Railroad survey application

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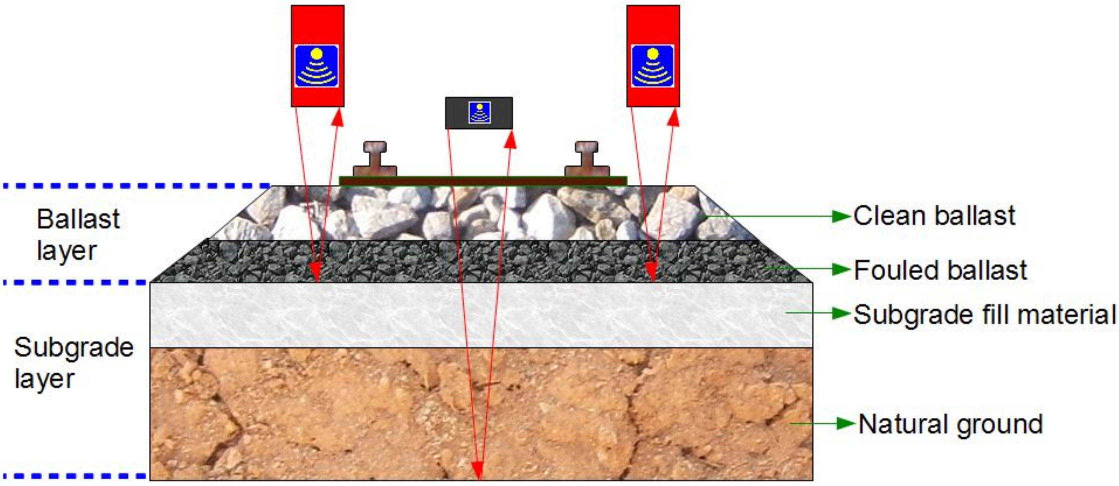
Introduction

The GPR technology has been introduced to the railroad engineers as one of the easy tools for quick and non-invasive railroad inspection. Since these surveys tend to stretch for a number of kilometers the amount of data can be overwhelming. However, with some clever preparations and proper tools for post processing the data one can create swift and easy to understand reports. These reports will be highly precise and at the same time the results can be combined with many other methods (borehole, auger hole, dynamic stress tests). The biggest benefit of GPR survey is that the equipment can be mounted on almost any standard train wagon/locomotive and then connected to any train composition. This allows you to collect the data without closing the section of the railroad for regular traffic.

Higher frequency antennas are used to determine ballast layer fouling. Lower frequency antennas are used to locate anomalies in the ballast and sub-grade layers (water eroded places, water pockets, voids etc..). Usually the survey is providing the information about the left /right shoulder and the center line of the railroad. By combining lower and higher frequency antennas the survey's scope can be set for each of the lines.



Simplified railroad cross section with GPR antennas positioned over the areas of interest

Survey example

In this survey example we gathered data over a section of the railroad inside a tunnel made through a solid limestone mountain. The 3 kilometer section was defective and this survey was a part of the maintenance/rebuilding price calculation. The section had not been serviced much in the last 100 years and the maintenance was limited to partial replacement of the ballast layer, rails and rail beams. The problem with this section was that the ballast layer was on top of a solid bedrock and not entirely compliant with the minimum of 40cm in thickness. Also there usually is a great amount of water flowing through the tunnel during the rain season of the year filling the thin ballast with mud and clay. This results in a very stern contact of the rail and bedding and a tendency for horizontal sliding. The problem is escalating nowadays due to the greater speeds and weights of the train compositions passing the section.

The result requested from the GPR survey was to determine the thickness and state of the ballast layer. The report results must be delivered in a numerical model, so they could easily be used in the calculations and implemented in the rest of the technical documentation.

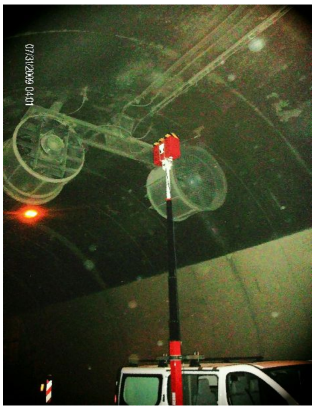
Due to the facts that there was no artificial sub-grade layer and the ballast layer was very thin, the entire survey could be done with only one type of antenna: the HA1000.

