How to use the GPR Calculator and why even bother ?

This will be as straight forward guide on using the freqwave tool and therefore there will be some things that you should try and find additional information from other sources.

Why would you want to use it anyway?

Well, I guess that everyone of us using the GPR equipment wants some straight forward answers from the manufacturers on simple questions like how deep can it go, and what's the resolution. Most of the time the manufactures (or resellers) don't know how to answer these questions or they are trying to make their product look better then it is so you end up with a piece of equipment that is supposed to see a mosquito burried 10 meters into ground but when you try to do it, you find out that you cannot see an elephant 10 cm below surface. OK, we understand that everything depends on field conditions (dielectric constant for starters) but even with a description of the conditions you get a lot of BS on how you should do it and what can you achieve. For me personally it doesn't matter if a piece of equipment has boundaries as long as I'm not wasting time trying to cross them and get some result where they cannot be achieved and I believe almost everybody has a similar view on that point.

The other thing that you can try is to get in contact with someone with the PhD but although they give you mathematicaly correct answers, in real life lot of those teorems don't end up being applicable at all. Reading some of those papers made me berserk with the „test site setup and conditions“ ideas that can be found only in a sterile laboratory.

So what do we do about that? I hope that this tool will give some of the answers, although you have to understand that it will give you only a rough picture and you should always leave some safe error space for the survey results.

Input into the tool

The tool consists of fileds marked edit where you should make some input, comboboxes to choose a measuring unit and buttons to activate calculations and it is all nicely separated into tabs.

The use of . (dot) as a decimal delimiter is mandatory!!!

Tab 1: Frequency to wavelength converter

Have you ever had a conversation with the reseller about how high from the ground you can lift a ground coupled antenna or how close you can bring the airborne antenna to the ground? Answer: 1/10 of wavelength at least.

Ok, that is a nice straigth forward answer but I have only the frequency of the antenna and although you learn in elementary school that $c=f*\lambda$ (in vacuum, and in air) would it kill them if they said 3cm or 5m!!!!! There is an even bigger problem here. What frequency should I calculate with? GPR system is a wide bandwidth system so it isn't a single frequency that we work with. After talking to a few people I came to a conclusion that in order to keep it simple the frequency to be used is the center frequency of the antenna (that would be the -10dB bandwidth center frequency). Then you find out that the generic name on your antenna isn't the center frequency (close but not quite). If you're lucky some of the manufacturers give that frequency in the datasheets, but some don't, so be careful untill you verify that part or work with the generic value but keep in mind that you are adding an error in the calculation.

If you are a bit more interested or trying to make a system of your own you'll need a few other values that are connected with the value of wavelength (1/2, 3/4…..) so I placed those formulas into the sheet as well.

Change1:

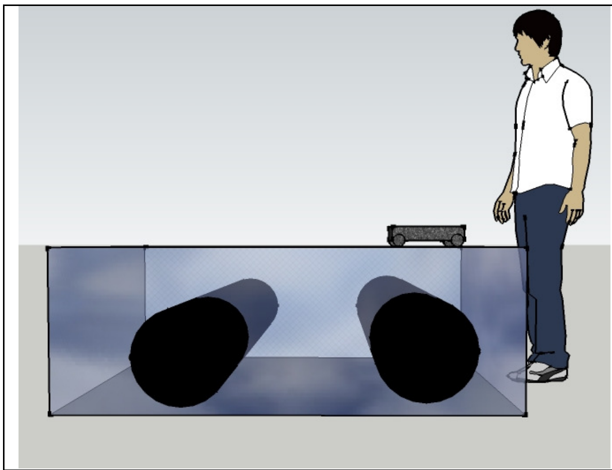
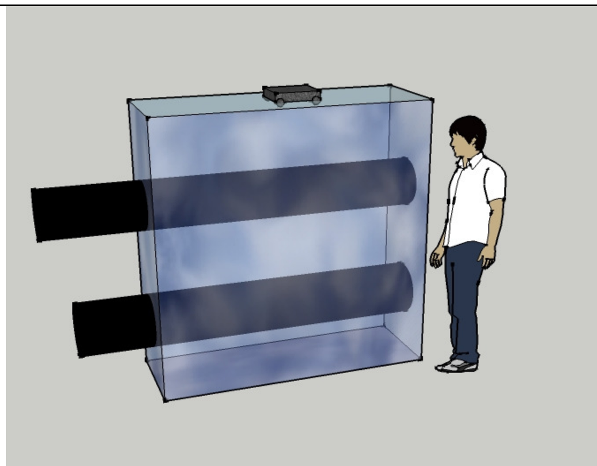
After disscussing with some people this calculations they pointed out that there are times when you need to take the velocity changes in the material into acount as well – so I redid the calculus so now it shows both the in air/vacuum values and the ones in the media for the wavelength

