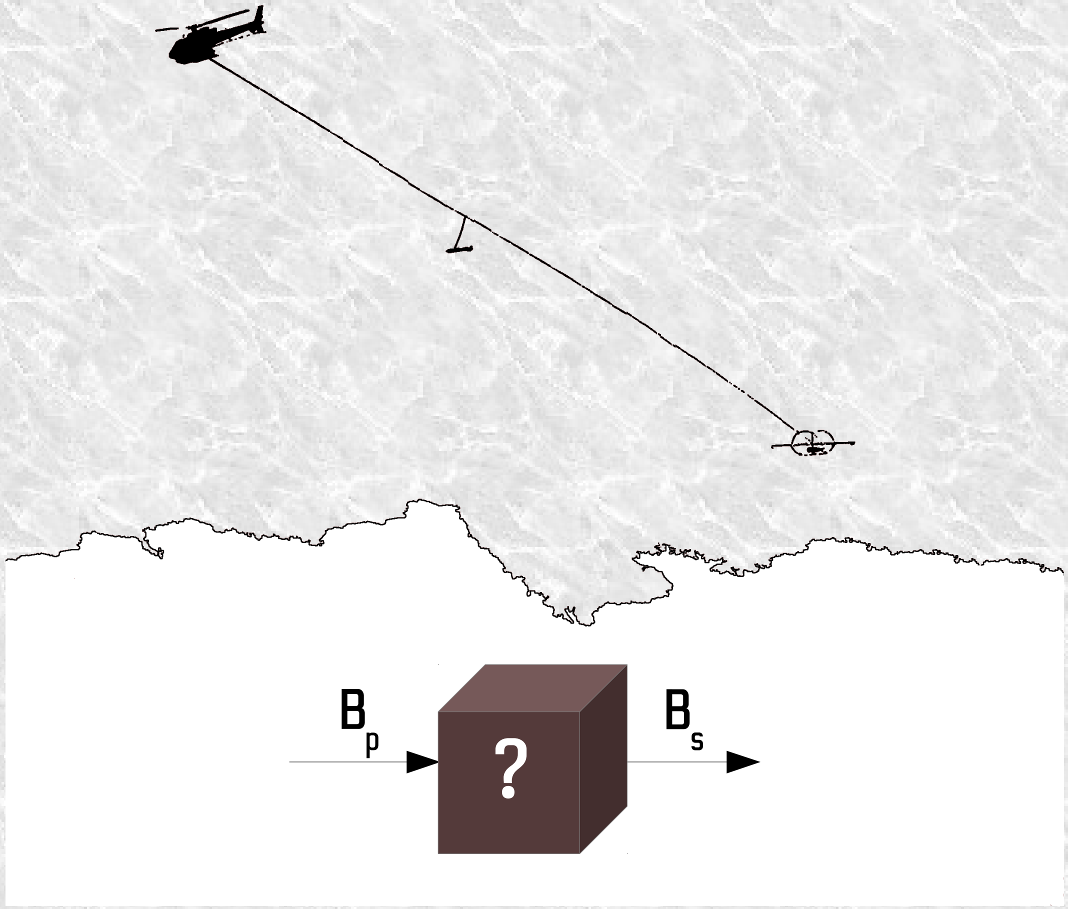
Overcoming Airborne IP in Frequency Domain: Hopes and Disappointments

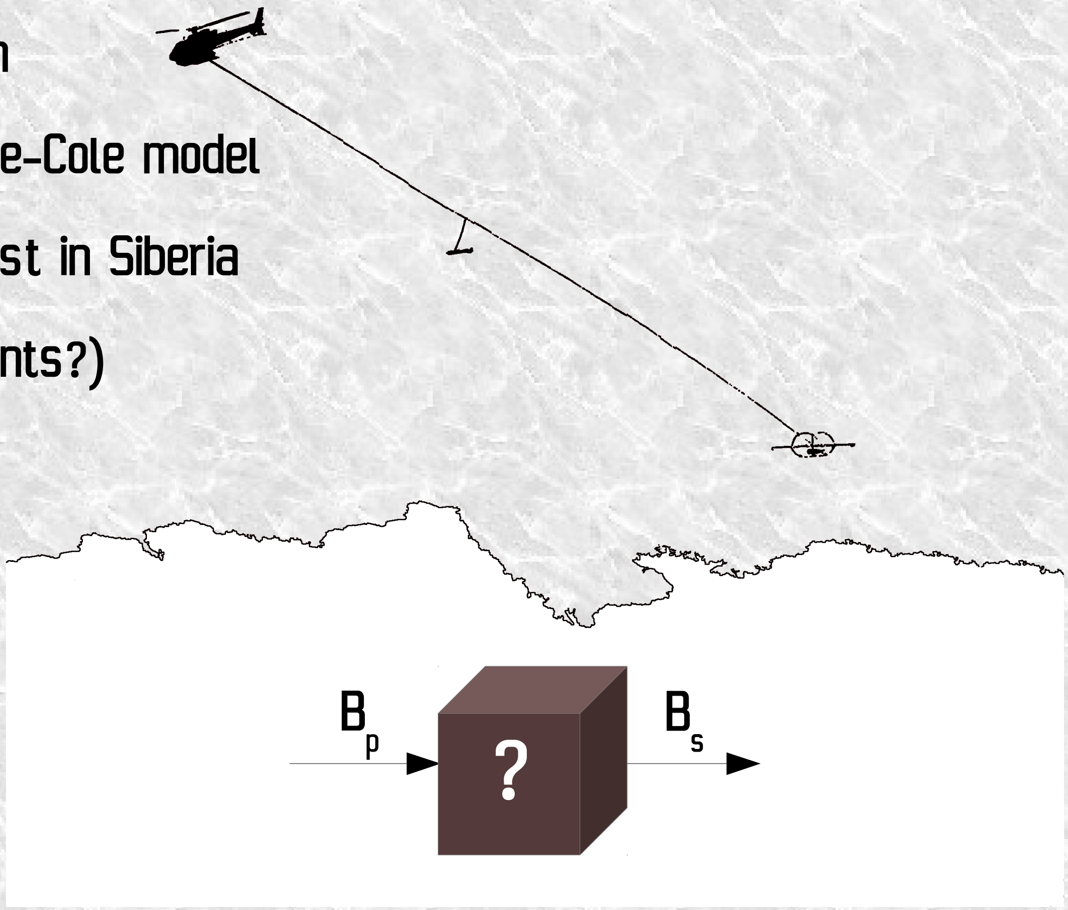
2019-078

Evgeny Karshakov*, John Moilanen



Summary

- Modern approaches to IP effect elimination/interpretation – a review
- Motivation of considering in FD (hopes)
- Currents distribution for an AEM system
- Circuit analysis as an alternative to Cole-Cole model
- Case studies: Airborne IP over permafrost in Siberia
- Discussion of the results (disappointments?)

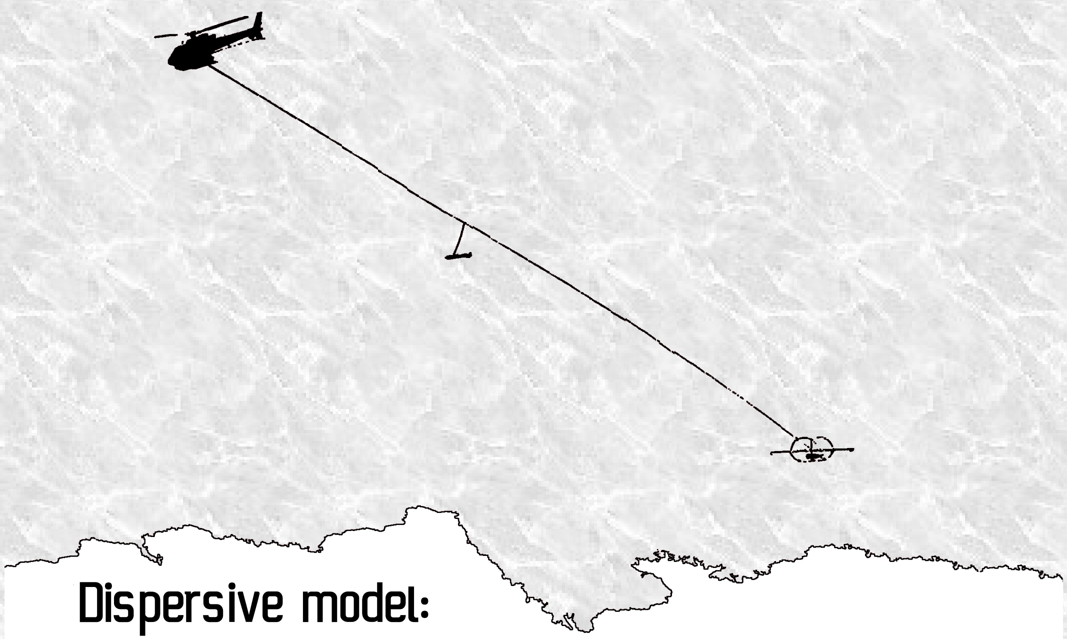


Modern approaches to IP effect elimination/interpretation

Chen, T., Smiarowski, A., and Hodges, G., 2015, Understanding airborne IP: First European Airborne Electromagnetic Conference, EAGE, Extended Abstracts.

Kaminskiy, V. and Viezzoli, A., 2017, Modelling induced polarisation effects in helicopter time-domain electromagnetic data: Field case studies: Geophysics, 82(2), 1-13.

Kwan, K., Legault, J., Johnson, I., Prikhodko, A., and Plastow, G., 2018, Interpretation of Cole-Cole parameters derived from helicopter TDEM data – Case studies: SEG Annual Meeting and Exhibition, Anaheim, Extended Abstracts, 1-6.



