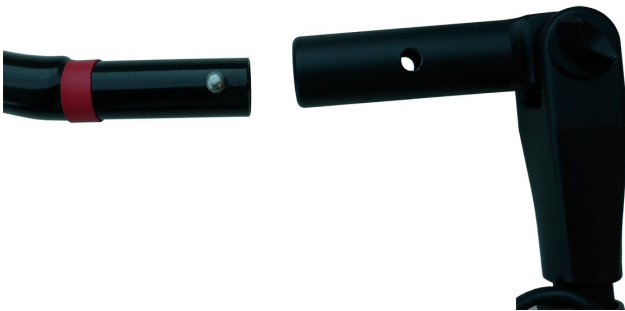
Preparing the Gepard - GPR for use is very simple. After inspecting all of the components and ensuring that all parts are present, assembly can begin.



*Illustration 5.1: Main Unit with extended battery housings.*

Remove the battery housings from the main unit and insert 8 “AA” size (LR6) (NiMH or Lithium) rechargeable or alkaline batteries. Inside of the housings, the battery orientation is shown.

Insert the battery housings back into the main unit and push in until they lock into place.



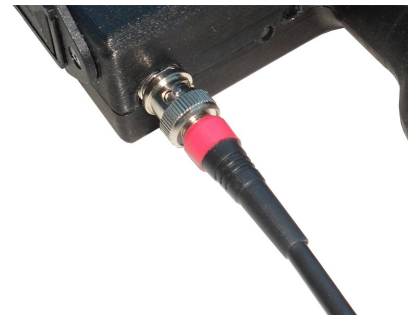
*Illustration 5.2: Line up the shafts*

Match the shaft color to the plug. Red to red and black to black.

Connect the BNC connectors to the control unit. Line up the tabs and turn clockwise to tighten and counter-clockwise to loosen.

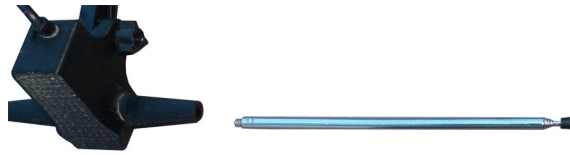


*Illustration 5.3: Push together the shafts and match the colors*

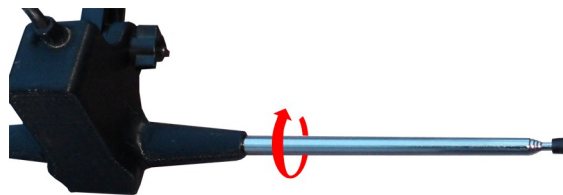


*Illustration 5.4: Connect the BNC to control unit*

Connect the extendable antenna to the lower portion of the transmitting and receiving shafts



*Illustration 5.5: Attach extendable antenna to shaft*



*Illustration 5.6: Tighten antenna by turning clockwise*

Turning the antenna clockwise will tighten it onto the bottom of the shafts. The extendable antennas can be interchanged with either of the shafts.

Prior to storing the unit back in the carrying case, unscrew the extendable antennas. This will help to prevent any damage to the antennas.

Insert the Android tablet PC into the holder and attach the holder to the main unit.



*Illustration 5.7: Attach the Monitor to the main unit.*

The holder slides on top of the bracket. To remove, simply lift off.



*Illustration 5.8: Fully assembled Gepard - GPR unit*

**When using disposable batteries, do not use Zinc Carbon (Zink-Braunstein) batteries to power the Gepard – GPR**



## 5.2 Headphones

Figure shows the controls for the delivered wireless headphones.



*Illustration 5.9: Wireless Headphones*

To use the delivered wireless headphones, you should insert two charged micro type AAA batteries inside the battery case. To do so, remove the battery cover on the left side "L" and insert the batteries into the battery case. Make sure that the polarity is not reversed. Place the battery cover back on the headphones and listen for a click. This will ensure that the cover is locked into place.

Power on the wireless headphones with the power on/off button (ON/OFF) and find the correct channel with the frequency regulator (TUNE). The device Gepard - GPR should be powered on and release an acoustic signal during this adjustment.

Via the volume control (VOLUME) you can regulate the volume of the headphones.



# CHAPTER 6

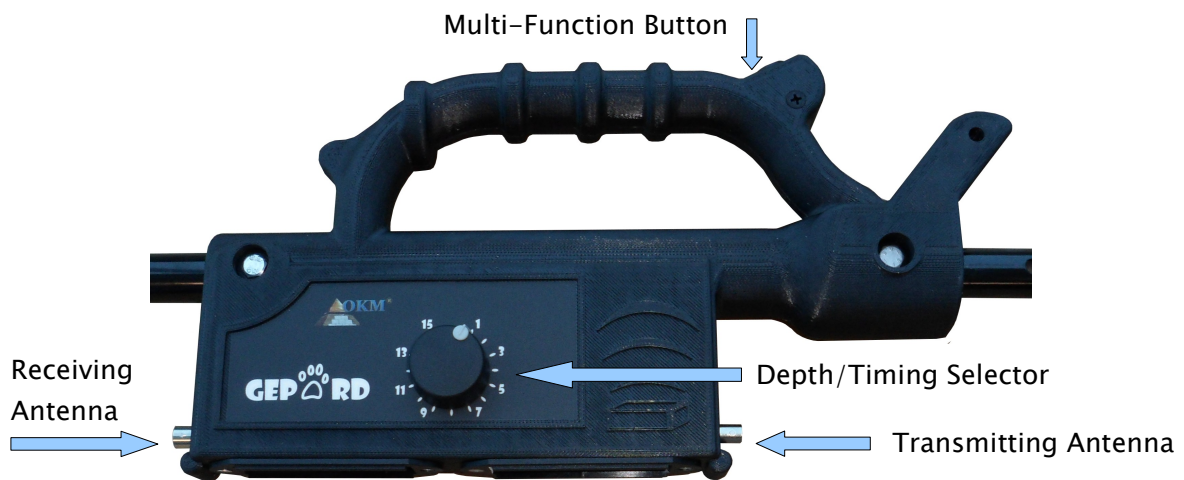
## Control Elements

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.

