Conductivity Experiments at Castleguard Meadows

Canadian cavers have been using electromagnetic methods to determine ground conductivity. ***Ian Drummond*** *presents the results.*

Abstract: An electromagnetic non-contact method, making use of the secondary magnetic field, was used to measure ground conductivity. This revealed an anisotropic element to the conductivity which could explain the difficulty in performing radio-locations in certain orientations.

Introduction

On July 28 - 30, 1996 John Donovan, his cousin Tony Lomas and I hiked to the Castleguard Meadows to measure the conductivity of the ground above Boon's Blunder Junction.

The reason for this trip dates back to the cave radio trips in the mid-80s. During these trips I found it difficult to do accurate radio-locations and I thought that the conductivity of the ground might be to blame. In particular I thought that the conductivity of the ground might vary with compass direction as the accuracy of location was good across the passage (north/south), but poor along the direction of the passage (east/west).

Conductivity measurements in the past have normally been done by current injection methods. Four electrodes are hammered into the ground. An electric current injected into the earth via two of the electrodes, and the voltage measured across the other two. The technique is hard work, and the equipment is not readily available, so the hypothesis at Castleguard Meadows remained untested.

Last year I was contacted by Brian Pease, a US cave radio experimenter, about his new radio locator beacon (Pease, 1995a, b). We collaborated in making a batch of circuit boards for his design, one of which I constructed here in Calgary. Brian's design works at a much lower frequency than the Alberta Speleological Society cave radios (3.5kHz compared to 115kHz) so it is better suited to location work. It does not provide voice communication, however. In particular Brian's design provides accurate measurement of the magnetic field strength at the receiver.

This suggests many possible experiments, including the measurement of ground conductivity with both the transmitter loop and the receiver loop on the surface. One advantage of the electromagnetic

Ground Conductivity Measurement by Electromagnetic Methods

Experimental Procedure

1. Set up transmitter loop on the surface of the ground, with the plane of the loop accurately horizontal.
2. Measure accurately a distance away from the transmitter loop that is close to the depth of interest. Set up the receiver loop horizontally at the same elevation as the transmitter loop and measure the field strength.
3. Rotate the receiver loop so the axis of the loop points at the transmitter. Slowly rock the receiver loop back and forwards, keeping the axis pointed towards the transmitter loop. Consider using a support stick to steady the loop as it is critical to find the exact minimum signal. The adjustment of the angle compensates for any slight misalignment in the relative elevation and horizontal placement of the transmitter loop. Record the minimum signal strength.

Calculation

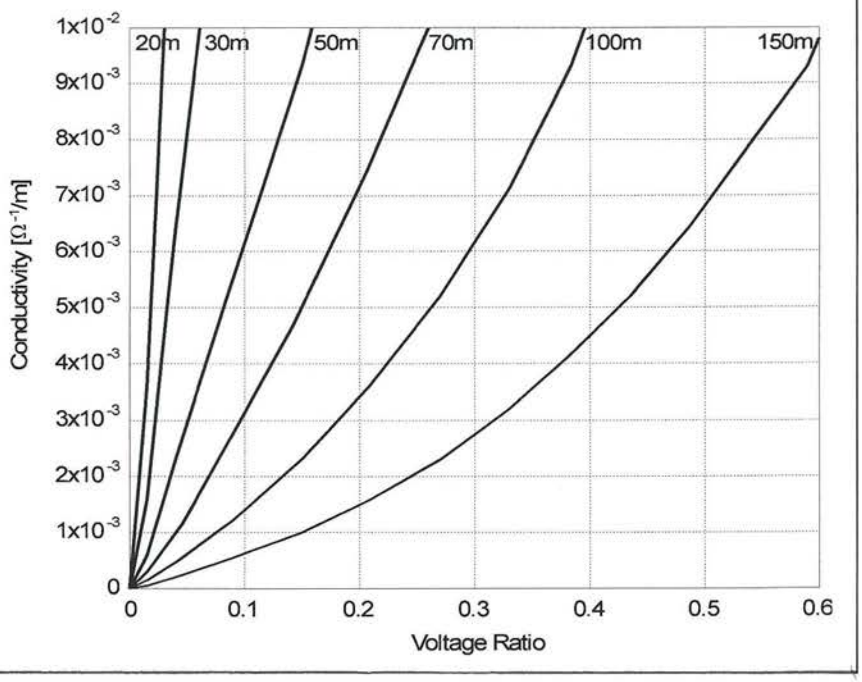
Basically, the Pease method depends upon use of equation [3] in his paper. This is reproduced below (modified to conform to CREG conventions):