Dispersive model:

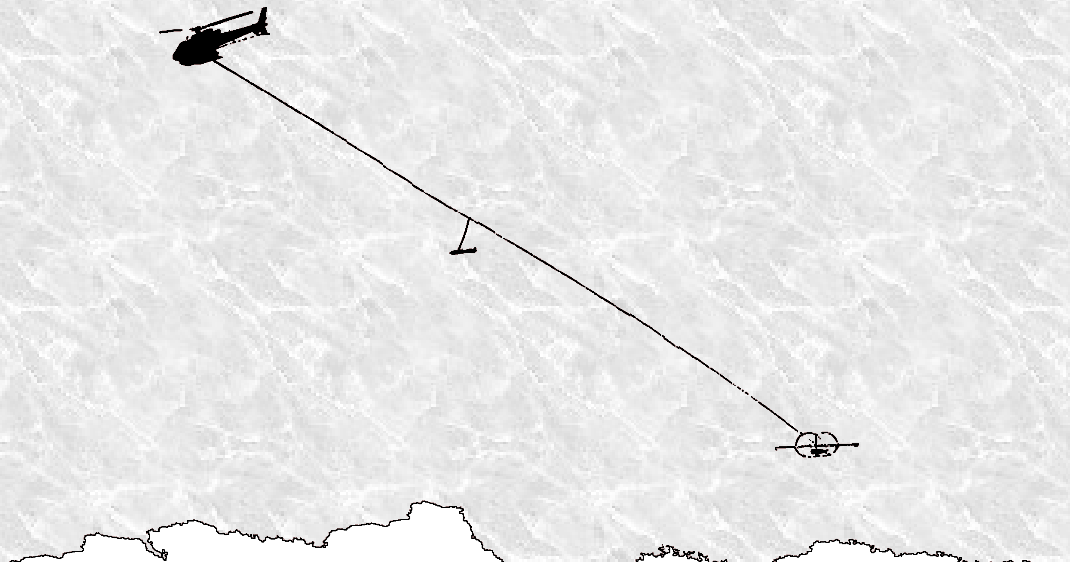
$$\zeta(\omega)=\rho\left[1-m_0\left(1-\frac{1}{1+(i\omega\tau)^c}\right)\right]$$

Modern approaches to IP effect elimination/interpretation

Cole, K.S., and Cole, R.H., 1941, Dispersion and absorption in dielectrics I. Alternating current characteristics: Journal of Chemical Physics, 9, 341-351.

Cole, K.S., and Cole, R.H., 1942, Dispersion and absorption in dielectrics II. Direct current characteristics: Journal of Chemical Physics, 10, 98-105.

Pelton, W.H., Ward, S.H., Hallof, G., Sill, W.R., and Nelson, P.H., 1978. Mineral discrimination and removal of inductive coupling with multifrequency IP: Geophysics, 43(3), 588-609



Dispersive model:

$$\frac{\varepsilon^*(\omega)-\varepsilon_\infty}{\varepsilon_0-\varepsilon_\infty}=1-\frac{1}{1+(i\omega\tau)^c} \quad \text{or}$$

$$Z(\omega)=R_0\left[1-m\left(1-\frac{1}{1+(i\omega\tau)^c}\right)\right]$$

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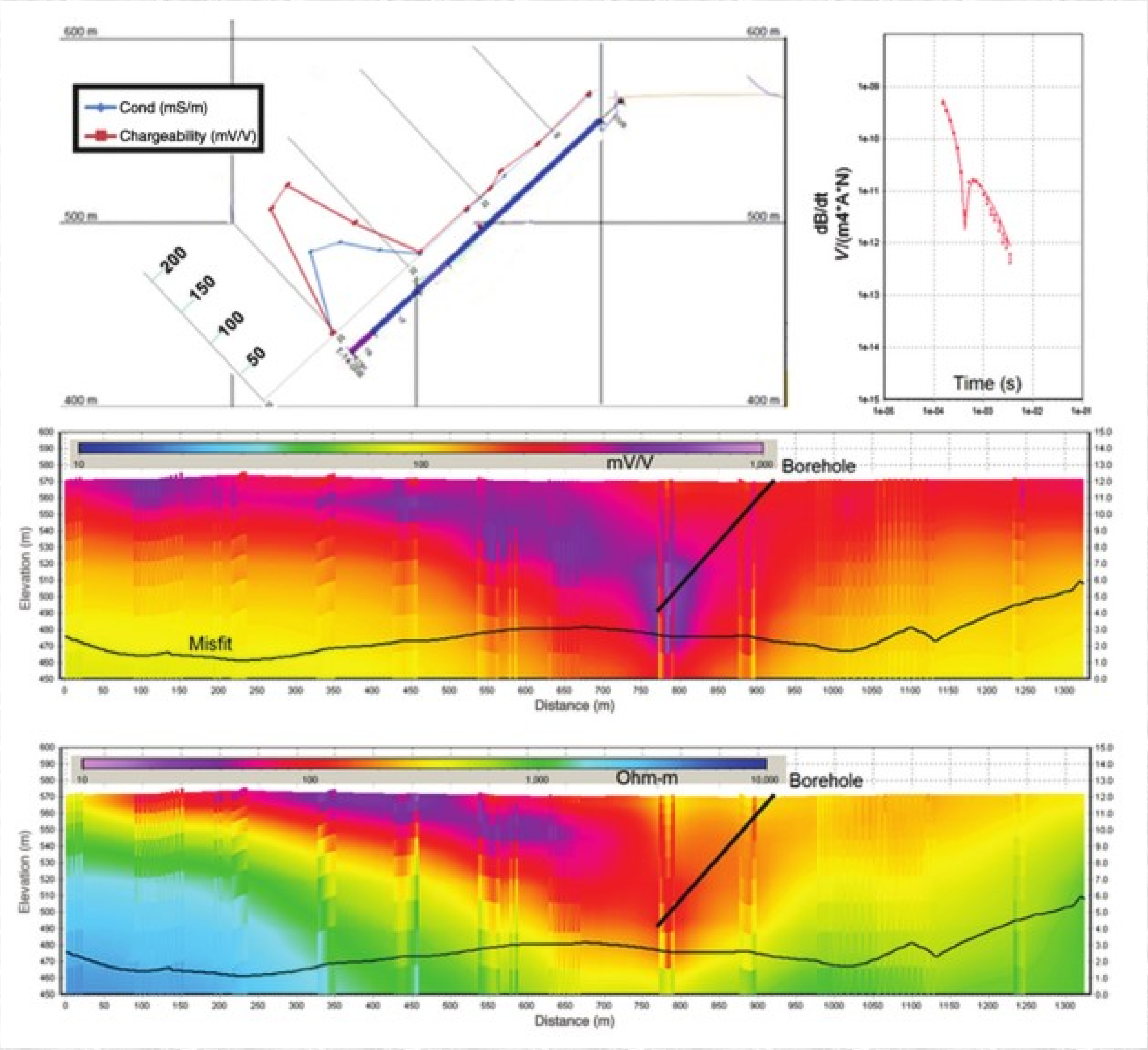

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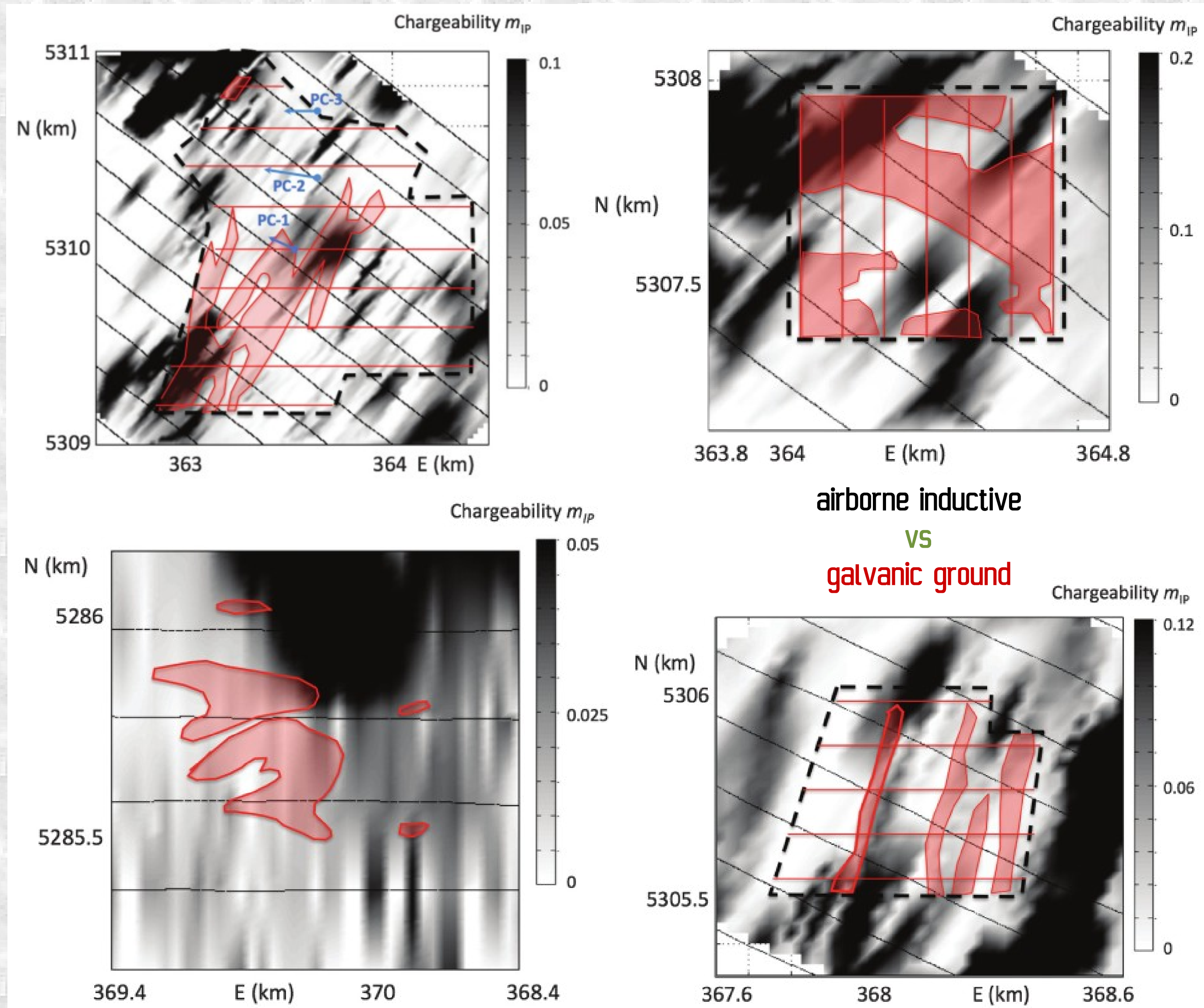
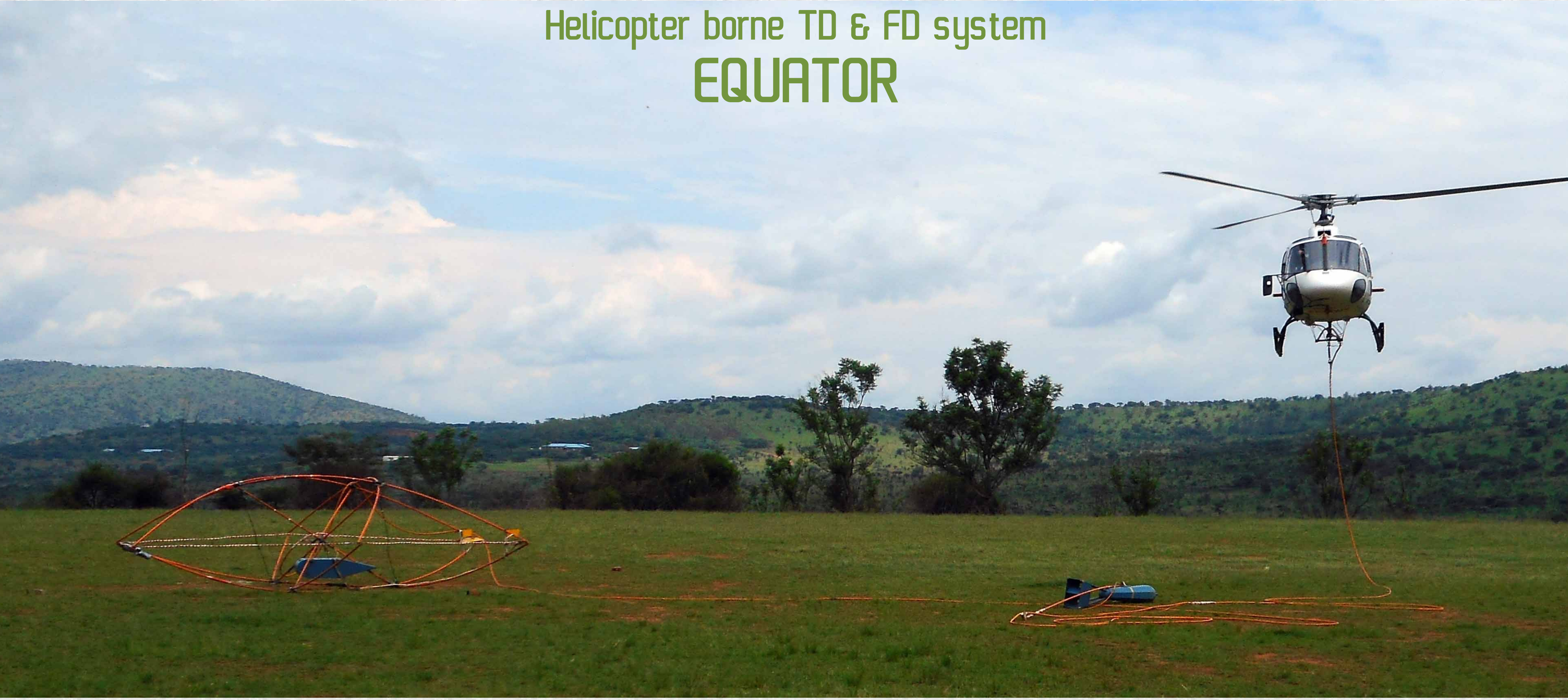
Macnae, J., and Hine, K., 2016, Comparing induced polarisation responses from airborne inductive and galvanic ground systems: Tasmania: Geophysics, 81(6), E471-E479.