Tab 2: Wavelength to frequency converter

This tab does the opposite from the first one and gives you the frequency value if you have the wavelength. What would you do with this, you are asking yourself now? Well the company I work for does a lot of survey on concrete constructions and most of them have rebar meshes inside them. These rebar meshes work like a Faraday's cage meaning that „…..if the conductor is thick enough and any holes are significantly smaller than the **radiation's wavelength,** the radiation will be significantly reduced….“ . This is a sort of guide what antenna to use if you know the distance between rebars and compare it to the wavelength of the antennas you own or if you are unlucky and don't have more then one antenna or have multiple rebar meshes and have to achieve greater depths it gives you an idea that your survey will be more difficult then you are used to or impossible.

Tab 3: Resolution

This tab I don't have to explain much but you have to be very carefull about using the results. Unfortunatelly there was no way to „invent“ an empiric formula for the calculation of either vertical or horizontal resolution so we are stuck with the mathematic principles. On the other hand I'll mention the most often confusion about the resolution: If you have a nice object for the reflection of the wave , even if the calculated resolution is higher you will still see it but there is no way to determine how thick the object is or distinct two objects that are closer then the vertical resolution. The same goes for the horizontal resolution. In order to make this a bit clearer read Mr. Alvarez-Cabreras, GPR Antenna Resolution paper on that subject.

	
Horizontal resolution	Vertical resolution

Change 1:

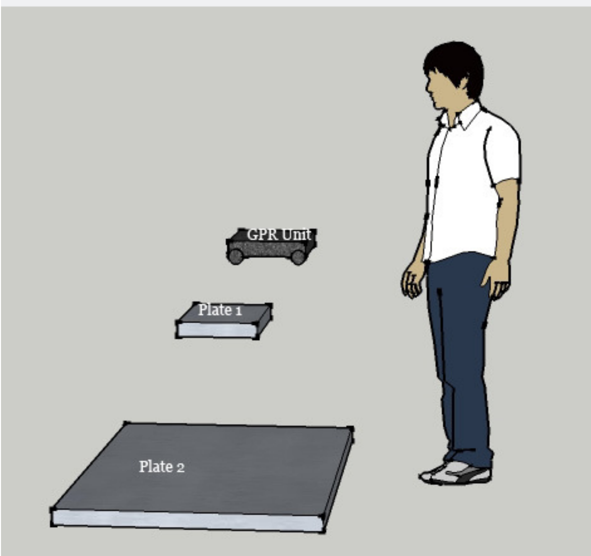
There are ways to roughly estimate the vertical resolution by checking ½ wavelength inside the media so you might want to check Freqtolength Tab as well

There is a need to take into consideration the subfoot of the antenna as well when it comes to the visibility of an object so check the Subfoot of antenna sheet as well.