## 6.1 Control Unit

The control unit is the processing center of the Gepard - GPR. Via the control unit, various functions from the Android tablet can be selected. Afterward the data can be transferred from the main unit to the Android tablet.

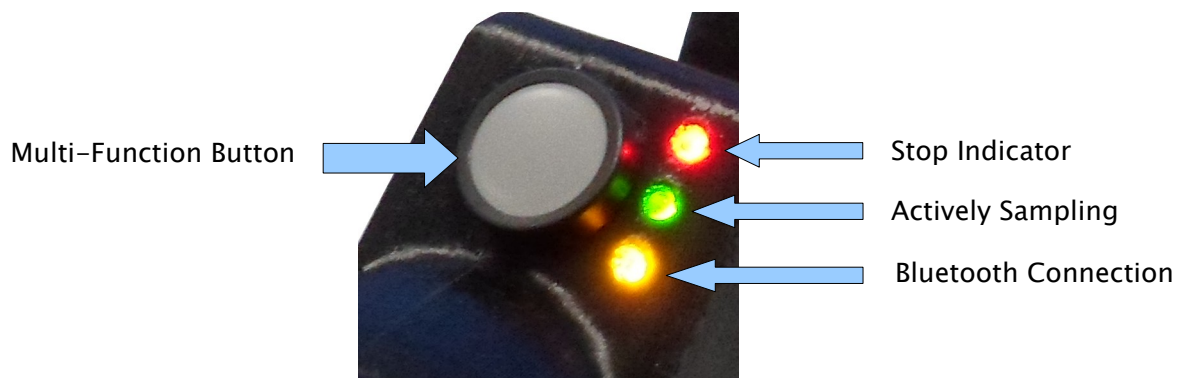
### 6.1.1 Front View



*Illustration 6.1: Front view of control unit*

The main unit controls are very simple. Primarily there are two controls on the main unit. The Multi-Function Button and the Depth/Timing Selector.

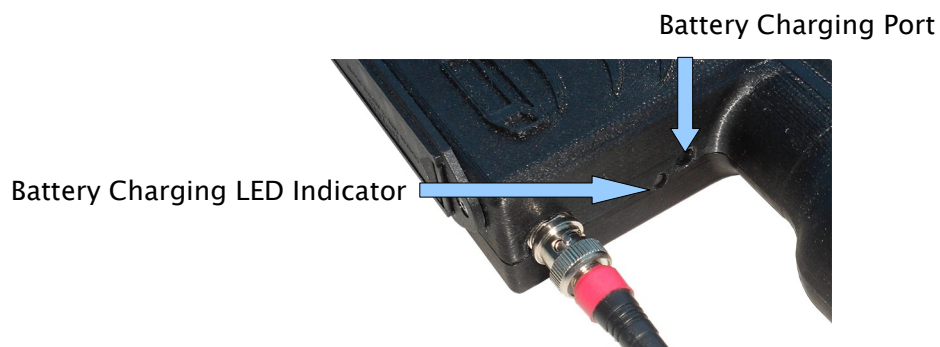
The Multi-Function button is the main control for turning on the unit, starting, stopping, manually controlling measurements and turning off the unit.



*Illustration 6.2: Multi-Function button and LED indicators*

To turn on the Gepard - GPR, simply press the Multi-Function button one time. The unit will turn on and as a test all three of the LEDs will illuminate for approximately 3 seconds, then will turn off for internal testing for the next 5 seconds. After approximately 8 seconds, the Red (No measurement or Stop indicator and the Green (Actively taking a measurement) indicator will illuminate. During the startup period or until the Red and Green LEDs are illuminated, do not press the Multi-Function button.

The Gepard - GPR can be operated from either internal or external batteries. The optional OKM Power Pack can also power the unit. This external power pack, when connected, can operate the unit and charge internal rechargeable batteries.



*Illustration 6.3: Charging Port and LED Indicator*

In Illustration 6.3: Charging Port and LED Indicator is shown where to connect the battery charger connector or the external power supply. When there are internal rechargeable batteries the Charging Indicator will illuminate. In the event that the internal batteries are not rechargeable, the unit will recognize this and not put a charge to the batteries.

To turn off the Gepard - GPR, press and hold the Multi-Function button for 3 seconds. As you are holding the Multi-Function button, the red LED will remain illuminated until it is released.



# CHAPTER 7

## Operating Modes

In this section you will learn more about the different operating modes of the Gepard - GPR. Every function is explained in its proper subsection.

Selecting the correct operating mode depends primarily on the desired output. Depending on the terrain and/or obstacles the mode will either be Automatic or Manual.

The Gepard - GPR has the following operating modes:

- **Automatic**  
Actively samples an area with an automatic timing of 9 complete transmission cycles per second.
- **Manual**  
Samples are taken via the manual method. Once selected the GPR will only sample the measuring area when the Multi-Function button is depressed and released.

For most instances when an area is clear of obstacles like plant growth, trees and shrubs and there is a clear path to conduct the measurement, the Automatic mode will be used. When using this mode in an open area, the GPS mode can be activated. With this mode activated a path will be stored in the scans memory allowing you to recall where you were during that scan.

When there is plant growth, shrubs, trees, big rocks or other obstacles, the Manual mode can be used. Using the manual mode allows you to go over an area, perform the sampling then move the GPR to the next area. Once selected the GPR will only sample an area when the Multi-Function is depressed. This mode is configured within the software, located on the Android tablet.

Click on the Menu tab and then select “New”

A new window will appear asking you if your would like to conduct the measurement using the Automatic Mode or the Manual Mode.