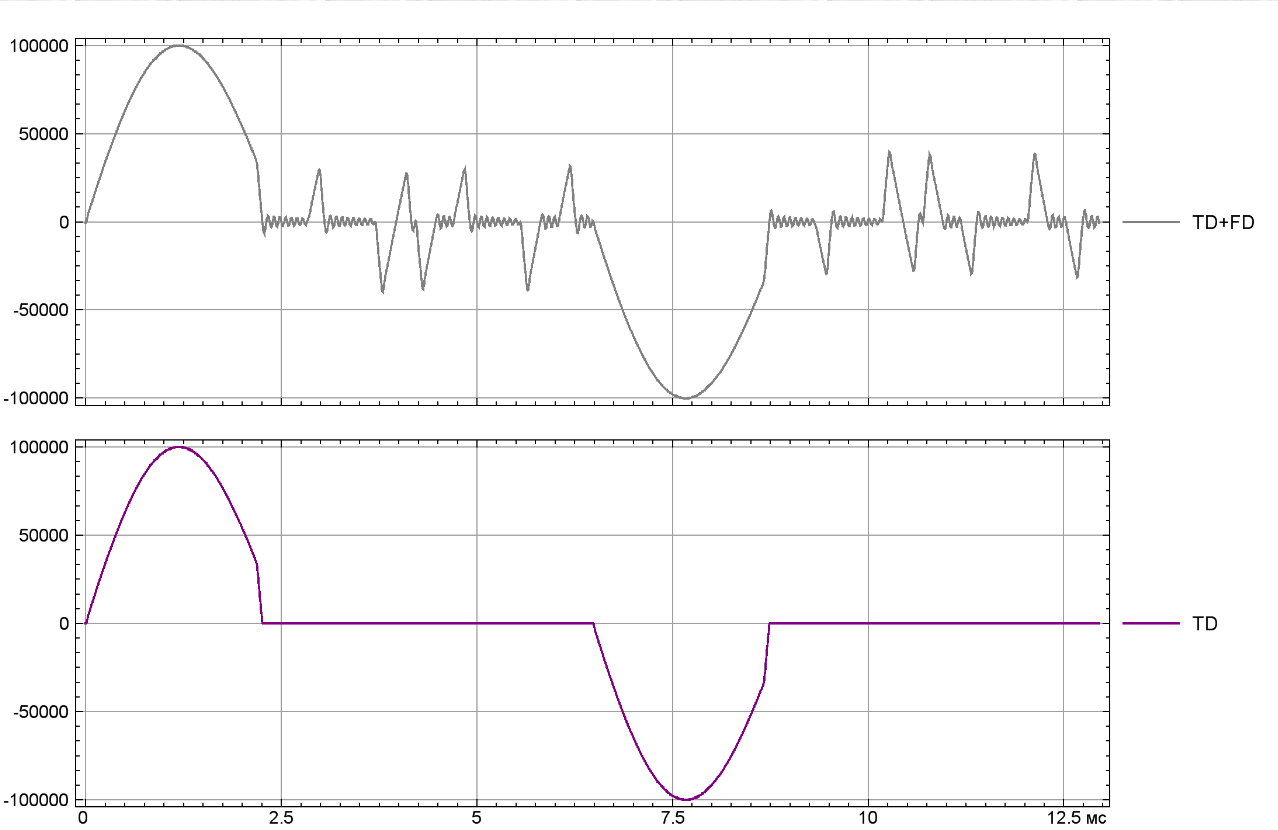


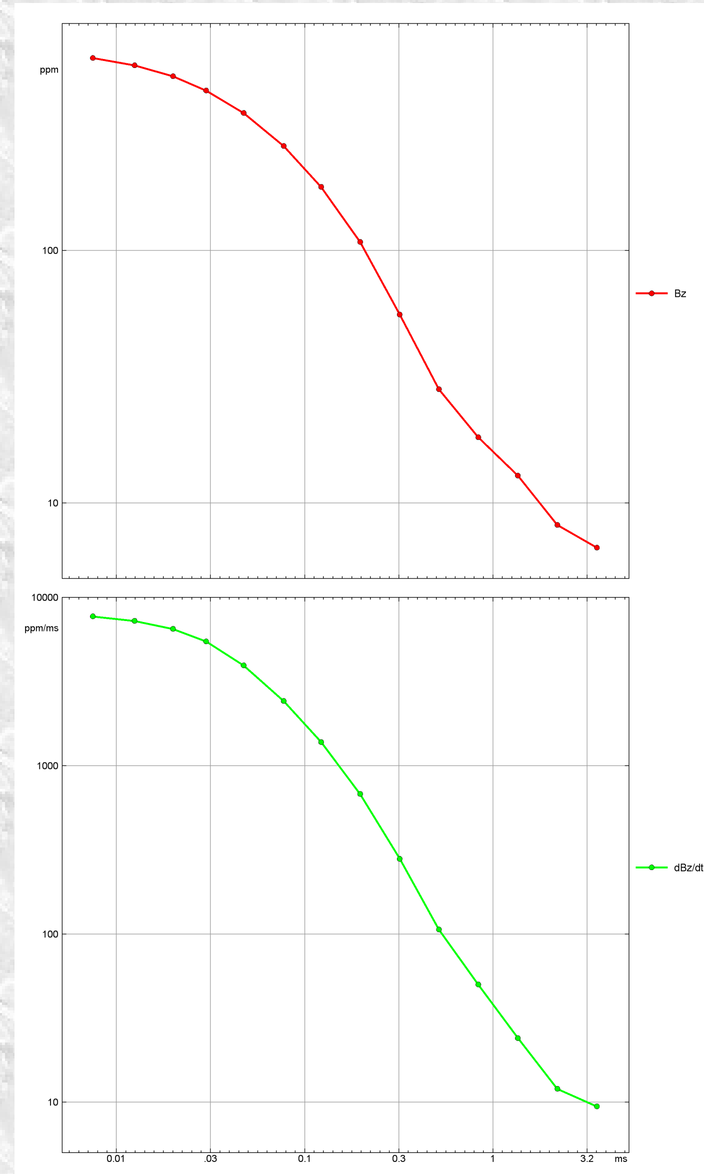
Motivation to consider FD:
1. Just because we can …

Moilanen, J., Karshakov., E. and Volkovitsky, A., 2013, Time domain helicopter EM system "Equator": resolution, sensitivity, universality: 13th SAGA Biennial @ 6th International AEM Conference, Extended Abstracts, 1-4.

