Frequency Effects in Hand-held Electromagnetic Short Coil Spacing Data

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Introduction

Hand-held electromagnetic induction (EMI) instruments are used in near-surface ground resistivity characterisation. Horizontal coil dipole-dipole (HCP) and vertical coil (VCP) are most common systems used. The Low Induction Number (LIN) range is important concept and has been used a) in system design, b) data interpretation. LIN range implies that Im-component response increases linearly with induction number B up to 0.2-0.5 (data conversion). On the other hand, LIN is valid when B is less than 0.02 in all the layers of the influencing resistivity structure.

Objectives

- ✓ Study how in the frequency sounding responses vary and how exact and LIN range based approximate parallel conductance (layer) modelling (McNeill, 1980) differs.
- ✓ Study what data interpretation method is advisable.
- ✓ Study of depth of investigation with HCP and VCP.

Depth penetration and frequency effect

Huang (2005): depth penetration equals ~√(skin-depth). In 100 Ωm earth the lowering of frequency from 10000 Hz to 1000 Hz increases the depth penetration from 7.1 to 12.6 meters (only!). Thus typically a) frequency effect is small, b) penetration is much more than 1-2 x coil spacing, b) frequency effect – if present – originates from deeper ground section resistivity variations.

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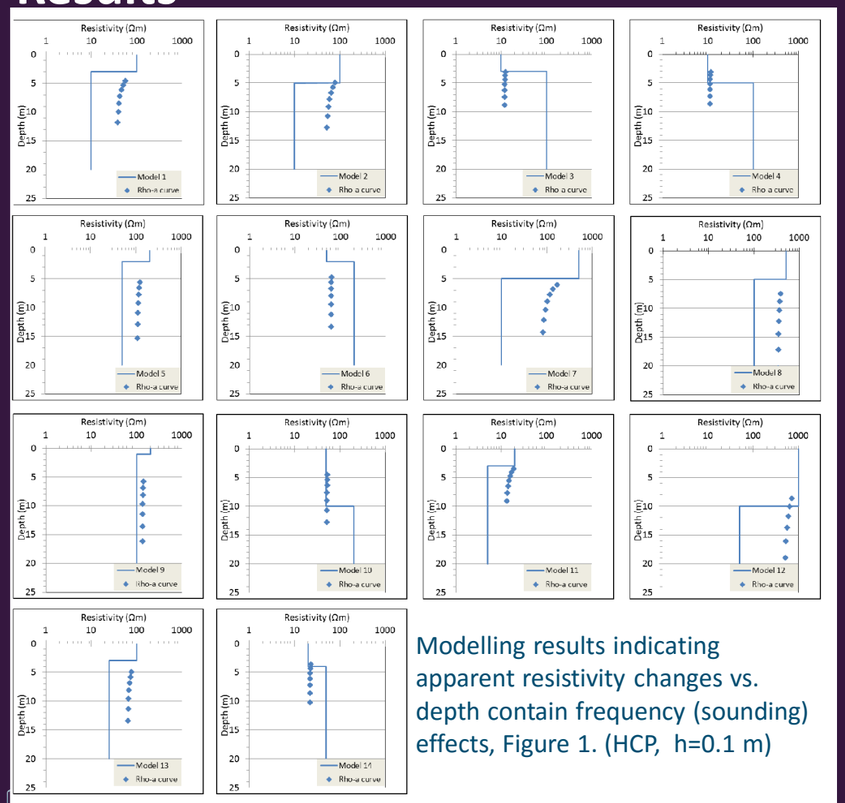
HCP and VCP model calculations

Exact responses vs. LIN range conductance model were analysed for 14 two-layer models in HCP and VCP. Frequency range applied was 0.5 – 32 kHz, coil separation 1.22 m. Resistivities varied between 10 – 1000 Ωm and layer thicknesses 1 – 10 m. Coil heights were 0.1 and 1.0 m. Apparent resistivities and depths were compared to no-frequency effect containing conductance model responses.

Results



Modelling results indicating apparent resistivity changes vs. depth contain frequency (sounding) effects, Figure 1. (HCP, h=0.1 m)

Sounding characteristics appear when more conductive bottom layer is present.

Deviations from LIN based model

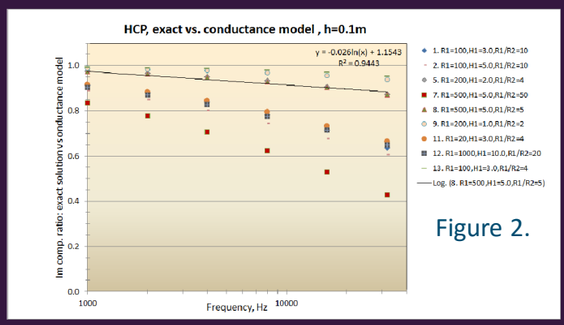


Figure 2.

Largest deviations at highest frequencies. Up to 30-60 % from no-frequency effect applying conductance model with resistivity contrasts 10 – 50.

Height influence and HCP vs. VCP

Coil height 1.0 m yield very similar results but differences from Fig.2 are even larger, both in HCP and VCP soundings.

In VCP geometry exact vs. approximate solution differences stay similar to HCP. In approximate solution VCP has depth penetration half of the HCP. Model calculations support this and HCP & VCP soundings together can be used for improved layer coverage.

Conclusions

It is necessary to use exact calculation scheme and inversion in normal ground conditions with varying resistivities. If resistivity decreases towards the depth, accuracy with approximate methods can be acceptable. Frequency sounding effect increases when deeper layers turn more conductive. Depth penetration seems to follow closely √(skin-depth) estimate. Joint use of HCP and VCP can extend the depth range covered.

References and acknowledgements

For references, please check the Extended Abstract publication.

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