Equipment for the job

Antenna name	Recommended settings			Size of target (m)	Recommended area of application
	HP(MHz)	LP(MHz)	Range (ns)		
HA1000	750	2000	7-30	0.05	(Rail)Road inspection, structural inspection

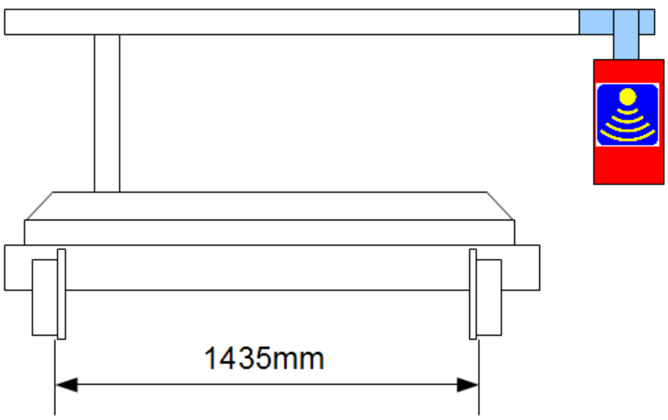
Horn antennas are used in many applications, from pavement thickness and road/railroad condition assessment to high speed tunnel surveys. The main property of these antennas is that they are very focused and have low ringing in the upper part of the range where it matters for the intended applications. Our HA1000 has been extensively used for road/railroad surveys and recently also for assessment of primary and secondary lining in tunnels.

Although some manufacturers provide ”standard” mounts for the antenna and radar unit on a vehicle for the road / railroad surveys, there is always a need for some customization. Depending on the type of the vehicle you plan to mount this system, you might need to do some heavy modifications. Try to find a solution that doesn't involve a lot of welding and drilling.



Conducting the survey

The survey was taken while the section of the railroad after the tunnel itself was closed for traffic due to maintenance. Because of this other maintenance job, there was no available train locomotive for us to use. We mounted the antenna on a lightweight railroad transport cart (Walter). We decided to collect two profiles. The profiles pass on the left and right outer side of the rails. Although towing the cart through the dark and wet tunnel was not easy, we managed to collect the needed data in one working day (8 hours).