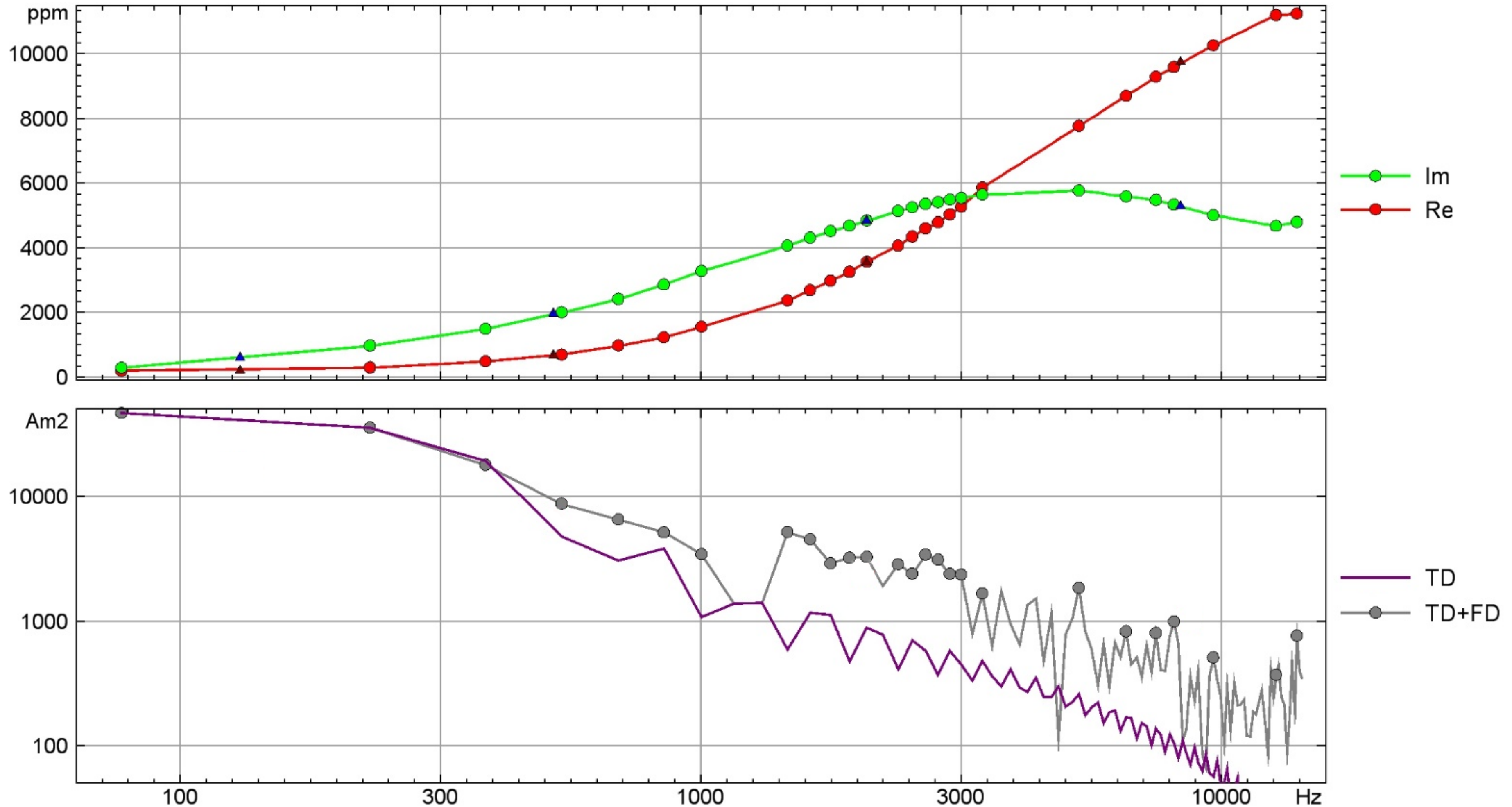


Motivation to consider FD:
… not only in TD …



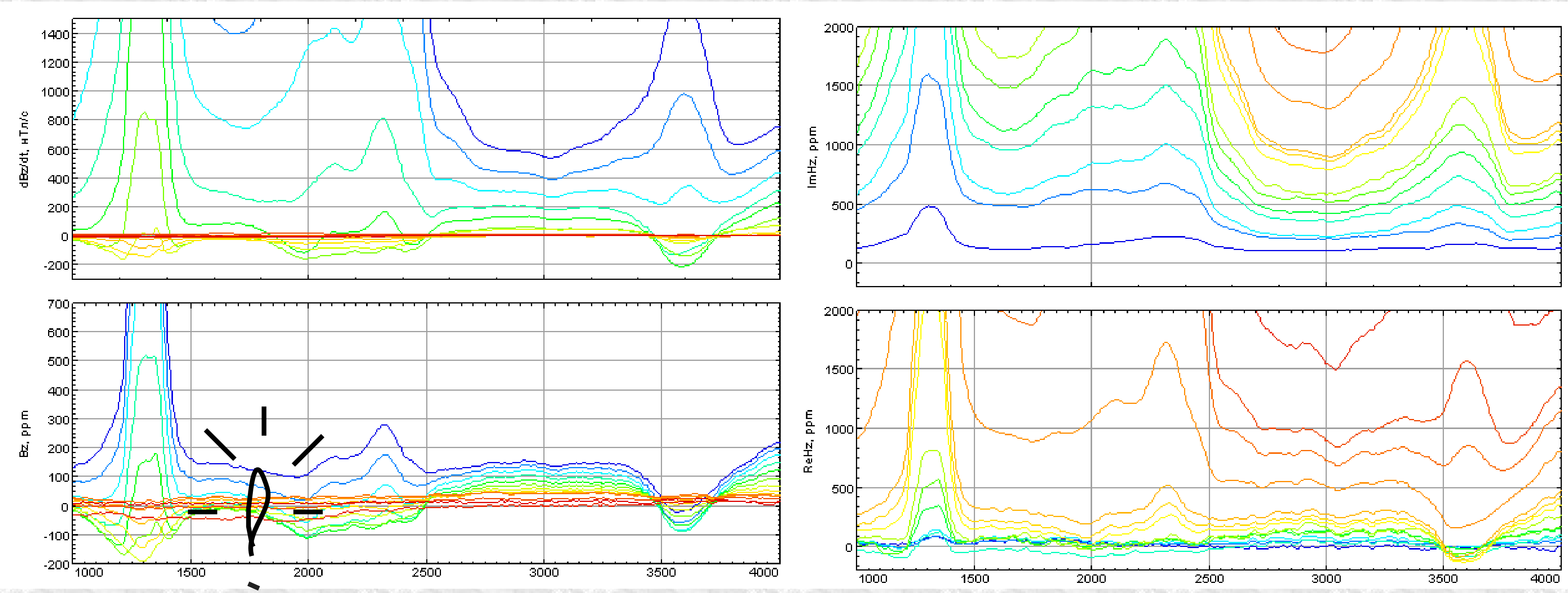


Motivation to consider FD:
… but also in FD

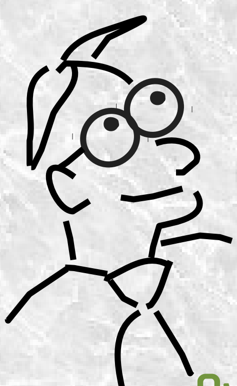


Motivation to consider FD:
2. The case of measurements in Siberia

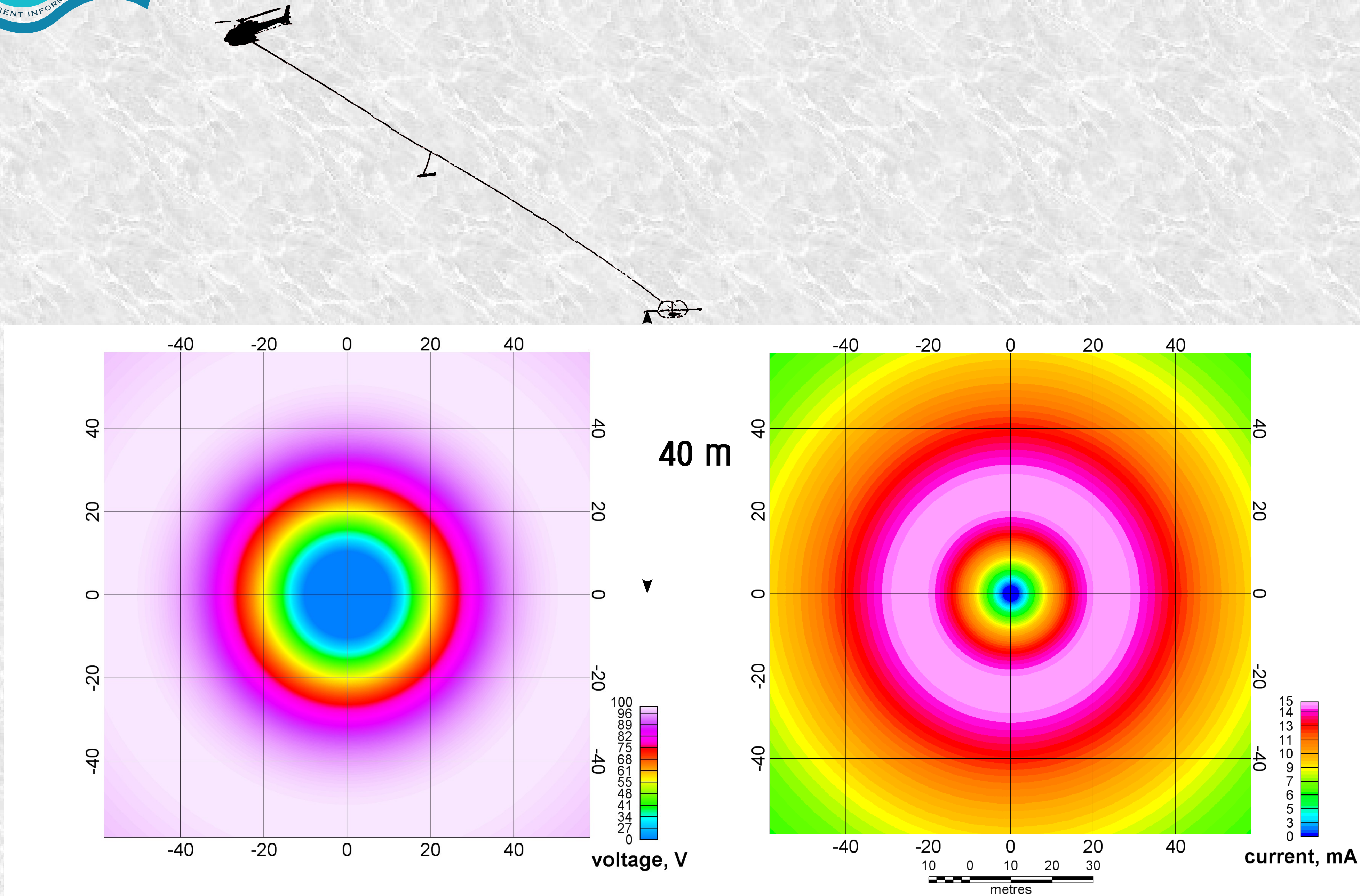
dB_z/dt Im B_z



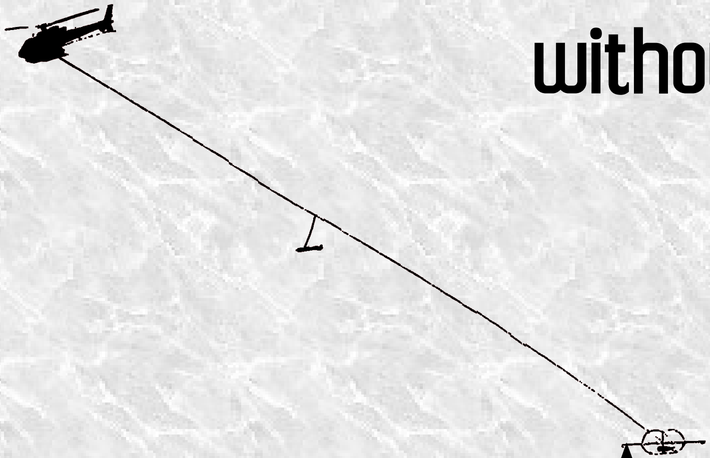
B_z Re B_z

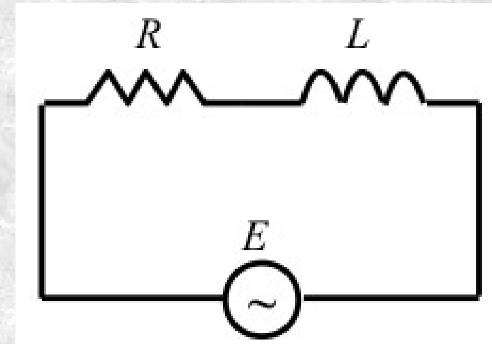


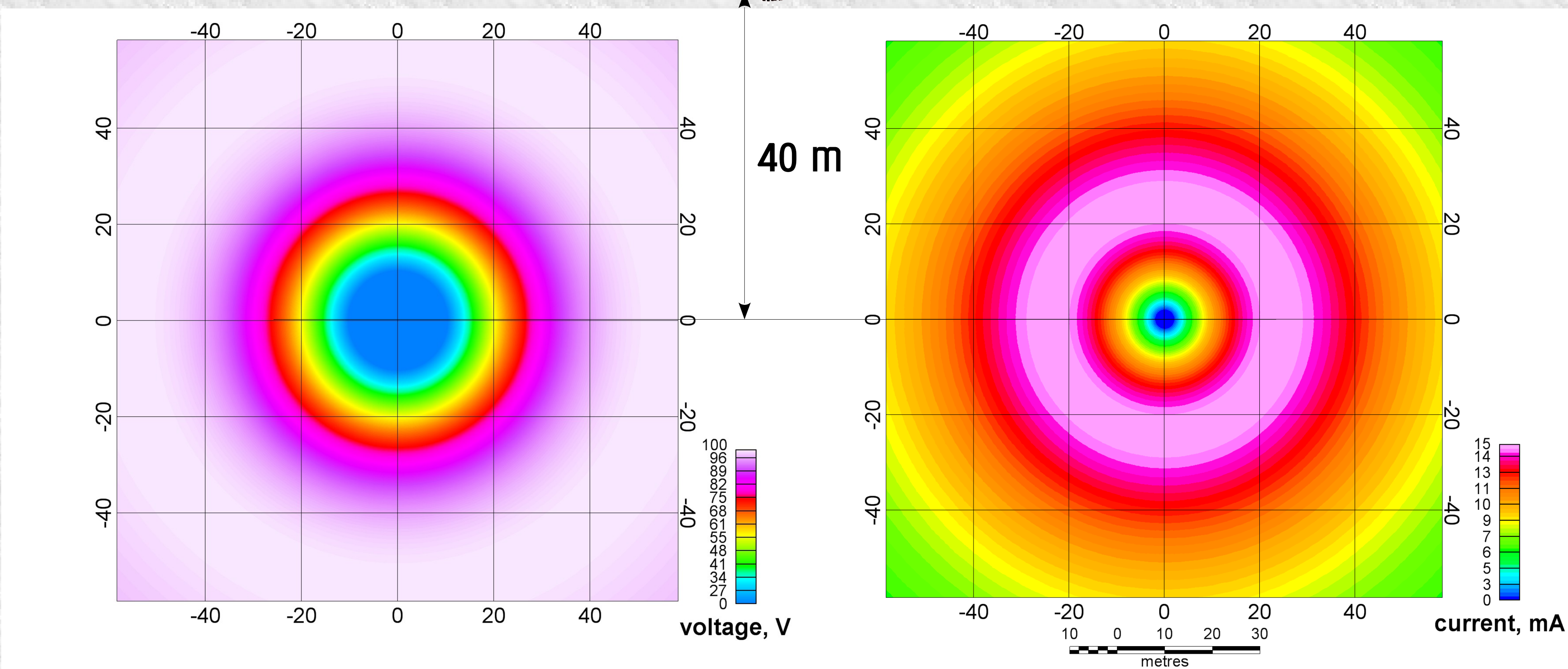
Currents distribution



Circuit analysis without IP







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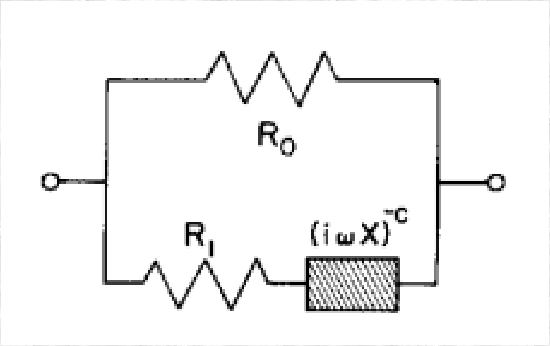
Cole-Cole model



$$Z(\omega)=R_0\left[1-m\left(1-\frac{1}{1+(i\omega\tau)^c}\right)\right]$$

where

$$m=\frac{1}{1+R_1/R_0}$$ and $$\tau=X\left(\frac{R_0}{m_0}\right)^{1/c}$$

Circuit analysis with IP

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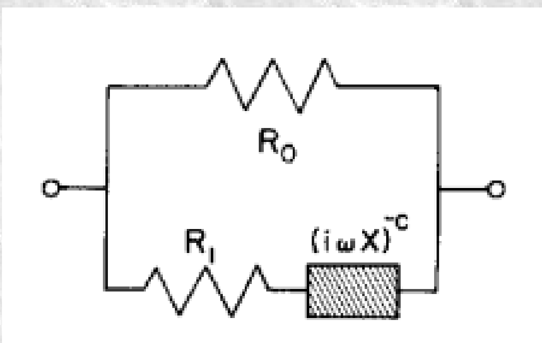

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How to separate L and C in Cole-Cole model?