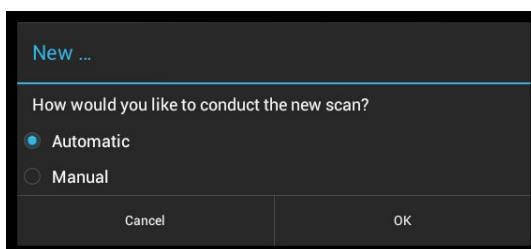


Illustration 7.2: New file option screen

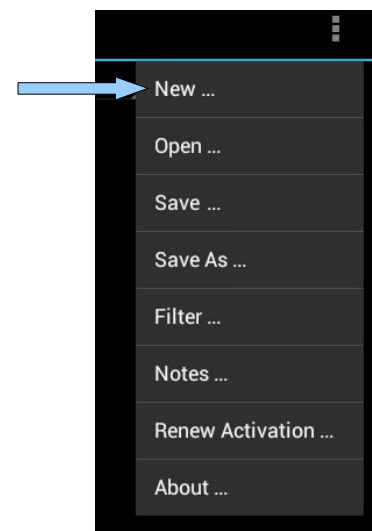


Illustration 7.1: Select New



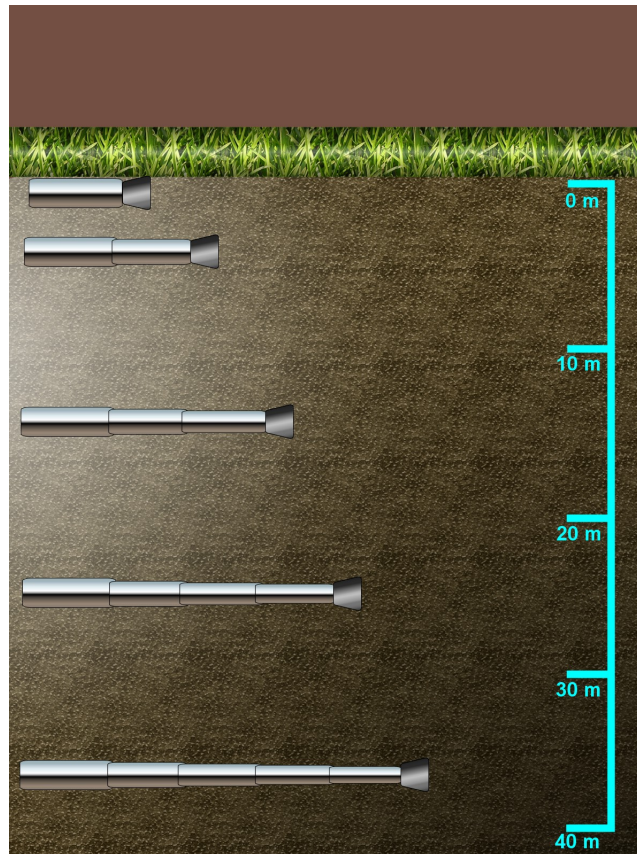
# CHAPTER 8

## **Field procedure**

This chapter gives practical instructions about the general procedure of scanning an area. The different scanning methods and procedures will be explained in detail.

## 8.1 GPR Antenna Setup

Take the fully assembled unit and extend the antennas. The extension of the antennas will dictate the frequency as well as the ultimate depth. For smaller items that are very near the surface the antennas can be shortened which will be able to see nearer to the surface. To see larger items that are deeper, lengthen the antennas.



*Illustration 8.1: example of antenna extensions and depth capabilities.*

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 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.

The Gepard - GPR does not use a shielded transmission system and transmits in an omni directional pattern. Be aware when in enclosed spaces that the data being measured may be above as well as below.

Keeping notes of the measured area are very important. Notes can be written directly within the file and saved.

# CHAPTER 9

## Software

The Gepard - GPR software is fully explained. How to work the various features and conduct the data analysis.

### 9.1 Starting Software

To start the software, from the main screen, tap your finger on the



icon



Illustration 9.1: Android Home Screen

## 9.2 Screen Layout

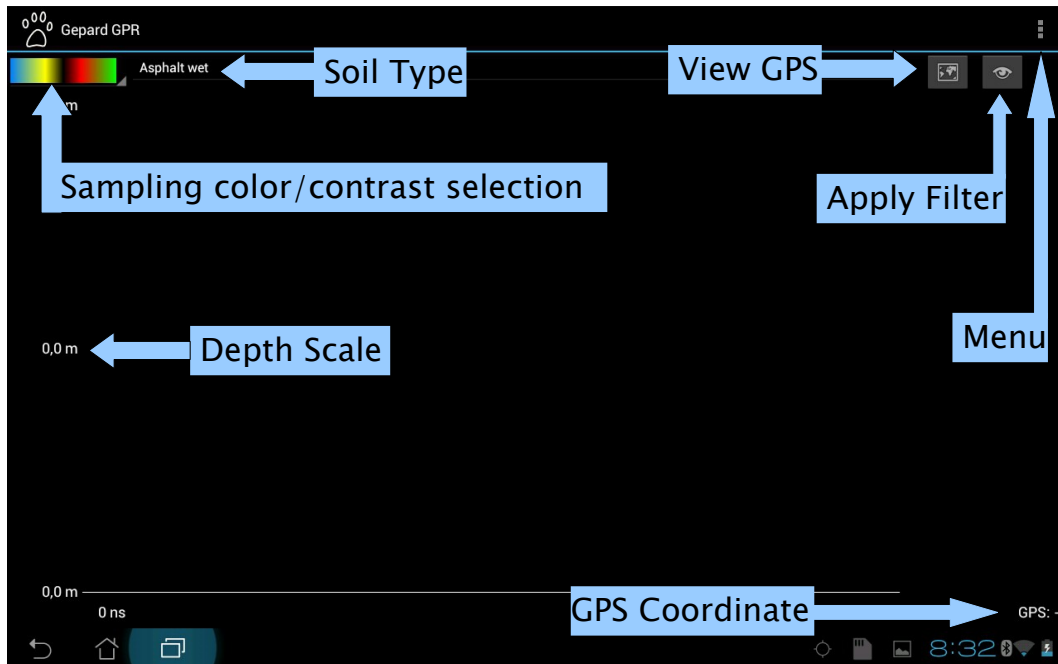


Illustration 9.2: Home Screen of GPR Software

The screen of the software is very simple and easy to operate. Select a function and tap on it with your finger.