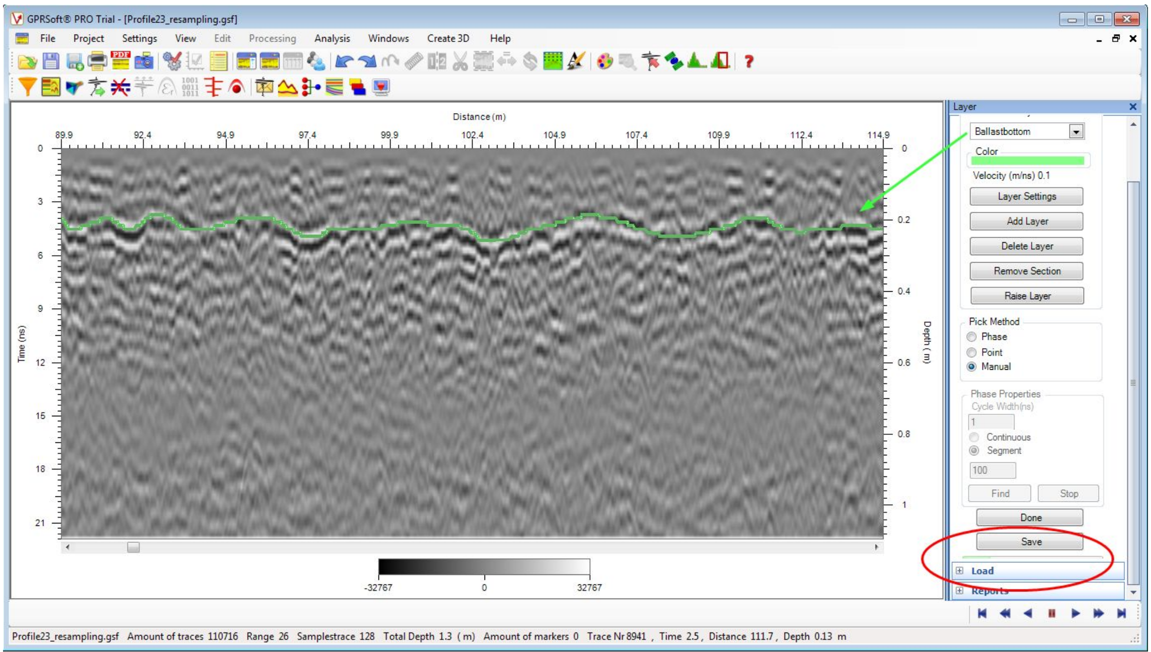


Setup schematic

Processing and Conclusions

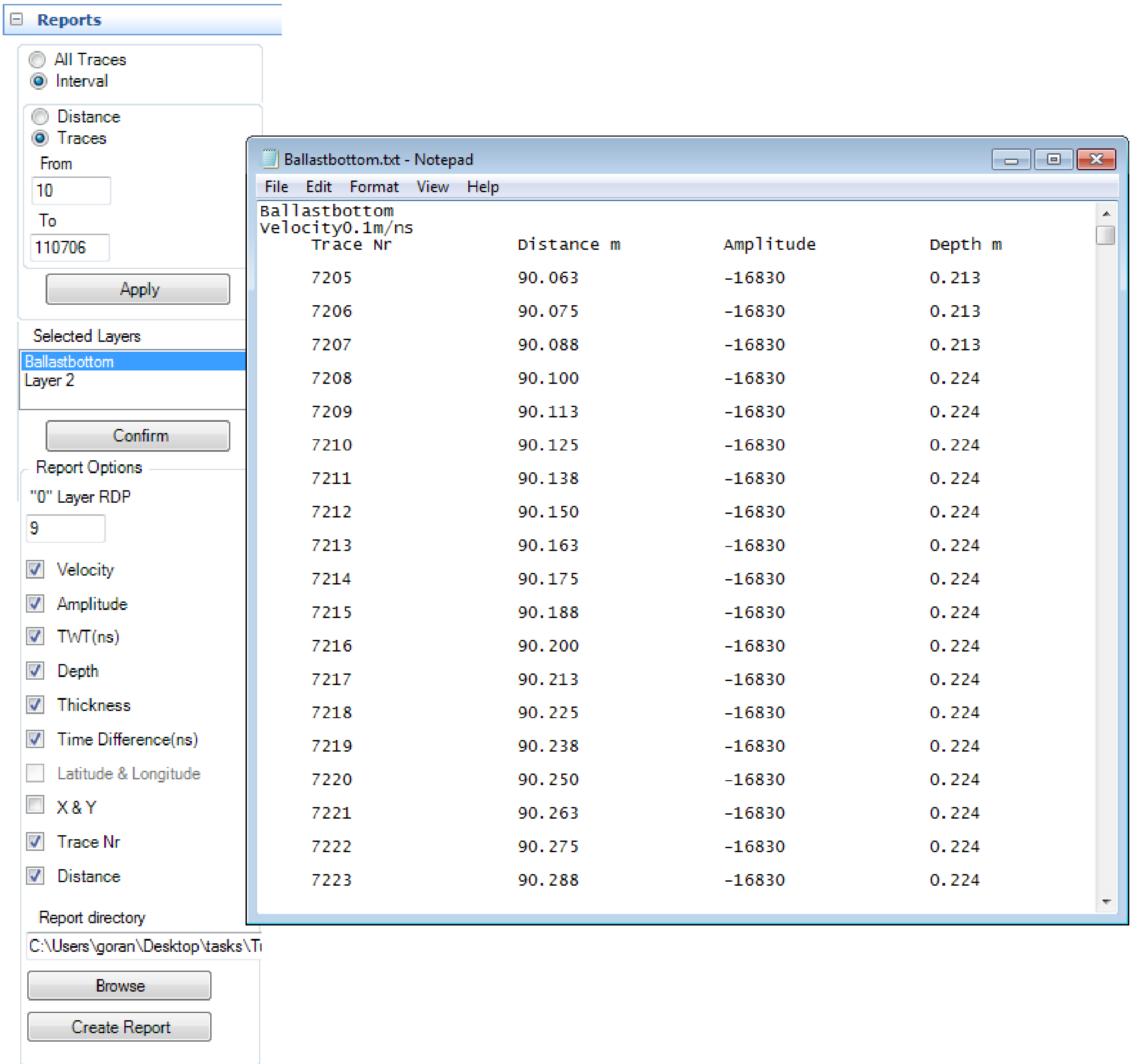
The acquisition of the data was quite easy and quick, but it gave us 6km of data to be interpreted! This amount of data is to be respected and there is no way to avoid going through the entire data thoroughly but, a proper tool can help in the process. We opened the profiles in the GPRSoft™PRO post processing package for the GPR. By using basic processing steps we cleaned the data and made it ready for interpretation. At this point we opened the specialized advanced tool in GPRSoft™PRO called the Layers. In the Layers sidebar you will find all the tools that you need for interpretation and report creation for this kind of data.