Circuit analysis with IP

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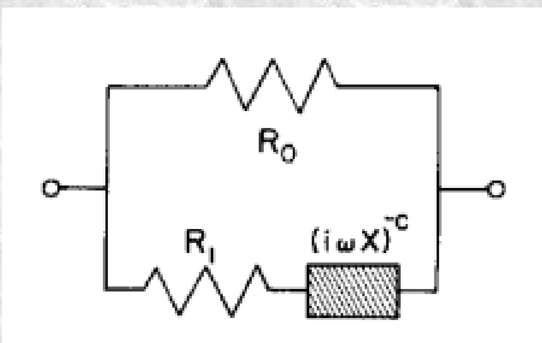

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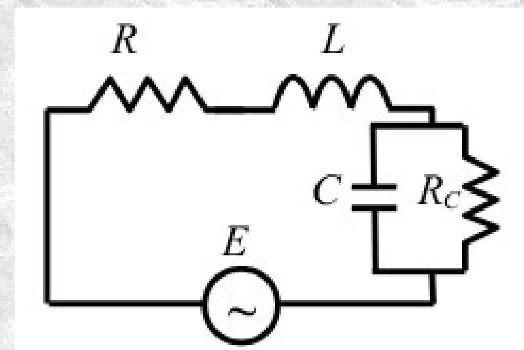
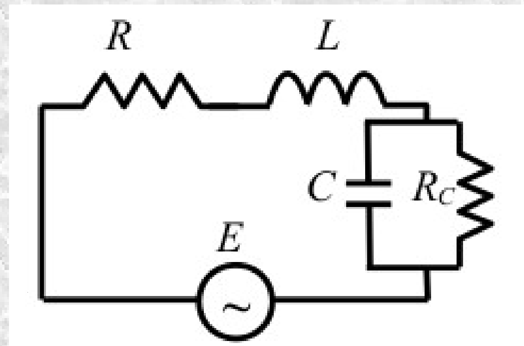
Inductive model



How to separate L and C in Cole-Cole model?

Circuit analysis with IP

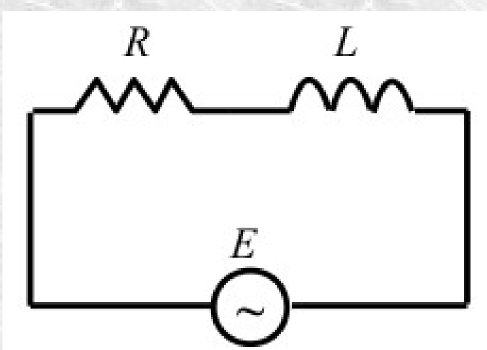
Inductive model: Ohm's law



$$E = I\left(R + i\omega L - \frac{i R_C}{\omega R_C C - i}\right)$$

$\omega R_C C << 1$

$\omega R_C C >> 1$



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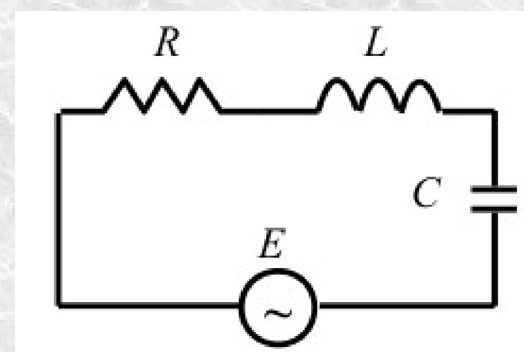
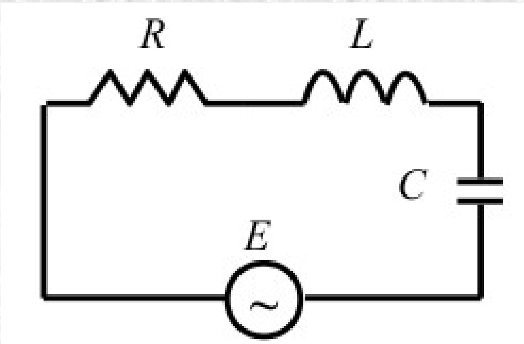
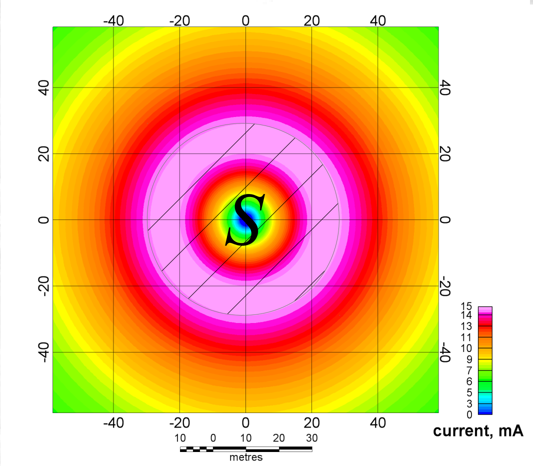


$$E = I\left(R + i\omega L - \frac{i}{\omega C}\right)$$

Circuit analysis with IP





Asymptotic inductive model

$$E = I\left(R + i\omega L - \frac{i}{\omega C}\right) \Rightarrow \frac{E\bar{I}}{I^2} = \left(R + i\omega L - \frac{i}{\omega C}\right)$$