### 9.3 Menu

To enter into the Menu, tap on the upper right hand corner.

#### 9.3.1 New

This prepares the software to receive data from a new scan

#### 9.3.2 Open

This opens an existing scan from memory

#### 9.3.3 Save

This saves the current scan.

#### 9.3.4 Save As

This saves the open scan under a different name

#### 9.3.5 Filter

This applies a filter to assist in the data analysis

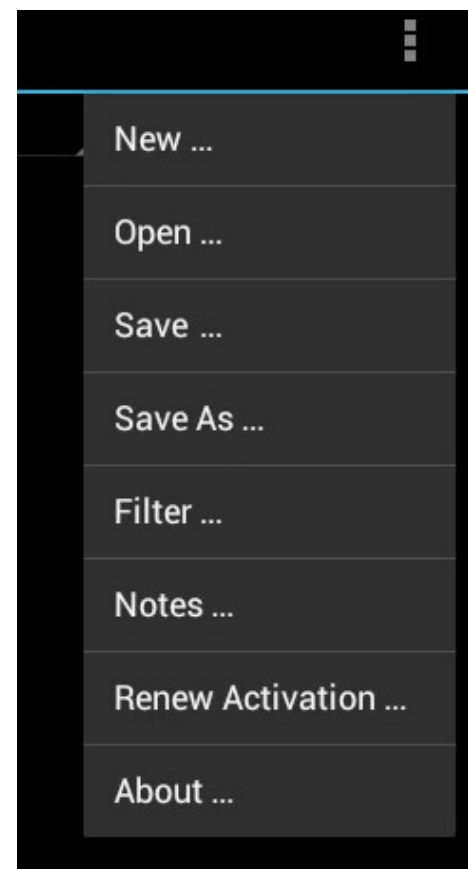


Illustration 9.3: Menu Screen

### **9.3.6 Notes**

This is the area where you can enter notes about a scan. Notes would include where you were, the length of scan and other pertinent information.

### **9.3.7 Renew Activation**

When the Android tablet is changed and a new installation has occurred, this function will allow the software to be activated.

### **9.3.8 About**

Here is the software version number, serial number and licensing information.

## **9.4 Software Setting**

Many of the software settings are tied directly into the Android tablet PC.

### **9.4.1 Depth/Sampling**

To change the Depth/Sampling timing, on the control unit, change the desired level from 1 to 16. Items near the surface will use a value of between 1 and 5 and larger deeper items will use values between 10 and 16.

### **9.4.2 Bluetooth**

Bluetooth is the primary communication between the Gepard - GPR and the Android tablet PC. If the Bluetooth is turned off, communication with the GPR is not possible. To activate the Bluetooth, enter into the Android: Settings > Bluetooth and tap to activate.

### **9.4.3 GPS**

To use the built in GPS on many Android tablet PC's the GPS must be activated. To activate the GPS, enter into the Android: Setting > Location services > (activate the following) Google's location service, GPS Satellites and Location & Google search.

### **9.4.4 Language**

To change the software language, it is directly tied into the Android unit. Enter into the Settings > Language & Input > Language.

There are many languages available, in the event that the software is not yet translated into the chosen language, it will default to English.

Available languages: English, German, French, Dutch, Turkish, Russian, Arabic, Farsi, Spanish, Italian, Greek, Chinese and Japanese.

## 9.5 Soil Types

Selecting the correct soil type will make the depth measurements 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.

Air	Limestone dry	
Asphalt dry	Limestone wet	
Asphalt wet	Permafrost	Soil clay dry
Clay dry	Rock salt dry	Soil clay wet
Clay wet	Sand dry	Soil loamy dry
Coal dry	Sand wet	Soil loamy wet
Coal wet	Sandstone dry	Soil sandy dry
Concrete dry	Sandstone wet	Soil sandy wet
Concrete wet	Sea water	
Freshwater	Sea-water ice	
Freshwater ice	Shale dry	
Granite dry	Shale saturated	
Granite wet	Snow firm	

Illustration 9.4: List of available soil types

Various soil types will have different attenuation factors. Soil magnetic permeability (detailed table located on page 46) 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.

## 9.6 Filters

Using filters to better analyze the data is possible and recommended. The software can filter out approximately 70% of the background to better recognize a target.

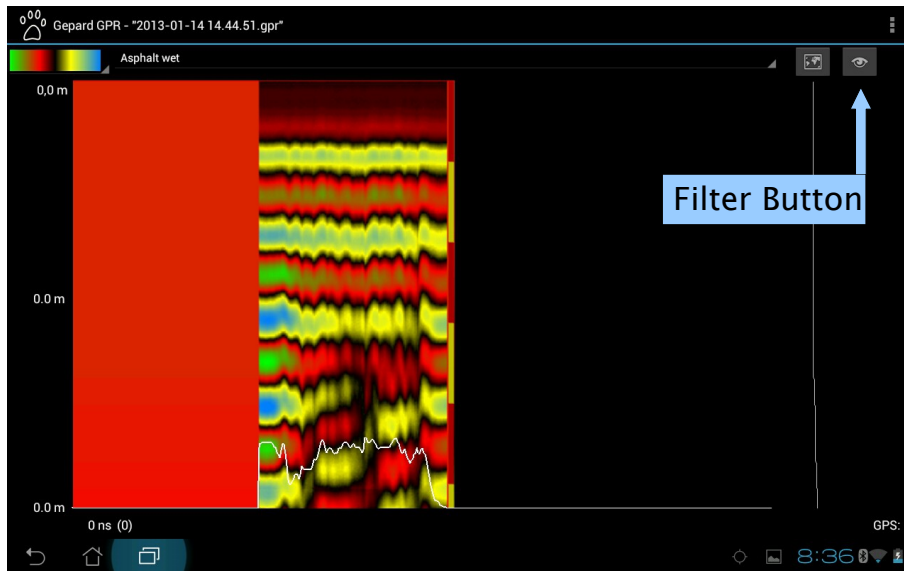


Illustration 9.5: Unfiltered Image

Tap on the Filter button  to bring up the filter menu.