By combining the phase and manual layer pick method we managed to mark the contact between the ballast layer and the bedrock in a semi-automatic manner. The ability to save the part of the work that we did and continue later on allowed allowed us to take breaks during the interpretation. This is vital for the quality of the report because the process can be very tiresome.



Marking layers in GPRSoft™PRO

The thickness of the ballast layer was quickly determined and now it was time to create a numeric report that can be used in analytical and technical drawing documentation. This step was done automatically with the reports tool in the layers sidebar. The report tool allows you to pick which information from your layers files you wish to export. Selected values are placed into columns of a tab delimited text file. A tab delimited text file is an ideal export format because of its ease to integrate with almost any other program. The data can be imported into a table calculator, statistic database, mathematical simulators or CAD programs with available import tools or easily defined user scripts. If however, there is no such a tool available, one can always read/type the values from the text file manually.



Trace Nr	Distance m	Amplitude	Depth m
7205	90.063	-16830	0.213
7206	90.075	-16830	0.213
7207	90.088	-16830	0.213
7208	90.100	-16830	0.224
7209	90.113	-16830	0.224
7210	90.125	-16830	0.224
7211	90.138	-16830	0.224
7212	90.150	-16830	0.224
7213	90.163	-16830	0.224
7214	90.175	-16830	0.224
7215	90.188	-16830	0.224
7216	90.200	-16830	0.224
7217	90.213	-16830	0.224
7218	90.225	-16830	0.224
7219	90.238	-16830	0.224
7220	90.250	-16830	0.224
7221	90.263	-16830	0.224
7222	90.275	-16830	0.224
7223	90.288	-16830	0.224

Numerical layer reports output

With thickness of the ballast layer determined, depicted and numerically reported there was only one final request for this survey to be made: determine the quality of the ballast layer!

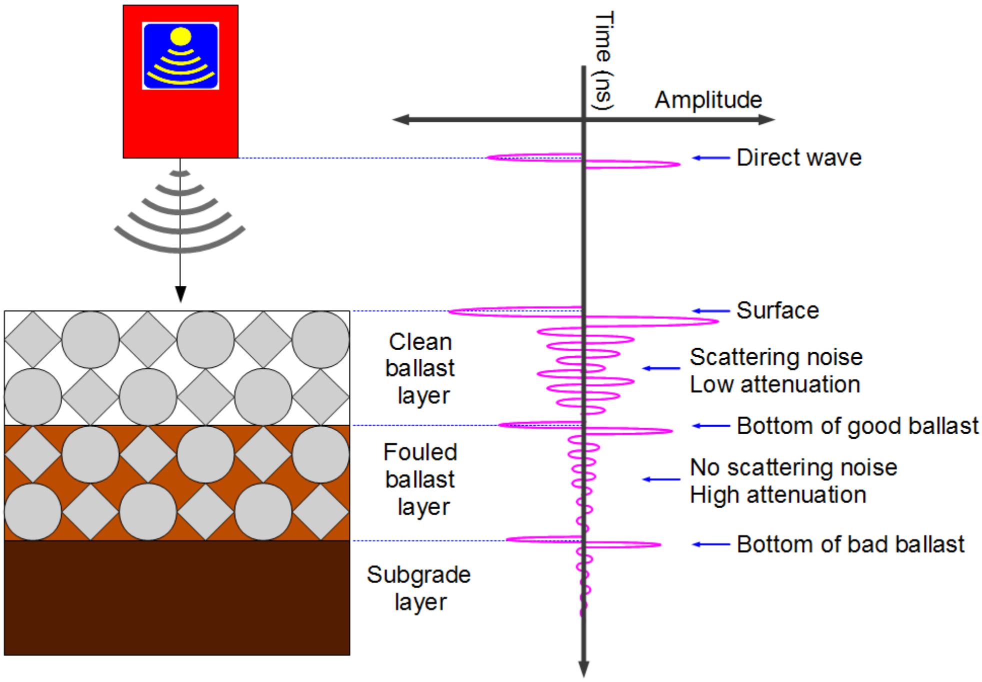
In order to make this interpretation we first created a logical description for some of the anomalies we expect to find in our GPR data:

a) the good ballast layer is made out of rocks the size of a child's fist, so there should be scattering effects there.

b) the good ballast layer is made out of rocks the size of a child's fist, so it should be dry.

