Using Malå GPR systems with GPS equipment

Description of problem

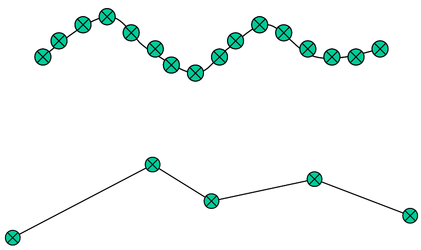
In many situations it is convenient to use a GPS to keep track of the position in terms of x- and y-coordinates for all measured GPR profiles. This combination will give the opportunity to easily couple the measured lines and the information within the radargram to maps for further presentation work. The Malå GPR systems are developed to easily handle this type of position information. However, there are some important details to discuss, to make the combination of GPR and GPS successful.

Equipment used

A GPS unit can be connected to both the Malå XV Monitor or to a laptop where the radar measurements are carried out with Ground Vision. Small consumer-grade GPS units, as well as advanced professional GPS units can be used.

The only requirements are that the GPS can communicate through a serial com-port (as default com1), and export data using a so-called NMEA protocol. Modern laptops can often lack this serial port but this problem can be overcome by using a USB port instead. This USB port has to be configured to convert USB signals to com signals. Most often the GPS retailer supplies a driver routine for this.

It should be noted that a special variant of the CX units now supports a low cost GPS receiver, communicating directly on the USB port. Contact Mala for further information.



Investigation method

Depending on the purpose of the GPR investigation the measurements can be carried out in different ways. If the purpose is measurements on land, to map geological features etc., it is advisable to use an ordinary Malå encoder (wheel or hip-chain) to trig the GPR measurements. Depending on the quality of the GPS signal, the GPS data can be stored for every trace measured, or only for breakpoints along the measurement line, see picture at left. The encoder solution makes detailed interpretation of the radargram easier, compared with the time triggering method.

If the measurements are done on a lake, from a boat, or after a fast moving vehicle, the best way to trig the GPR is to use time triggering, and then try to move with a constant velocity. The GPS position is then saved for each measured trace.

Measurement settings

The settings made prior measurements in the XV Monitor or in Ground Vision differs, so below both are explained:

XVMonitor

The GPS used has to be set as:

Protocol: NMEA 0183
Baudrate 4800 (or higher). Note, that the settings in the GPS and the Monitor/PC must be identical.
Parity N
Data bits 8
Stop bits 1

As output the XV Monitor creates a *.cor file giving the trace number, date and time (in Greenwich Mean Time zone), latitude, longitude, height above mean sea level, and HDOP (a theoretical measure of the accuracy in the horizontal coordinates, where a lower value indicates better accuracy). See example below:

```
105  2000-9-13  11:9:33  65.18164955141  N  18.75051193218  W  357.26  M  1.454542
106  2000-9-13  11:9:34  65.18164955141  N  18.75051193218  W  357.26  M  1.454657
107  2000-9-13  11:9:35  65.18164955141  N  18.75051193218  W  357.26  M  1.454898
```

Ground Vision

Ground Vision can read GPS data from any GPS receiver that supports output of data with the NMEA or TSIP communication protocols. The TSIP protocol is supported by Trimble GPS units. There are also several options for the settings Baude rate, Parity, Data bits and Stop bits. The important is that all these settings in Ground Vision match those of the GPS.

If using a GPS with a low update rate (time delay form 0.5 to 1 s) several traces may end up with the same position in the GPS data file if the measurement speed is high. In Ground Vision an Interpolation option can be used, where an interpolation is carried out between different positions.

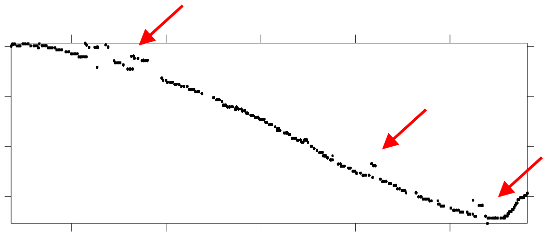
As output Ground Vision provides four different formats:

- **Ground Vision Standard** (*.cor). See file structure above.
- **WSKTRANS** (*.fri). Suited for the WSKTRANS coordinate transformation software made by “Statens kartverk in Norway”. The first line is a header required by WSKTRANS. The file format is defined as:
  ”EU89-Geodetisk,P,G,HE”
  “Trace #” “Latitude” “Longitude” “Height above ellipsoid”
- **UTM coordinates** (*.utm). Contains coordinates in the global UTM system. The coordinates are calculated from the GPS data using Redfearn’s formulas on the WGS84 ellipsoid. The file format is defined as:
  “Trace #” “Northing” “Easting” “Height above MSL” “UTM zone”
- **Local Coordinates** (*.lcf). Can be used with GPS systems that directly send transformed coordinates (with a so called extended NMEA-protocol)

Critical elements

In order to ensure the correct functioning, the GPR and the GPS should initially be connected in an environment with good GPS reception.