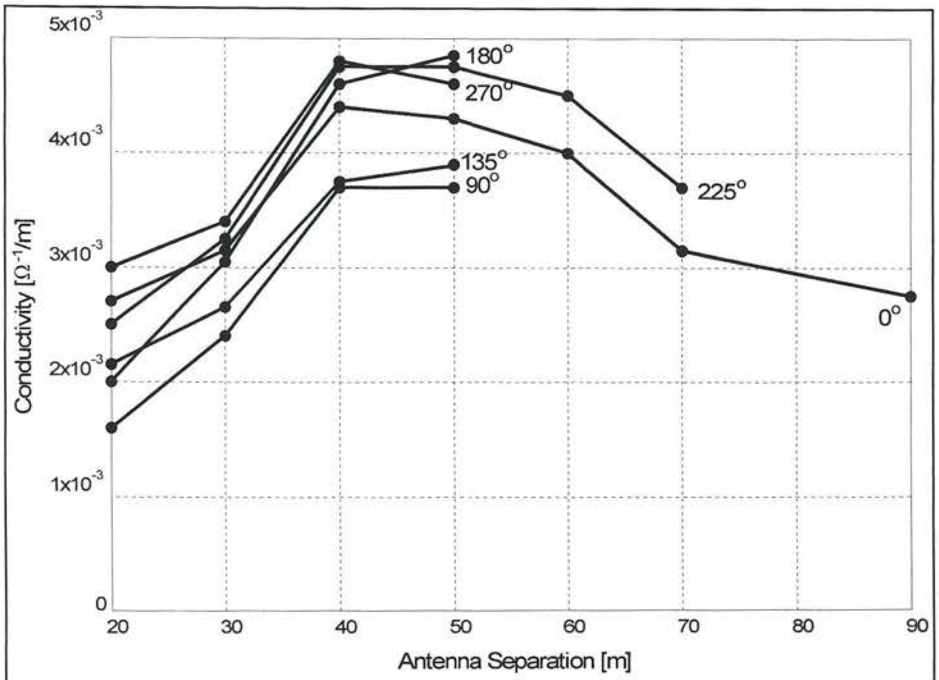
$$\sigma = \left(\frac{H_{hor}}{H_{ver}}\right) \cdot \frac{4}{\mu_o \omega R^2}$$

where σ is the conductivity in Ω^{-1}/m, H_{hor} and H_{ver} are the received vertical (primary) and horizontal (secondary) magnetic field strengths respectively, μ_o is the permeability of free space (= $4\pi \times 10^{-7}$ H/m),
ω is the angular frequency of the transmitter (=$2\pi f$),
and R is the distance from the transmitter to the receiver.