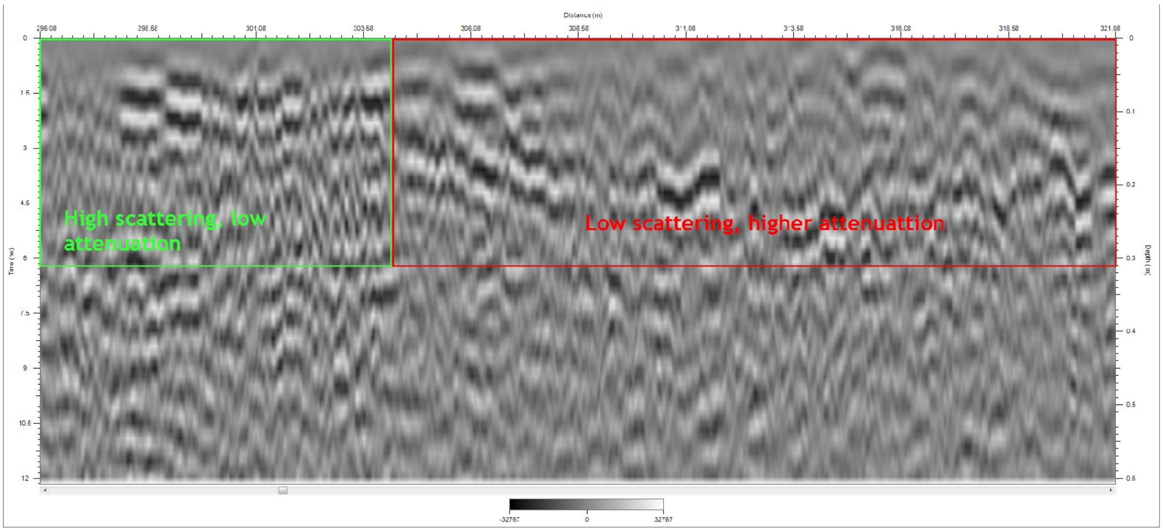
c) the bad ballast layer infiltrated with mud,clay and water will be a more homogenous layer without scattering.

d) the bad ballast layer infiltrated with mud,clay and water will be more conductive so we can expect more attenuation.



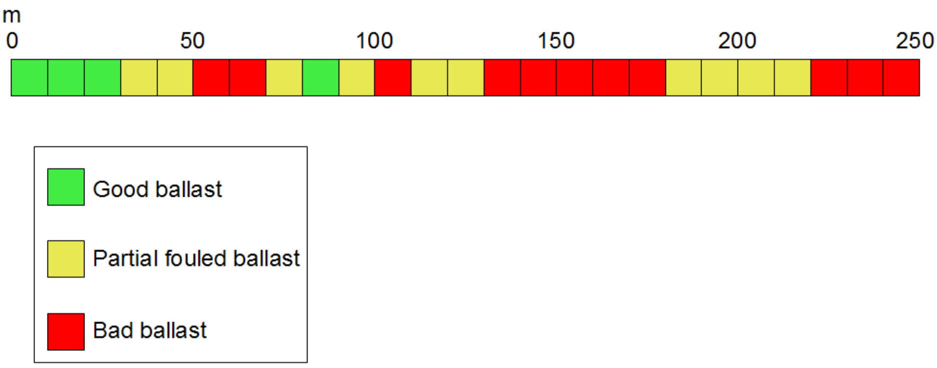
Representation of GPR trace from the railroad survey

The ballast fouling interpretation was made by manual observation of the files and asked for one more pass through the data. The railroad engineers gave us advice on how to create a simple output report. We created a color coded distance disposition with simple color code values: good ballast - green, partial fouled ballast - yellow, fouled ballast - red.



Example of the good and bad ballast zone

The final report for this task is a simple distance disposition with the three color codes available.



Color coded output for quick and easy usage

Railroad and road surveys produce very long files and great amount of data. Even with the most advanced algorithms for automatic picking of layers or amplitudes you will be forced to interpret or check the result yourself. Be careful to include enough time for the interpretation when you offer the quotation for the job.