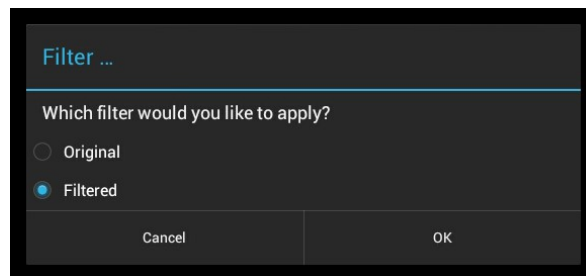
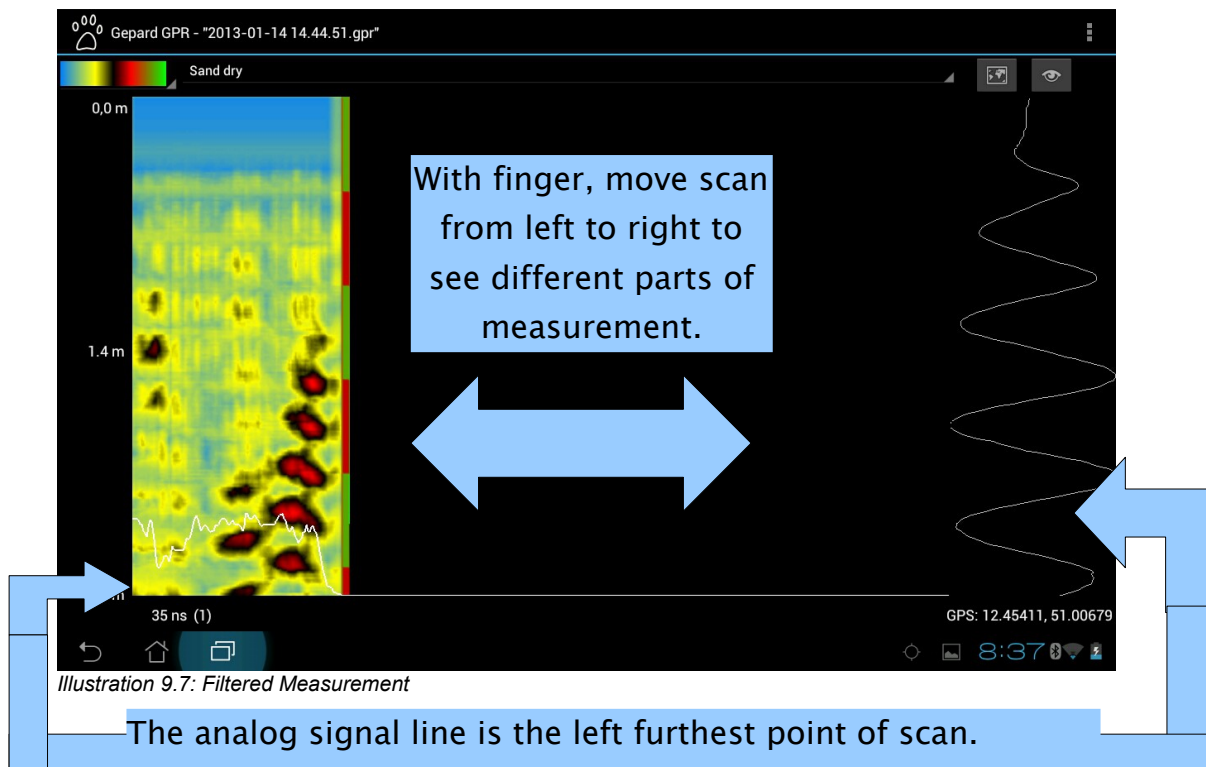


Illustration 9.6: Filter Menu

Tap on “Filtered” then tap on “OK”. The filter will be applied. A status bar will keep you informed of the filtration progress.



The acquired analog signal wave is a reading from the far left edge of the scan.

## 9.7 Sampling Colors/Contrast

By tapping on the color bar in the upper left hand corner of the screen will bring a drop down selection of colors. To change colors and contrast differences, simply choose a color and tap on it. The scan will redraw and the new colors will replace the old ones.

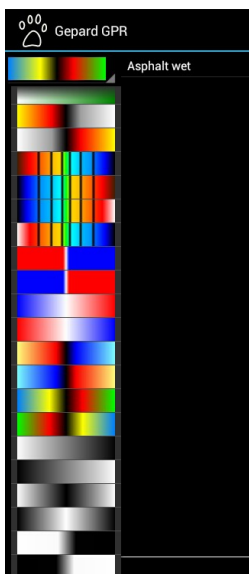


Illustration 9.8: Color Options

This method of filtration will not remove any of the background noise. When using a filter, like that in Illustration 9.7: Filtered Measurement, you can remove parts of the background to better see your object.



### 9.8 Notes

When files are saved, pertinent information that belongs to any particular file should be entered into the scan itself.

Information that should be included is position, terrain, weather, obstacles and other important features that will help the user locate the scan area.