One should observe that the measurement point of the GPR and GPS can differ, especially when working with the low frequency RT antenna as seen at right, or when the GPS antenna can not be mounted directly on the GPR antenna. The GPR measurement point is considered top be in-between the transmitter and receiver antennas while the GPS in this case is situated in the boat, and therefore gives the boat position. This can be taken into account and corrected for.



The quality of the GPS coverage can also differ along the measurement line, due to high buildings, dense vegetation etc. The example shown to the right, marks out some incorrect positions along the measured line. It might sometimes be better to only measure the breakpoints and then interpolate the positions in-between, as shown above. This is applicable if measurements are performed in straight line segments between the breakpoints.

To change settings in more advanced GPS systems can often be quite complicated. The settings of the GPS are crucial, as they have to agree with the settings of the Monitor or GroundVision. This is most important for the used protocol and the baud rate. Often best help to change the settings is found when contacting the GPS retailer directly.

Advanced GPS units often contains filtering functions, making it possible only to transmit coordinates when the reception is good, and when differential correction (DGPS) is available. This should be remembered and set according to data quality needed. The XV Monitor or GroundVision will only store the coordinates transmitted by the GPS, and assign them to the correct trace number.

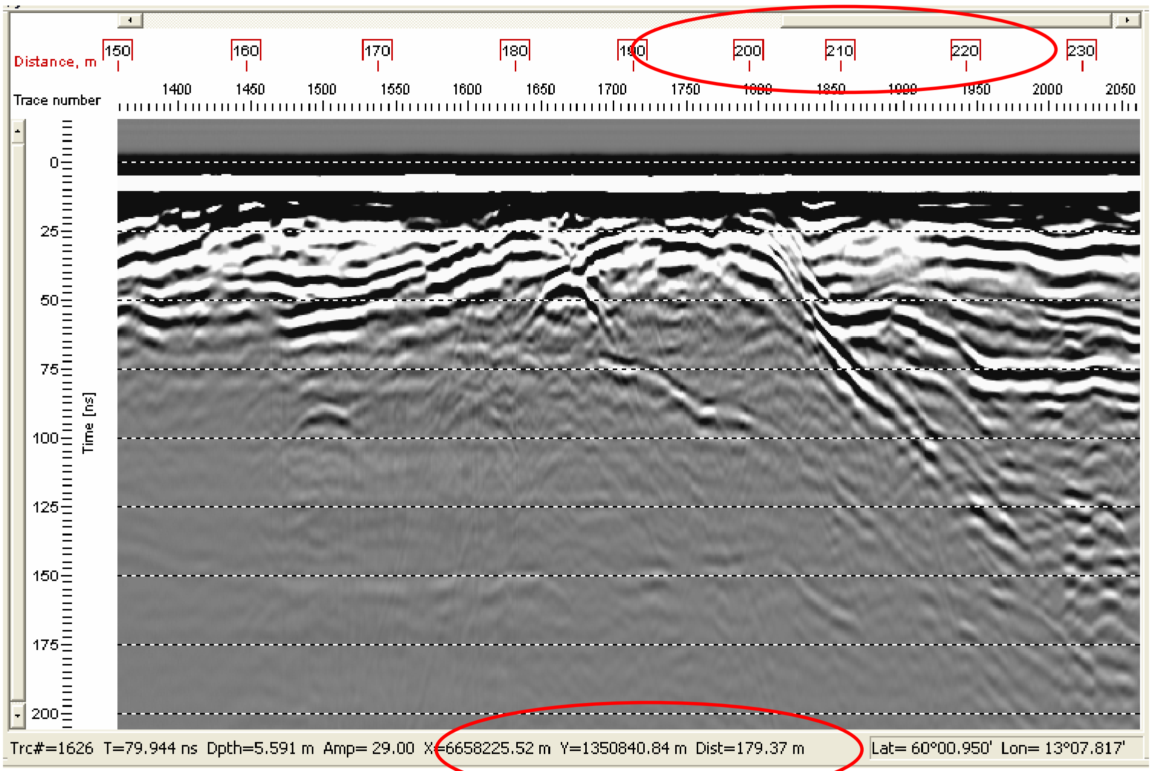
Modern GPS systems available today can also create troubles when connected to a GPR due to the update rate (the frequency of sent position data), which can be too fast for the GPR system or the used computer. A high update rate, 5 Hz or more, most certainly needs a change of the com-port, from 4800 bps to 9600 or higher. The Malå System with Ground Vision can handle 5 Hz as maximum update rate. For the Monitor the maximum up date rate is 2 Hz. If the update rate is higher, the position data from the GPS is collected at the highest available speed that the Monitor and GroundVision can handle. If a GPS unit is used, which sends position data at uneven time intervals; the GPR system will still pick the position data at a maximum rate of 5 Hz and assign the position data to a trace number.

