Estimating Soil Conductivity for GPR

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The results of a ground penetrating radar survey depends on many factors, but one of the conditions to be able to get useful data is that the conductivity of the ground is not too high. The conductivity of the material together with the frequency of operation and the dielectric constant give us the loss factor that is used to estimate roughly the theoretical penetration.

There are many ways of estimating the bulk relative dielectric constant, one of them with the radar itself. By using some reflection from an object at a known depth and a velocity analysis tool like in our GPRSoft PRO version we can accurately find out the layer relative dielectric permittivity or RDP.

It is however, a little bit more difficult to estimate the conductivity of the soil if one doesn't have a resistivity meter or any other piece of hardware for doing so. Since this is quite an important parameter I'll try to explain here a simple, yet effective method to estimate the conductivity of the soil under survey.

A little bit of theory first

A while ago, almost one hundred years soon, Mr. F. Wenner suggested that a linear array of four equally spaced electrodes would make all the problems they had at that time with soil-electrode contact problems go away. Ever since most of the resistivity measurements are carried on using the four electrodes principle.

If we insert four electrodes into the ground as shown in figure one and apply current between electrodes A and B then a potential will appear between electrodes M and N.

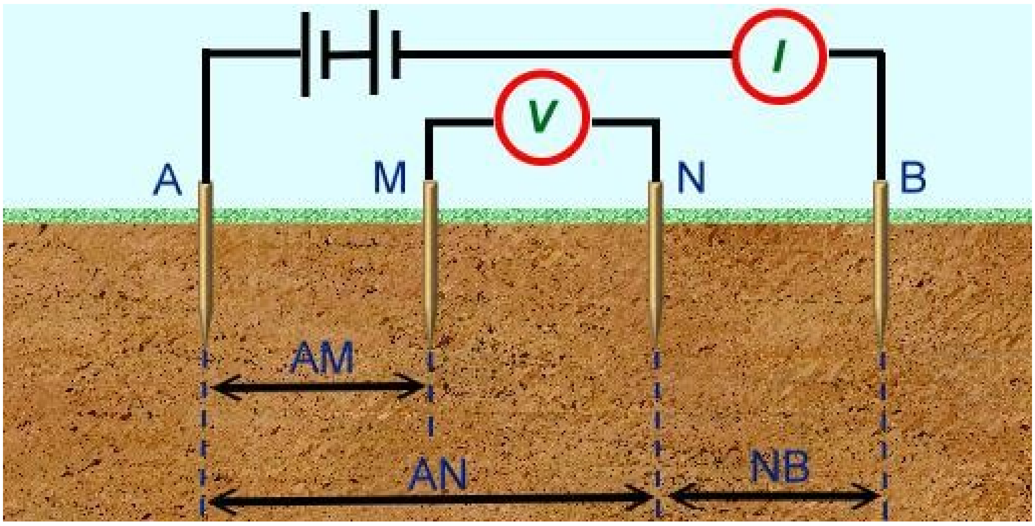

Fig. 1 Four electrodes resistivity measurement setup.

The theory also says that the electrical resistivity of any material is equal to the potential that appears over a length of a material L with a cross sectional area A.

$$Rho = \frac{A \cdot dV}{L \cdot I} \quad (1)$$

where:

Rho – is the electrical resistivity of the material ,

A – is the cross sectional area,

L- is the length of the uniform conductor,

dV – is the potential over the length of the uniform conductor, and

I – is the current flowing through the uniform conductor.

If we substitute now the ratio of cross sectional area to the length of the conductor with some coefficient K we obtain:

$$Rho = \frac{K \cdot dV}{I} \quad (2)$$

This coefficient K is found to be a geometric factor that can be calculated based on the distance among the electrodes A, M, N, and B. For linear arrays like the one shown in figure one this coefficient is calculated as follows:

$$K = \frac{Pi \cdot [AM] \cdot [AN]}{[MN]} \quad (3)$$

It is not difficult to see that if all the distances between adjacent electrodes are equal then the coefficient simplifies to:

$$K = 2 \cdot Pi \cdot s \quad (4)$$

where:

s = [AM] = [MN] = [NB], all the electrode are equidistant from adjacent ones.

Now we can put the expression for K from equation 4 into equation 2 and get the formula for the resistivity in Ohms per meter.

$$Rho = \frac{2 \cdot Pi \cdot s \cdot dV}{I} \quad (5)$$

where:

Rho – is the electrical resistivity in Ohms per meter

Pi – is a mathematical constant, 3.14159...

s – is the distance between the electrodes in meters

I – is the applied current in Amperes.