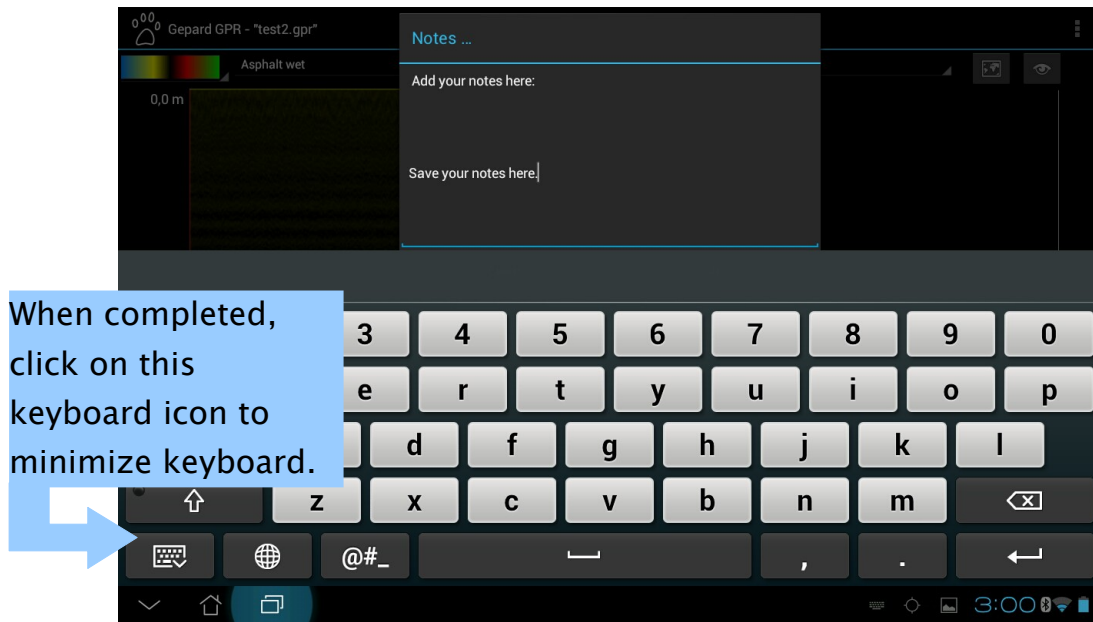


Illustration 9.9: Notes keyboard

Type in your notes then minimize the keyboard which is displayed to complete the notes process.

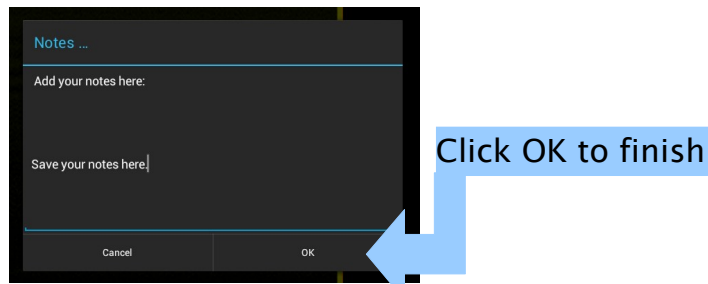


Illustration 9.10: Notes window

## 9.9 GPS

Using the GPS has been simplified. Once the Android tablet PC has the GPS activated, it is automatically recorded during a measurement.

To view the GPS coordinates, they are on the bottom right hand corner of the screen. When you have a connection to the Internet, you can receive a map from Google Maps and see the path you have scanned.

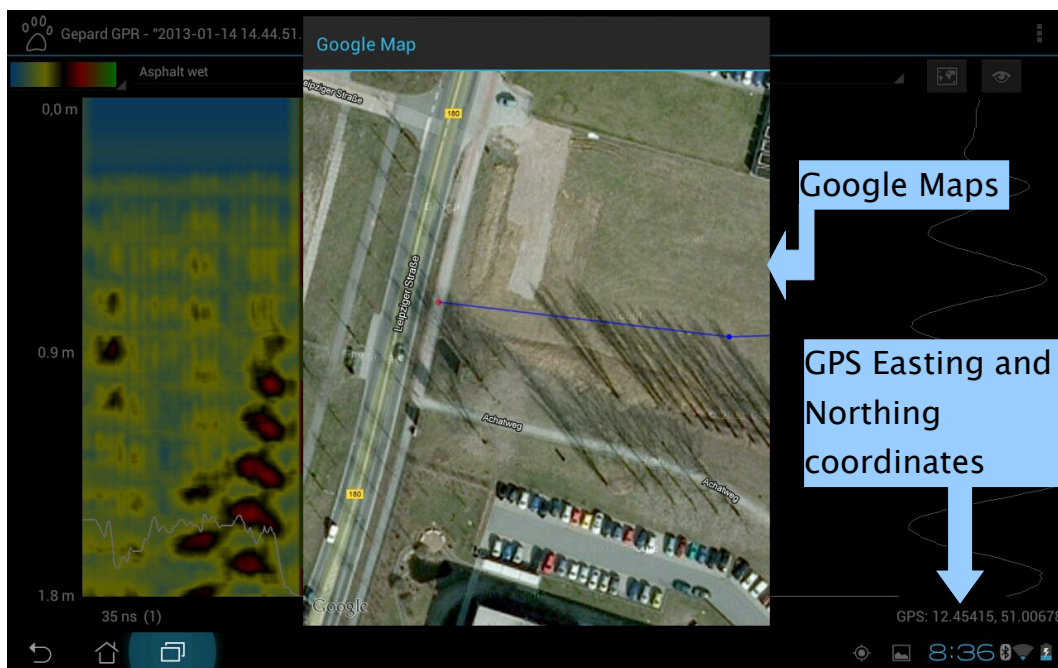


Illustration 9.11: GPS Map and Coordinates

Once you have activated the GPS, it is recommended to allow the Android several minutes to acquire a GPS signal.