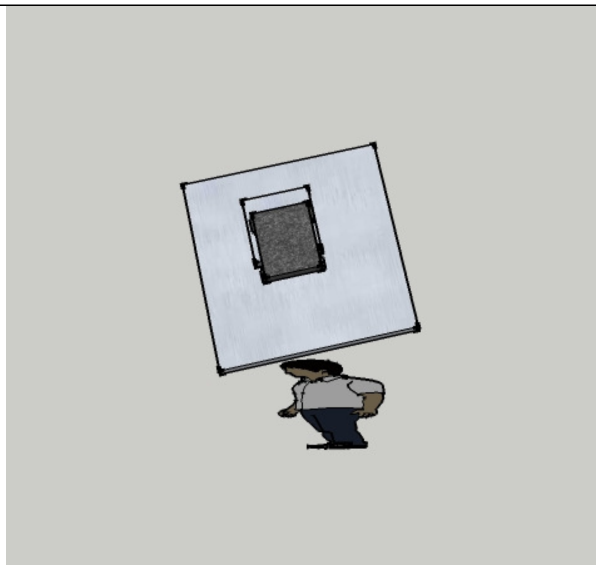
Tab 4: Zero shift

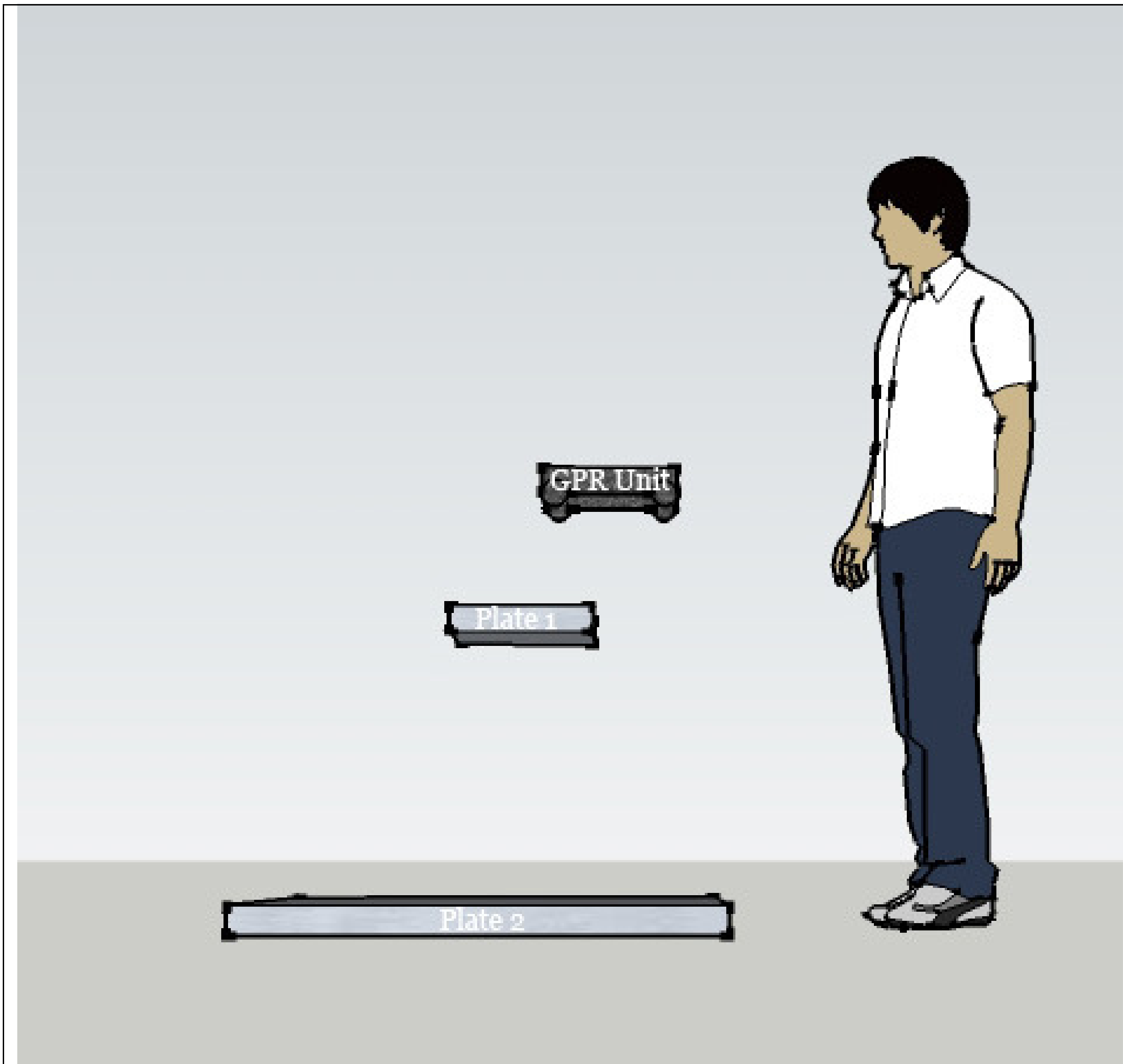
As I mentioned earlier the company I work for does a lot of concrete inspection and on these kind of surveys there is a need for precise depth estimation (working inside the 20-30 cm of concrete wall every centimeter counts). Therefore we need to resolve ground truth, dielectric constant etc. very accurately. Something that you rarely hear from the manufacturers/sellers is that all of the triggering devices create a sort of time lag and there is also some influence of the length of the cable you are working with. Those two things together give (for one of the antennas we own) 0.288 ns (if ε=9, v=10cm/ns, travel error=2.88cm, depth error=1.44cm) of lag which gets sumarized in the two way time.