The conductivity, which is the one that present interest for us is calculated simply by taking the inverse of the resistivity. It's that simple.

$$S = \frac{1}{Rho} \quad (6)$$

The conductivity is measured in Siemens per meter and sometimes old timers like myself call it Mho which is Ohm the other way around. However, Siemens is the correct unit and nothing else.

Enough theory, let's measure!

We are going to need to modify our previous setup so we can get some meaningful and easy to make measurement. We are going to need four electrodes, for that we can take some metallic rods with the same length and diameter. It would be a good idea to sharpen then in one end so it is easy to insert them into the ground. We also are going to need some sort of current generator any voltage source with 20 to 50 volts would do. A high watt resistor, for instance 20 Ohms 5 Watt would serve us fine. Finally a multimeter it's a a must to measure our potential between electrodes M and N. Pick a multimeter with high input impedance to alleviate the effects of the measurement device on the results of the measurement.

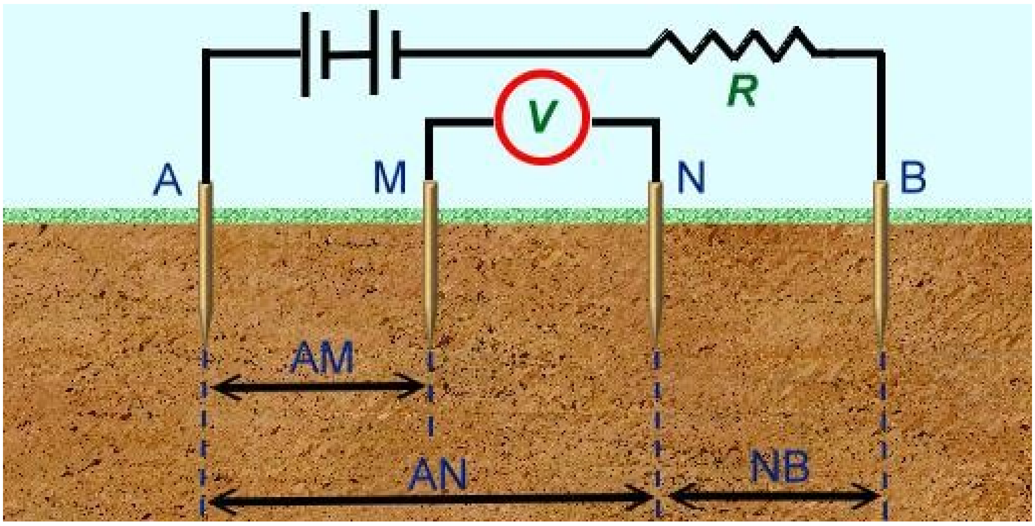

Fig. 2 Modified setup for resistivity measurement.

Insert the electrodes into the ground along an imaginary line and making sure the distance between one another is the same. For electrodes 0.5 meters long I'd insert them 0.4 meters apart and around 0.3 meters into the ground. Connect one end of the resistor to electrode B like in the figure 2 and the other end to one of the terminals of your voltage source. The other terminal of the voltage source gets connected to the electrode A.

Now measure with your multimeter the voltage over the resistor and take note of that, let's call it V2. Measure then the voltage between the electrodes M and N and also take note of that, let's call it V1. This voltages are depending on the conductivity of the soil you are measuring and the output voltage of your voltage source, so it would be meaningless to give some exact figures here. I get for instance around 2 and 0.65 volts with 60 Volts in my yard.

Now it is rather easy to get the value we want, the conductivity of the soil you are measuring should be equal to:

$$S = \frac{1}{2 \cdot Pi \cdot R \cdot s} \cdot \frac{V2}{V1} \quad (7)$$

where:

S – is the conductivity in Siemens per meter S/m

R – is the resistance of the resistor in Ohms

V1 – is the voltage between electrodes M and N, and

V2 – is the voltage drop over the resistor R

Conclusions

We have presented a simple and easy to follow method for measuring the bulk conductivity of the soil for ground penetrating radar applications. A more correct way to do this would be of course to take some samples and send them to a laboratory for analysis. Since not all the time that is a viable solution and we most of the time need only a fair estimate of the conductivity of the soil, I consider this method to be accessible, affordable and easy to do. There are many affordable soil resistivity meters available and if you can afford to buy one then by all means do it, otherwise use the explained method and you should be right on the spot.

References

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