Faraday's law: $E \sim S \cdot i\omega B_p$ (primary field)

Amper's law: $B_s \sim S \cdot I$ (secondary field)

$$\frac{k\omega B_p}{B_s^2}\left(i\,\mathrm{Re}\,B_s + \mathrm{Im}\,B_s\right) = \left(R + i\omega L - \frac{i}{\omega C}\right),$$

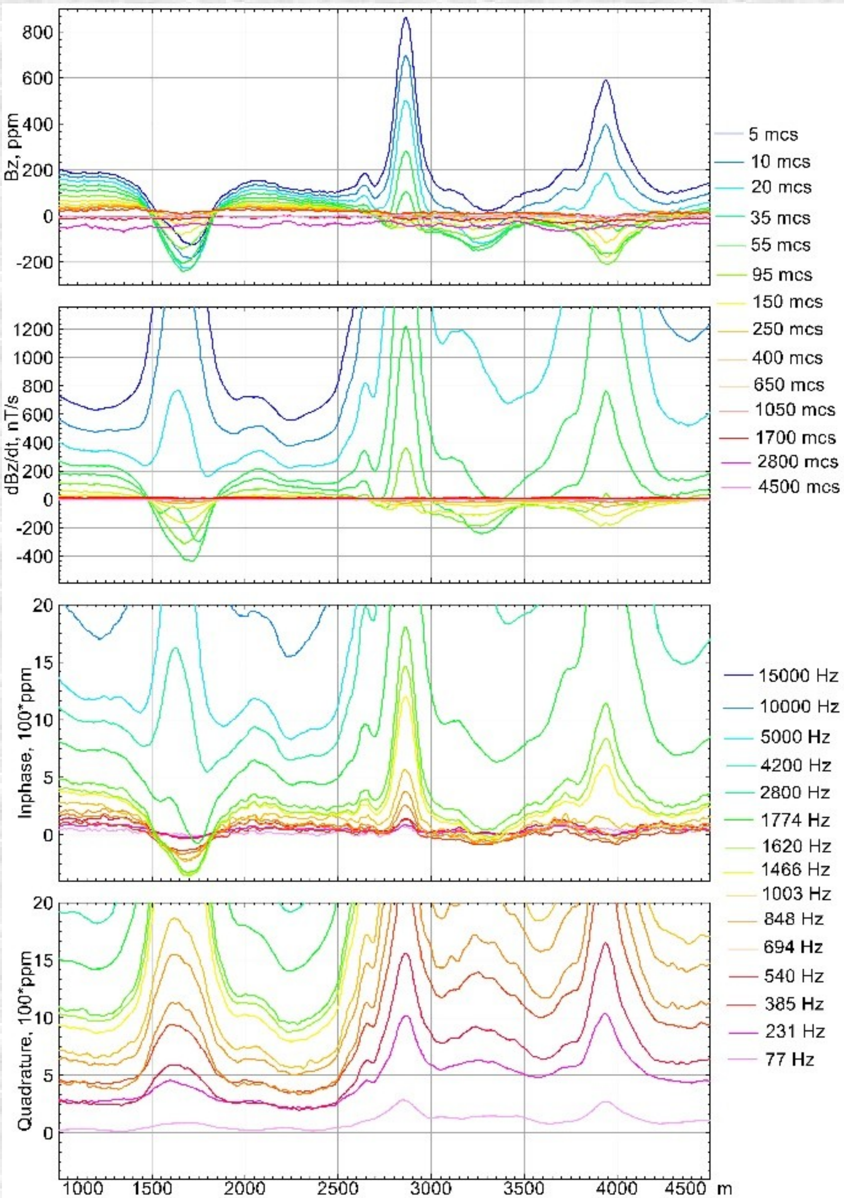
Real part:

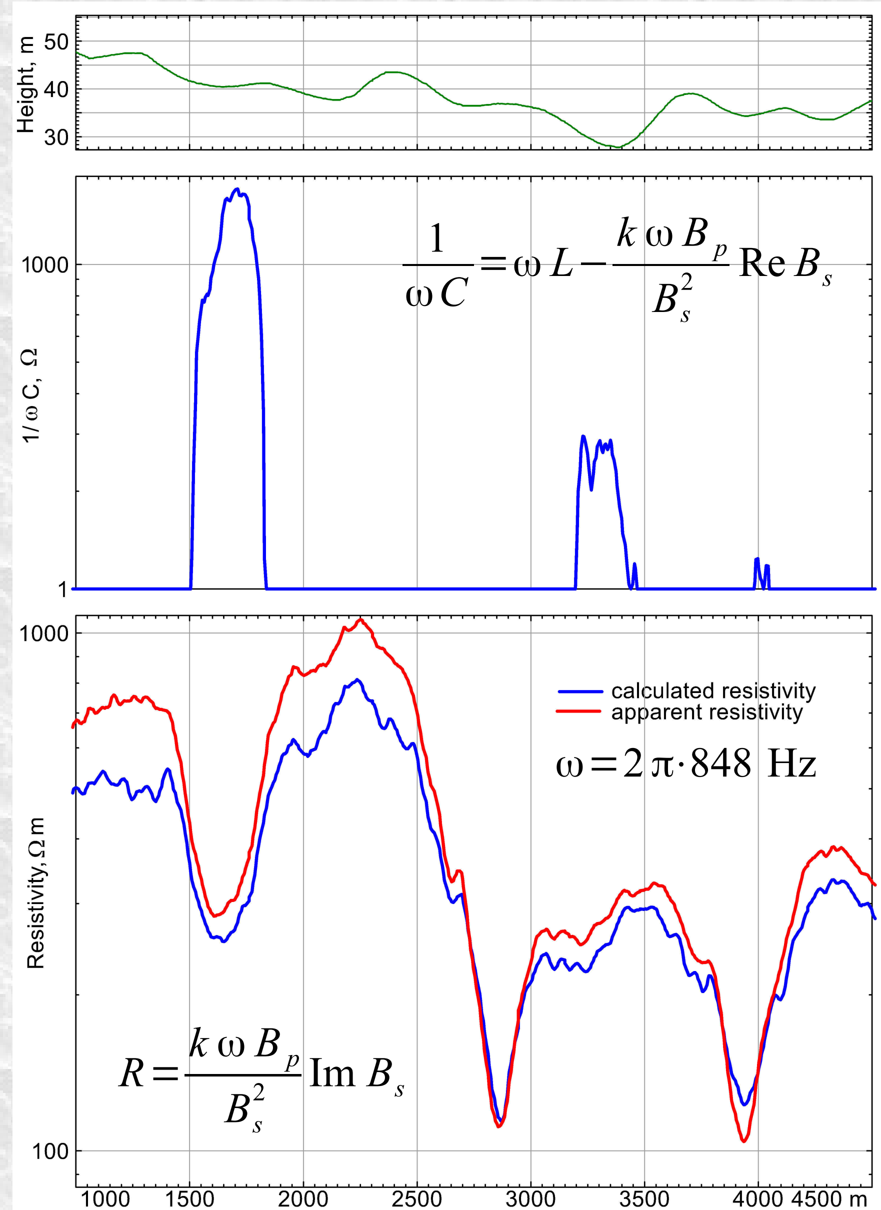
$$R = \frac{k\omega B_p}{B_s^2}\,\mathrm{Im}\,B_s.$$

Imaginary part:

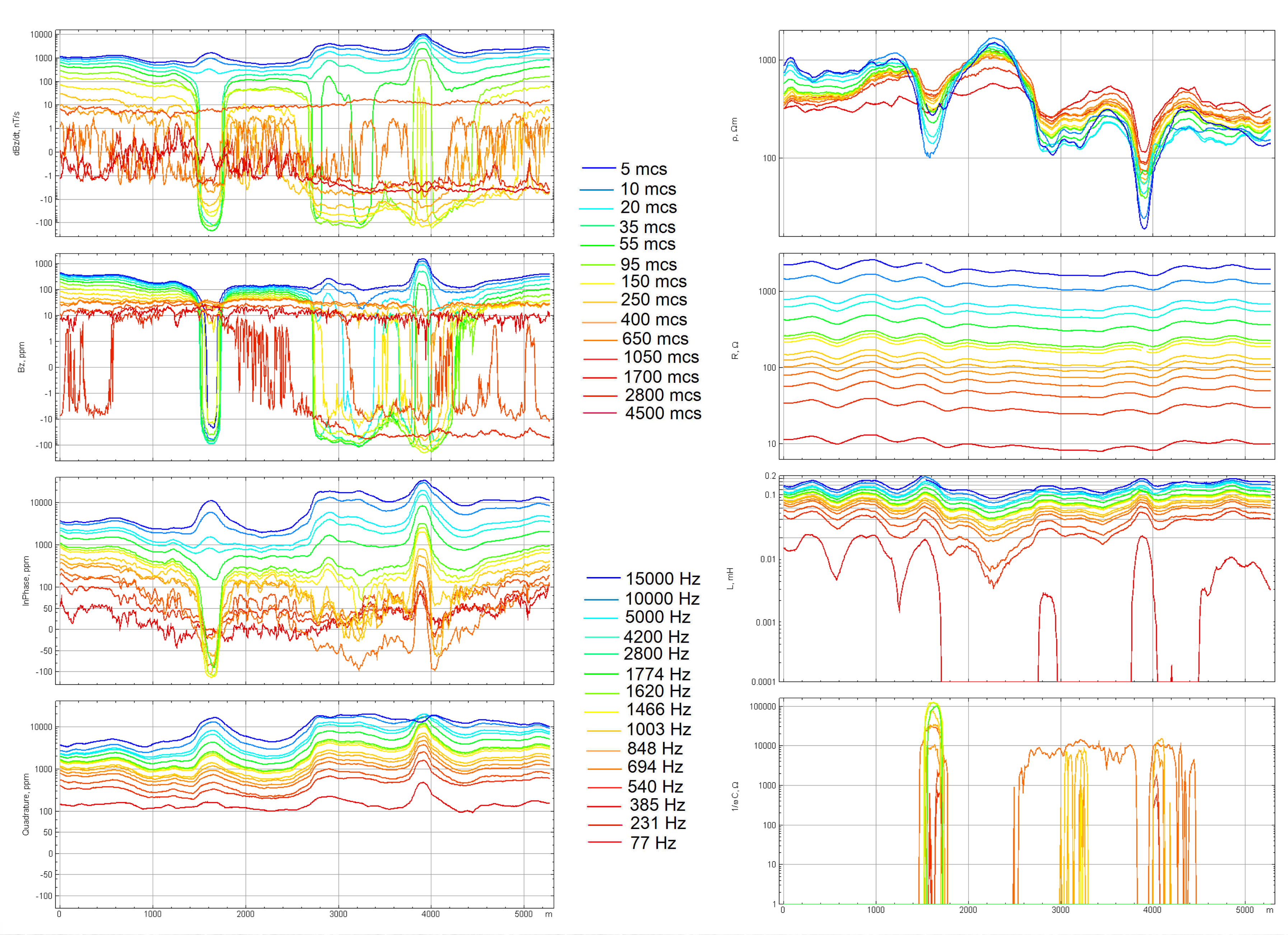
$$\frac{1}{\omega C} = \omega L - \frac{k\omega B_p}{B_s^2}\,\mathrm{Re}\,B_s.$$