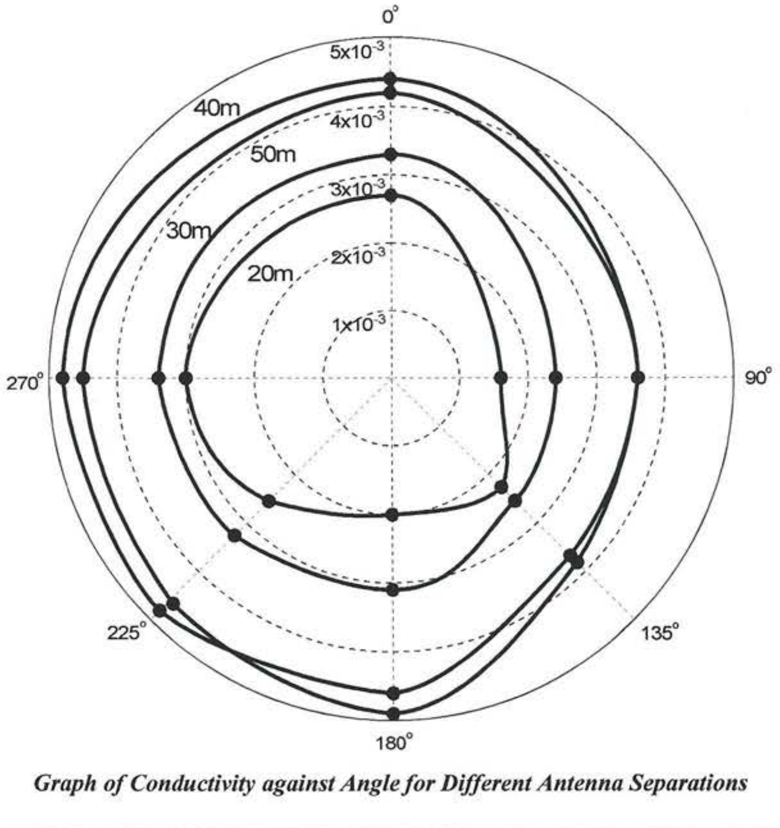
Graphical Method

The Drummond method is graphical, using the data provided by Wait (1955). A graph based on this data, for 3.5kHz, is reproduced opposite.





Graph of Conductivity against Antenna Separation at Various Angles



Graph of Conductivity against Angle for Different Antenna Separations

method (over the current injection method) is the relative speed. This, in turn, allows much more data to be collected. Both Brian and I had published articles describing how this might be done in *Speleonics*. See (Drummond, 1989) and (Pease, 1991) for full details but an outline of the experimental procedure, the calculation (Pease) method and the graphical (Drummond) method are summarised in the box at the bottom of the previous page.

Results at Castleguard Meadows

To test the hypothesis that the conductivity differed with compass direction, we set up the transmitter loop on the horizontal surface over Boon's Blunder where the cave is approximately 80m below the surface. We then moved the receiver antenna away from the transmitter loop on 6 different compass bearings (0°, 90°, 135°, 180°, 225° and 270° magnetic) making measurements at 20m, 30m, 40m, and 50m at all sites, and extending to 60m, 70m and 90m in two directions.

The results are shown in the two graphs which are reproduced on this page. There are two clear trends.

Variation with Antenna Spacing

As the antenna separation increases, the conductivity increases in all compass directions. (The drop in conductivity for distances over 50m is an artefact of the Pease method of calculation method as the loop spacing exceeds the range of the method. The Drummond method shows the conductivity remains constant beyond 50 metres.) This simplifies analysis of the variation with direction.

Variation with Direction

For all antenna separations, there are clear variations in conductivity with direction. At this location the cave runs approximately east/west magnetic. At right angles to the cave (magnetic north/south) the conductivity is approximately constant at about $0.0045\Omega^{-1}/m$. Along the line of the cave (100° and 280°) the conductivity varies from $0.0037\Omega^{-1}/m$ to $0.0048\Omega^{-1}/m$.

In other words, I had been able to do accurate cave radio locations in the N/S direction where the conductivity was constant, but not in the E/W direction where there was a conductivity gradient.

Conclusions

Does this prove my hypothesis that the conductivity differences caused the poor location performance? I think not. The conductivity difference is not great, and there is little data for comparison at other sites. I would encourage other conductivity experimenters in limestone terrain to look for anisotropic ground. In the meantime the hypothesis can still be true. I look forward to trying Brian Pease's beacon underground to confirm the direction of Castleguard Cave through surface control points.

References

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