Results

As the GPR investigation is finished it is time to work with the interpretation of the data, where every interpreted layer or object should be connected to a correct position. First of all it should be decided in which format the coordinates should be given. Most often a local system (e.g. RT90 in Sweden) is preferred before the latitude/longitude saved in the .cor file. This conversion will ease the work to get the radar interpretation compatible with other types of maps.

There exist a number of different coordinate transformation programs, both as freeware and commercial software. Of course the required input format and also the output format to and from these programs differ. And depending on the GPR processing software to be used, the file formats in some cases need to be changed. For instance, ReflexWin reads the COR-files directly, so a transformed file should be saved in the same format.

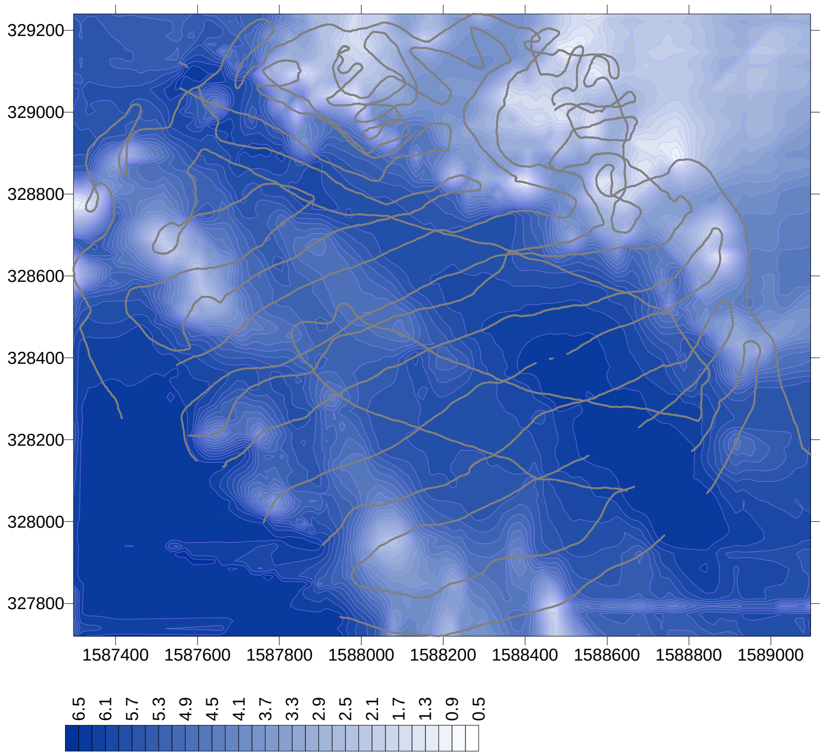
In both ReflexWin and RadExplorer the coordinates are linked to the trace number. These programs will directly show the measured path as a map, or the position data along the line. An example is shown below from RadExplorer, where the position data is displayed below the radargram, and the distance (in m) is corrected when needed according to the collected coordinates.



The interpretation of layers or objects is done as usual, and when saving the interpretation results the linked coordinates will join them. Most often the results are saved in ASCII format as a table readable in for instance Notepad. In the example below the depths to two layers are shown, Layer 1 and Bottom.

Position	X-Coord	Y-Coord	Layer1	Bottom
[METER]	[METER]	[METER]	[METER]	[METER]
0,00	6714795,020	1517462,780	0,17	0,34
3,89	6714795,020	1517462,903	0,17	0,35
7,78	6714795,020	1517462,748	0,17	0,36
11,66	6714795,020	1517462,622	0,18	0,36
15,55	6714795,020	1517462,260	0,19	0,37
19,44	6714795,020	1517461,440	0,17	0,37
23,33	6714795,790	1517459,420	0,17	0,37
27,21	6714796,951	1517458,472	0,20	0,37
31,10	6714797,550	1517456,290	0,22	0,37

The depth data and the position can then be used as input data to a surface presentation software (as Surfer, Oasis Montaj, RockWorks etc.). The map below shows the depth of a lake bottom interpreted from the measured radagrams, together with the measurement profiles in grey.



Conclusions

The combination of GPR measurements and simultaneous GPS loggings most often leads to an efficient way of post-processing data and the creation of informative maps. As the settings of both the GPR and GPS, especially the GPS, are autmatically done, there are seldom any problems with the data logging. The problem of weak GPS signals due to the surrounding environment has to be considered carefully. And it is no guarantee that good positioning data is collected even though contact is remained, the accuracy depends also on the number satellites used etc.

Which GPS unit to choose is of course a question of needed accuracy in the positioning. Is ± 5 m enough (for geological mapping) or is ± 10 cm needed (for archaeological investigations). Today the more advanced GPS units (with DGPS or RTK) are as expensive or even more expensive than the GPR system used. As a rule of thumb the following accuracies are stated; GPS 5-15 m, DGPS 0,5-1 m and RTK 1-2 cm.

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