Case studies in Siberia, Russia



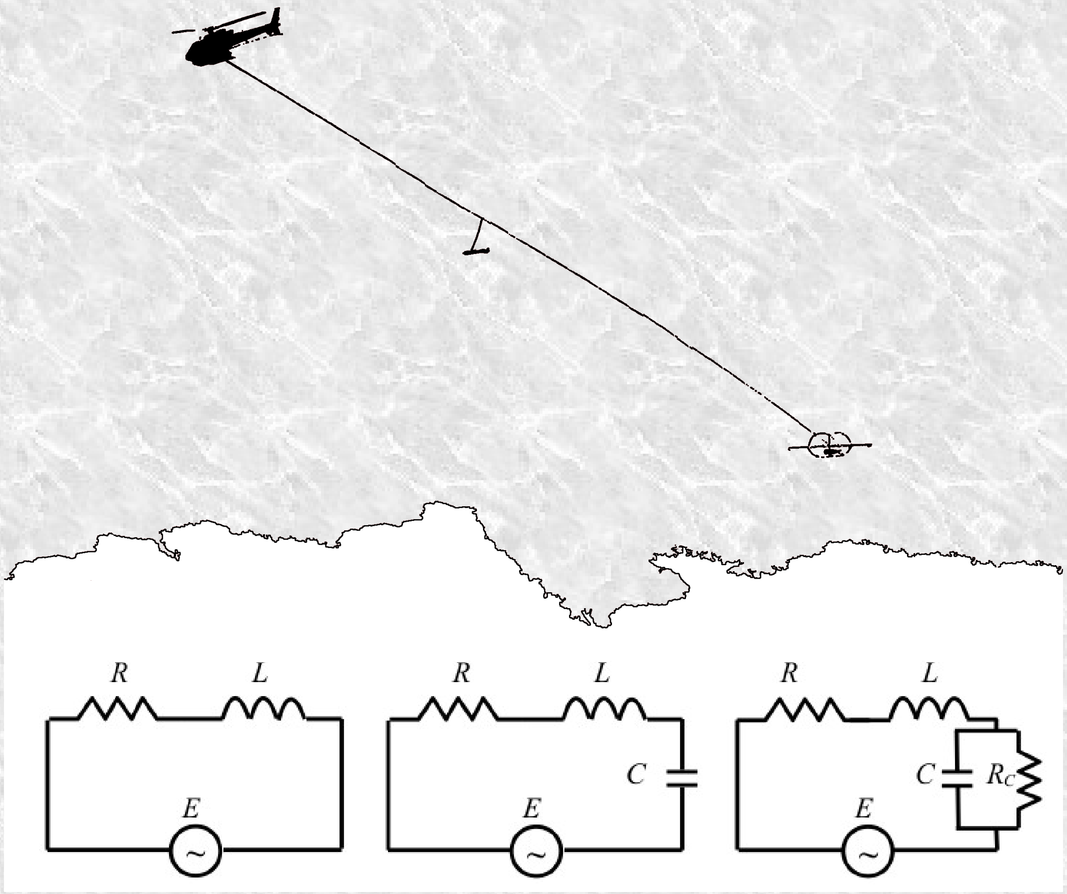


Case studies in Siberia, Russia



Results

- ☒ Cole-Cole model doesn't allow to separate inductance and capacitance



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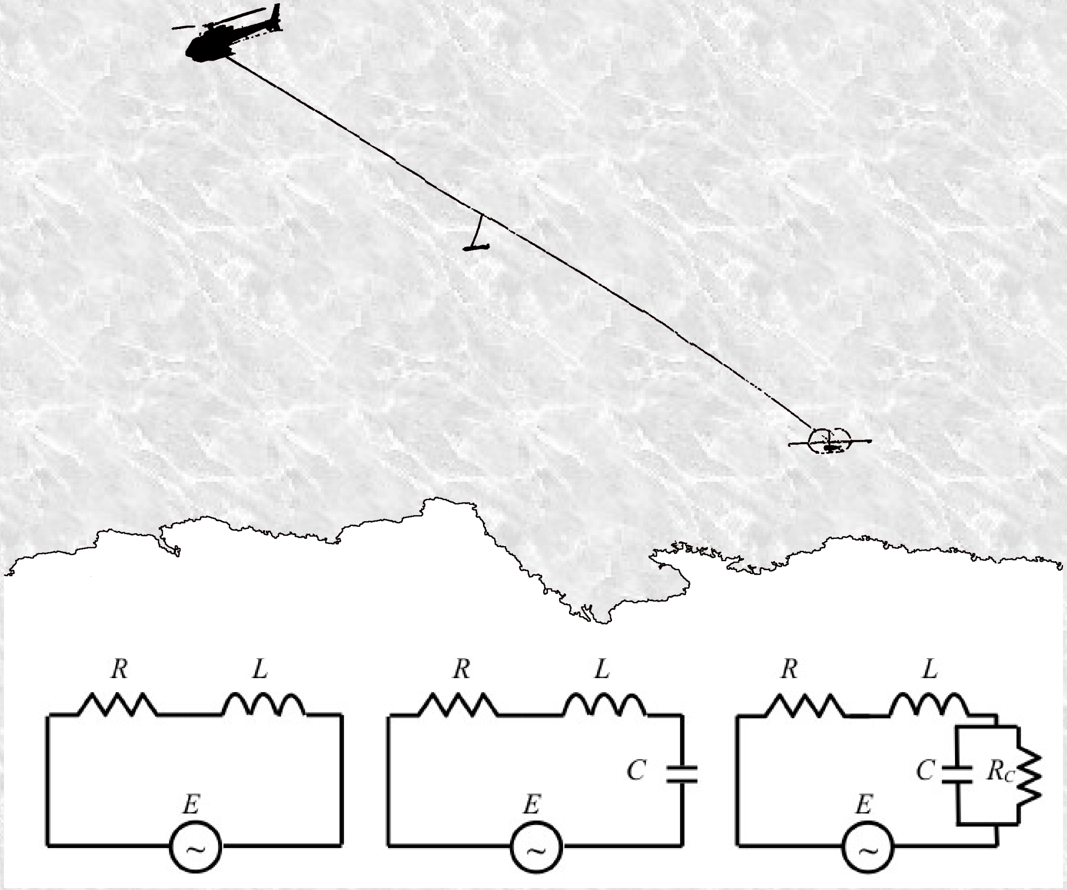
☒ Cole-Cole model doesn't allow to separate inductance and capacitance

☑ Quadrature component in FD seems being poorly influenced by AIP, at least for $\omega R_C C >> 1$ and $\mathrm{Im}\, B_s >> \mathrm{Re}\, B_s$



Results

- ☒ Cole-Cole model doesn't allow to separate inductance and capacitance
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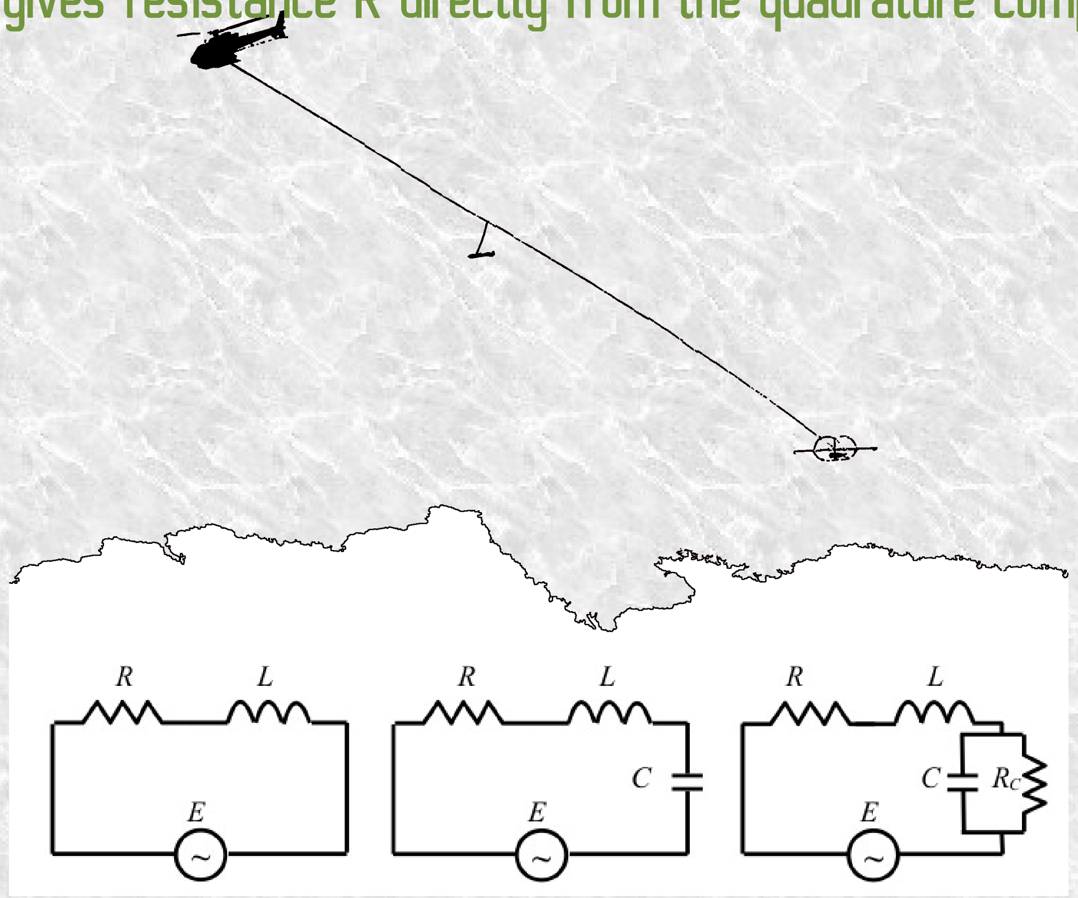
- ☑ Asymptotic model gives resistance R directly from the quadrature component