## 9.10 Software Activation

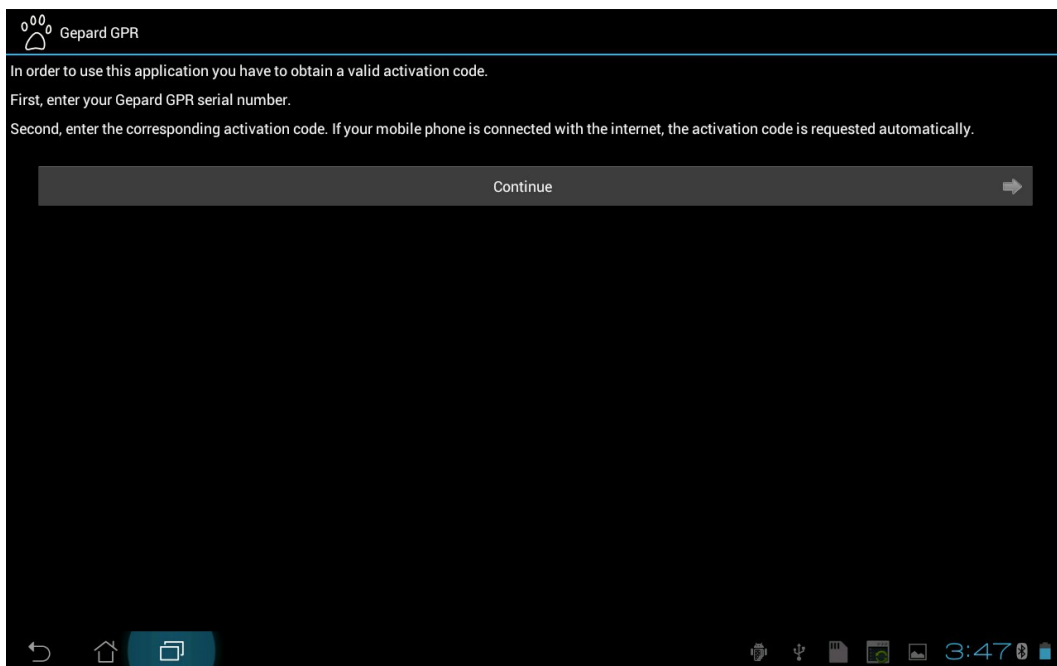
When you receive the Gepar - GPR with the Android Tablet PC it is already activated. In the event that you replace the Android, the following instructions explain how to activate the software.

In the very front of the user manual there is a small notice (leaflet). This notice has the software code for renewing the activation of the software. The leaflet is attached to the inside of the user manual, please make a copy of it and keep it in a safe place.

To obtain a new copy of the software, connect your Android to the Internet and go to Google Play. Conduct a search for OKM Gepard GPR and you can purchase an additional copy for a new Android.

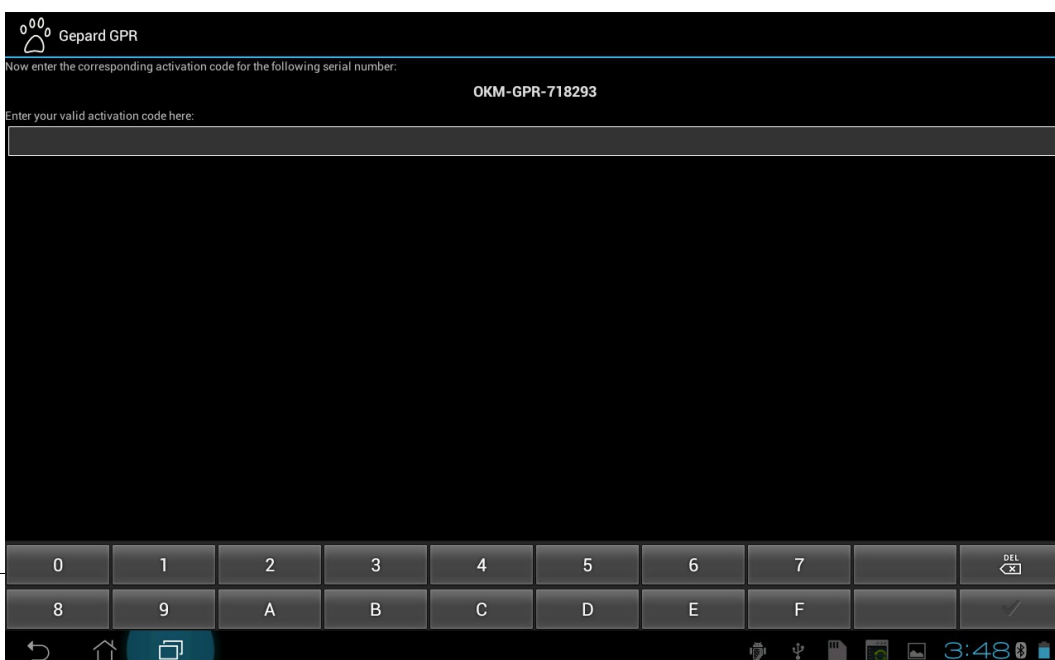
Start the software and click on the "Menu" tab.

Click on the "Renew Activation" tab and the following screen will appear.



*Illustration 9.12: First Renew Activation Screen*

After pressing the continue button, enter in the unit serial number.



*Illustration 9.13: Serial number activation screen*

You will then be asked to enter in the Software Activation code.