The solution for this problem is to make the two-metal-plates test. You take two metal plates, one large (be generous and use at least 3x the size of antenna, for example 1x1m) and one small (for example 20x20cm) and place the smaller centered and above the bigger one. Now roll your antenna not in contact with the smaller plate but above, leave at least 2 full wavelengths between the antenna and a upper plate. The material between the two plates and the antenna is air (this is a bit hard to achieve so you can use styrofoam blocks ε=1.023). What you'll get is two known depths and two known two way times. The direct coupling in air will be clear to see not being influenced by material „pull“ and ground reflection, and the response from the metalic plates is also clear so you can measure the two-way-time accurately from peak to peak. The difference in TWT from the one being calculated from the known depths and velocity (in air=c) will reveal to you the time lag the system is producing.



Setup viewed from the side


Setup viewed from the top



Description of values

*Take care that you warm up the system (leave it working for 10 minutes before test) because the system shifts slightly while warming.
*For bigger antennas use large enough metalic objects (metalic garage doors are a good objects too).
*If you are having trouble with two plates, you can use one big with two different depths and recording two different files – this is not as accurate but it could be acceptable.
*Try to do the test in a place with as less electromagnetic interference as you can achieve.

Tab 5. Subfoot of the antenna

Change 1:
Added this sheet into the table

Well I'm not quite sure about this one but here it goes:
This calculation will show you the spreading of your antennas wave in a manner that you'll get the measure of the elipsoid radiated below the antenna at a specific depth in a specific material. The elipsoid represents the area below the antenna from which the reflected amplitude is not to weak and is easy to spot the object. Spacing of the survey lines should allow the object to be in the area so you don't miss it dew to the resolution issue – in other words only the radiated area part of object would be recorded strongly so if you ride with the borders of the subfoot over the object you „see“ an object only the size of the part that is inside the borders, combined with the resolution boundaries you could miss the object .
Also there is a good rule of the thumb not to exceed the depth and the size of the target ratio of 10:1 in order to expect good results.

Tab 6.:Resampling

The question of resampling is taken into account for deliberately avoiding some of the information. Why? Well at some point in your data you have „too much“ information, in other words the sensitivity of the equipment records all of the changes in the material and since we usually search for a distinct objects/planes the additional information can be considered clutter.
Example:
You are searching for a pipe burried in a material which is highly unhomogenuos/scattering etc. so your line object (pipe) is „smudged“ with the responses from the surroundings making it hard to read out from the visual representation – most affected in the 3D surveys/representations of the data.
The way to emboss the data is by downsampling the data. This Tab provides you with 3 proposed values calculated by formulas from expirienced users.

Last but not least

I know this is said too many times but here it goes again:
Do not take the calculated values of vertical and horizontal resolution as a starting point for estimating the success of the survey. It is a rough calculation as it can get and it will only point you to the preferable setup for the survey.

This guide and table can be copied/used/redistributed free (after all, these are commonly used formulas) as long as you mention the gpr-forum.com as a source (hoping on getting more people and knowledge involved).

Sincerely yours,
Goran Bekić, Croatia

List of literature:

1. Mr. Reinaldo Alvarez-Cabrera; GPR Antenna Resolution

2. Unknown paper on GPR Timeshift – derivative from the ASTM D4748-06

3. Table of formulas for Physics, Technical school „Ruđer Bošković“, 1996

4. GPR-forum.com