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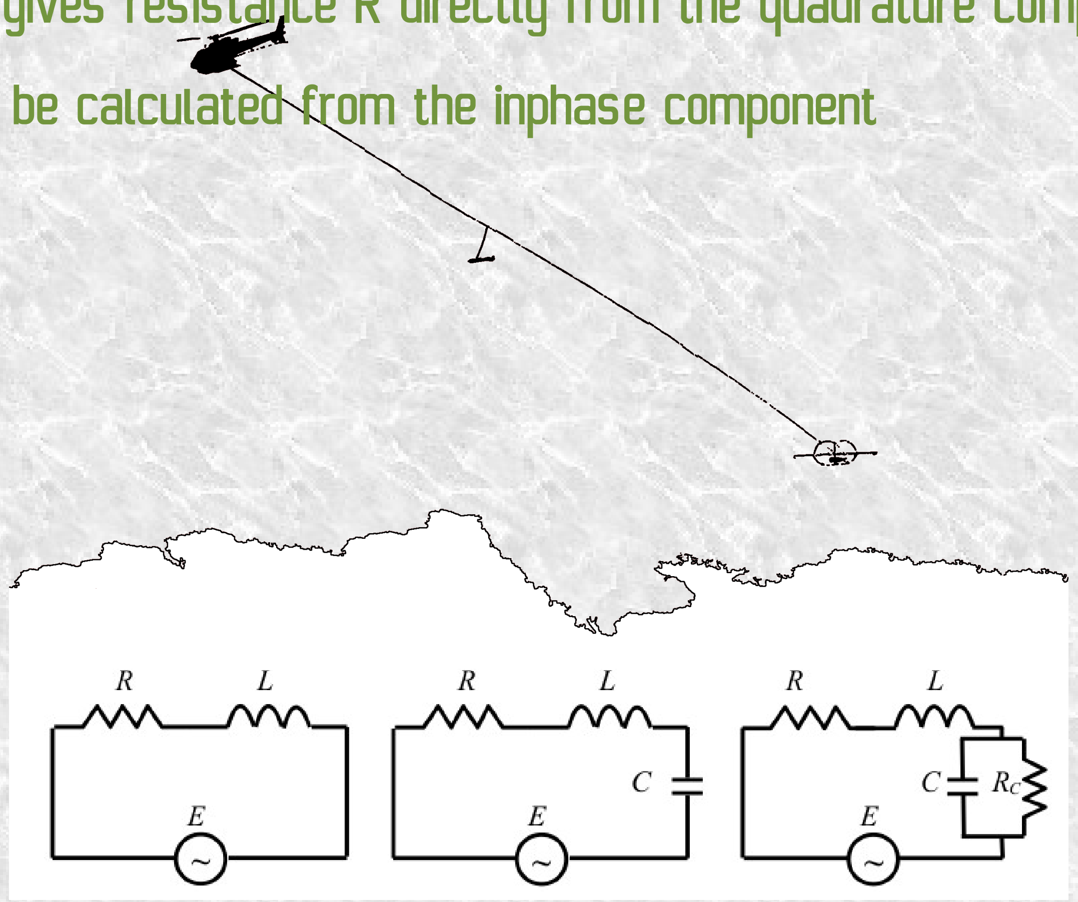

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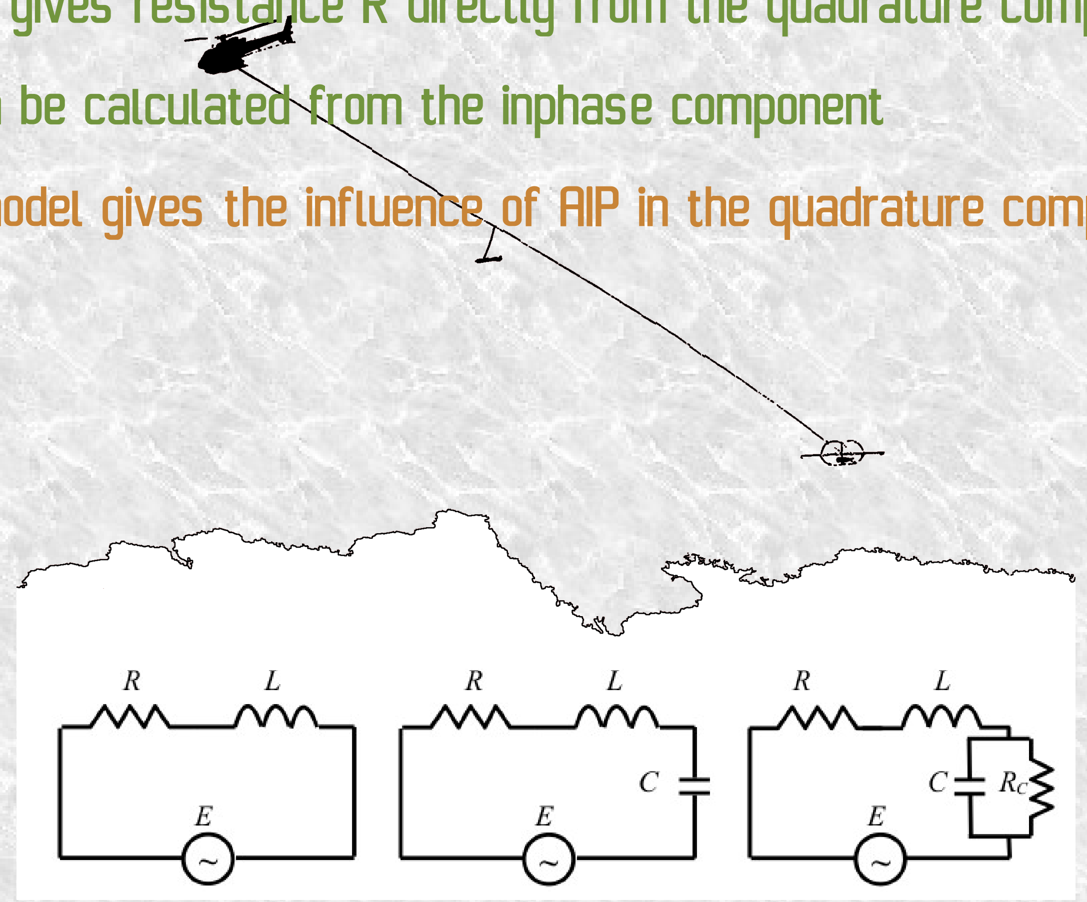
- ☑ Capacitance C can be calculated from the inphase component
- ☒ Non-asymptotic model gives the influence of AIP in the quadrature component



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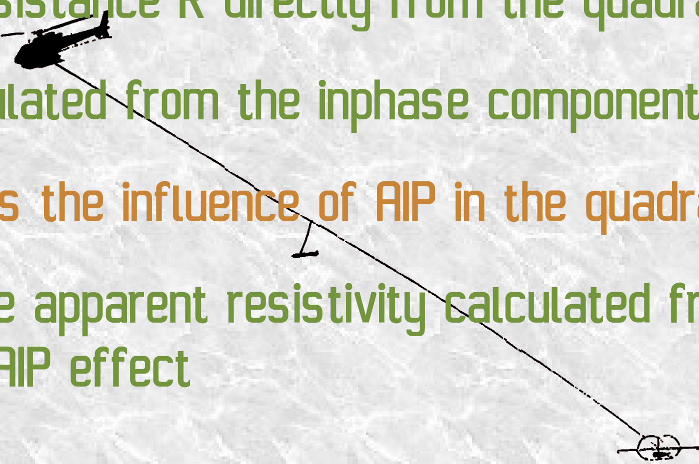
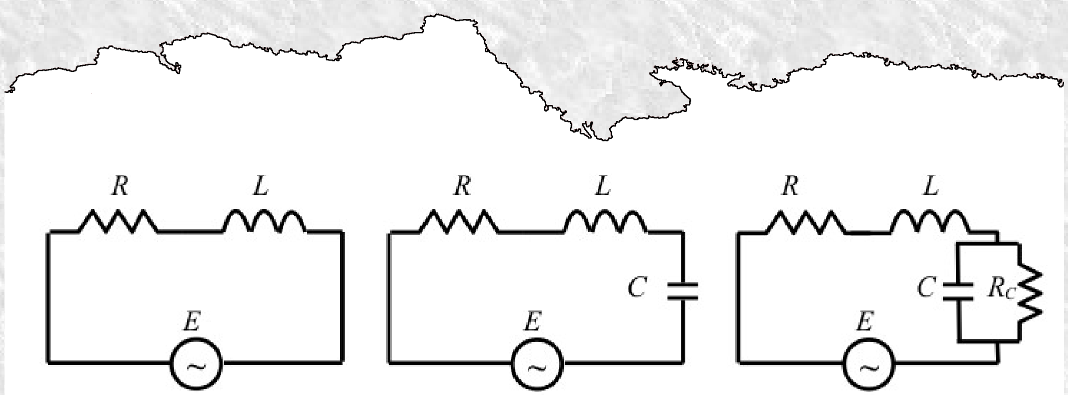
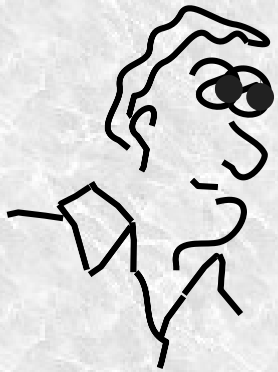
- ☑ Asymptotic model gives resistance R directly from the quadrature component
- ☑ Capacitance C can be calculated from the inphase component
- ☒ Non-asymptotic model gives the influence of AIP in the quadrature component
- ☑ Case studies show that the apparent resistivity calculated from quadrature component is almost not affected by AIP effect





THANK YOU FOR COMING!



Q & A

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