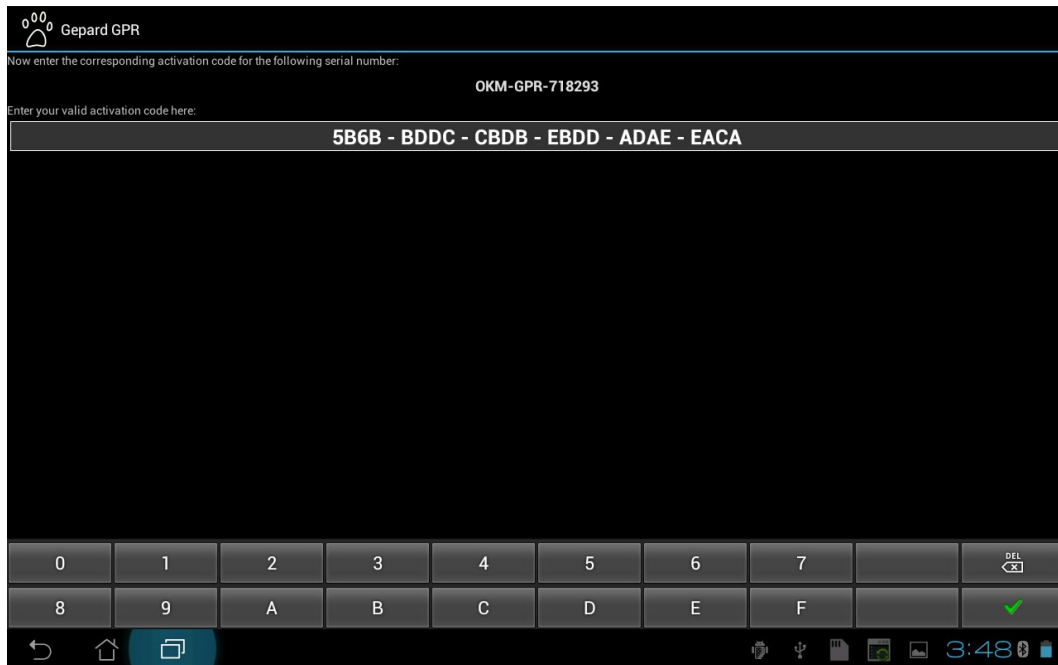


Illustration 9.14: License and Bluetooth number activation screen

Once that is completed you will receive a window stating “Success” and your software is now ready to use.

# CHAPTER 10

## **Appendix & References**

In this chapter you will find appendices to tables and references used.

## 10.1 Depth Table Calculations

**TABLE 5.4**  
Some Typical Dielectric Characteristics of Materials Measured at 100 MHz

Material	Conductivity, $\sigma$ (S-m)	Relative Permeability ( $\mu_r = \mu/\mu_0$ )	Relative Permittivity ( $\epsilon_r = \epsilon/\epsilon_0$ )	Attenuation, $\alpha$ (dB-m <sup>-1</sup> )
Air	0	1	1	0
Asphalt—dry	10 <sup>-2</sup> – 10 <sup>-1</sup>	2-4	2-4	2-15
Asphalt—wet	10 <sup>-3</sup> – 10 <sup>-1</sup>	6-12	6-12	2-20
Clay—dry	10 <sup>-1</sup> – 10 <sup>-9</sup>	2-6	2-6	10-50
Clay—wet	10 <sup>-1</sup> – 10 <sup>-9</sup>	5-40	5-40	20-100
Coal—dry	10 <sup>-3</sup> – 10 <sup>-2</sup>	3.5	3.5	1-10
Coal—wet	10 <sup>-2</sup> – 10 <sup>-1</sup>	8	8	2-20
Concrete—dry	10 <sup>-3</sup> – 10 <sup>-2</sup>	4-10	4-10	2-12
Concrete—wet	10 <sup>-2</sup> – 10 <sup>-1</sup>	10-20	10-20	10-25
Freshwater	10 <sup>-6</sup> – 10 <sup>-2</sup>	81	81	0.01
Freshwater ice	10 <sup>-4</sup> – 10 <sup>-3</sup>	4	4	0.1-2
Granite—dry	10 <sup>-8</sup> – 10 <sup>-4</sup>	5	5	0.5-3
Granite—wet	10 <sup>-3</sup> – 10 <sup>-2</sup>	7	7	2-5
Limestone—dry	10 <sup>-8</sup> – 10 <sup>-4</sup>	7	7	0.5-10
Limestone—wet	10 <sup>-2</sup> – 10 <sup>-1</sup>	8	8	1-20
Permafrost	10 <sup>-3</sup> – 10 <sup>-2</sup>	4-8	4-8	0.1-5
Rock salt—dry	10 <sup>-4</sup> – 10 <sup>-3</sup>	4-7	4-7	0.01-1
Sand—dry	10 <sup>-7</sup> – 10 <sup>-3</sup>	2-6	10-30	0.01-1
Sand—wet	10 <sup>-3</sup> – 10 <sup>-2</sup>	10-30	2-5	0.5-5
Sandstone—dry	10 <sup>-6</sup> – 10 <sup>-5</sup>	2-5	5-10	2-10
Sandstone—wet	10 <sup>-4</sup> – 10 <sup>-2</sup>	5-10	5-10	4-20
Sea water	10 <sup>2</sup>	81	81	100
Sea water ice	10 <sup>-2</sup> – 10 <sup>-1</sup>	4-8	4-8	1-30
Shale—dry	10 <sup>-3</sup> – 10 <sup>-2</sup>	4-9	4-9	1-10
Shale—saturated	10 <sup>-3</sup> – 10 <sup>-1</sup>	9-16	10-30	5-30
Snow—firm	10 <sup>-6</sup> – 10 <sup>-3</sup>	6-12	6-12	0.1-2
Soil clay—dry	10 <sup>-2</sup> – 10 <sup>-1</sup>	4-10	4-10	0.3-3
Soil clay—wet	10 <sup>-3</sup> – 10 <sup>-9</sup>	10-30	10-30	5-50
Soil loamy—dry	10 <sup>-4</sup> – 10 <sup>-3</sup>	4-10	4-10	0.5-3
Soil loamy—wet	10 <sup>-2</sup> – 10 <sup>-1</sup>	10-30	4-10	1-6
Soil sandy—dry	10 <sup>-4</sup> – 10 <sup>-2</sup>	4-10	4-10	0.1-2
Soil sandy—wet	10 <sup>-2</sup> – 10 <sup>-1</sup>	10-30	10-30	1-5

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

*Illustration 10.1: Dielectric reference for various soil attenuation*

open office multiple images single caption

With varying soil attenuation, the Gepard - GPR was calculated with a median frequency value of 100 MHz.<sup>1</sup>

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Reference material used from DJ Daniels, Institution of Electrical Engineers, *Ground Penetrating Radar*, 2<sup>nd</sup> Edition, 1996

<sup>1</sup> DJ Daniels, *Ground Penetrating Radar*, 2004