# Capacitive coupling in broadband spectral electrical impedance tomography (sEIT) measurements with a centralized multiplexer

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## Introduction

- Advanced methods have been developed to address capacitive coupling effects in broadband sEIT measurements acquired using a customized system with distributed amplifiers (Zimmerman et al., 2008; Wang et al., 2024)
- Implementing these methods with a centralized multiplexer is desirable to extend the bandwidth of sEIT measurements acquired with commercially available systems
- To discard the influence of inductive coupling in the analysis of capacitive coupling, a fan-shaped cable layout is used in this study

## Methodology

- To simulate a centralized multiplexer, a switch tool shown in Fig.1(a) is built to connect cables with the customized sEIT system

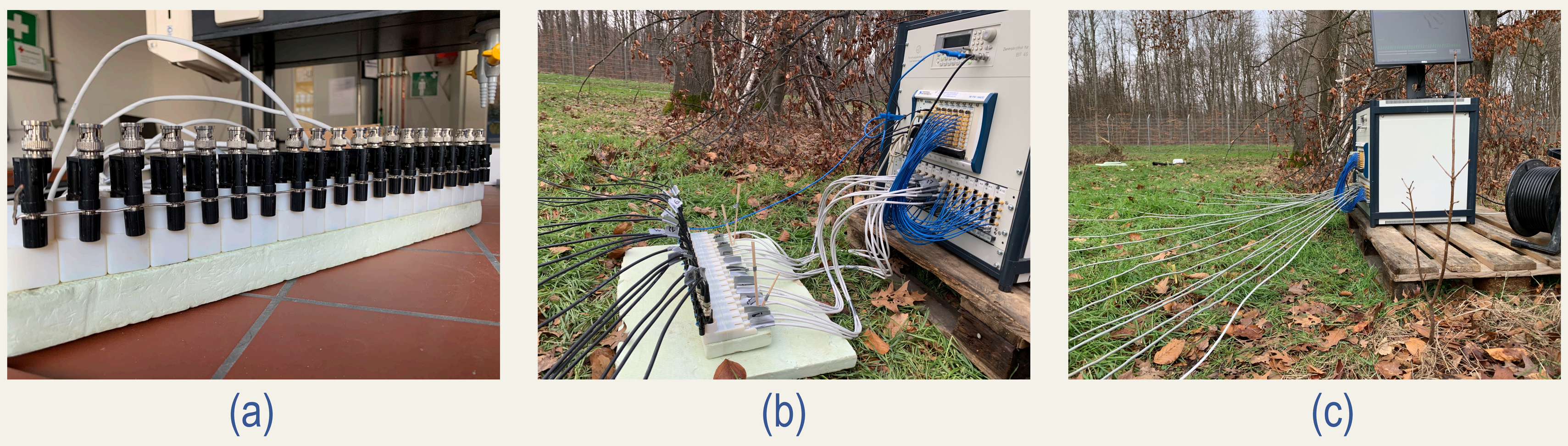
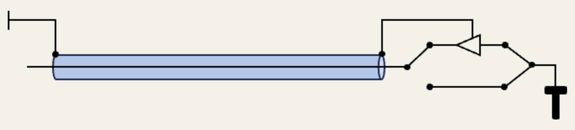
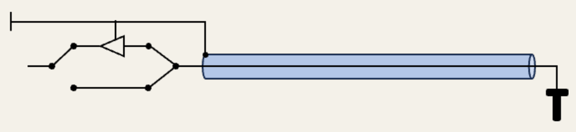



Figure 1. (a) Switch tool with mounted amplifiers, (b) Passive shielded setup connected to the system through the switch tool, and (c) Fan-shaped cable arrangement

- Three types of measurement setup as listed in Table 1 were considered
- 11 electrodes with 1 m spacing
- sEIT measurements were carried out using a skip-6 scheme (i.e. 1-8, …, 11-7) for current injection in the frequency range from 1 Hz to 10 kHz

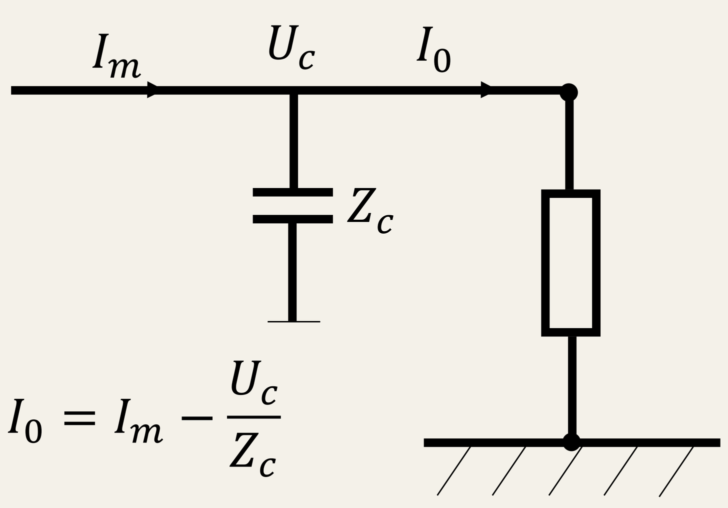
Table 1. Three types of measurement setup

| Measurement setups | Capacitive coupling | Position of amplifier | Schematic diagram |
|---|---|---|---|
| Active (Reference) | Wire-to-shield (I) Shield-to-ground | Distributed at electrodes |  |
| Passive shielded | Wire-to-shield(I&U) Shield-to-ground | Centralized near the system |  |
| Passive non-shielded | Wire-to-wire Wire-to-ground | Centralized near the system |  |

- Correction methods for measurements with coaxial cables including active setup and passive shielded setup are presented below

**Active measurements:**

Step-1: Correction of currents




$$I_0 = I_m - \frac{U_c}{Z_c}$$

Step-2: Correction using FEM modelling

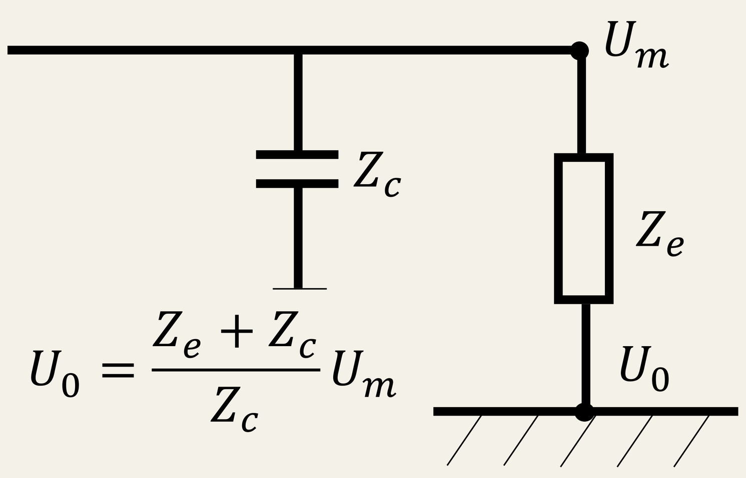
$$(Y_s + iY_c)U = I_s + iI_L$$

(Wang et al., 2024)

**Passive shielded measurements:**

Step-1: Correction of currents
Same as active measurement

Step-2: Correction of voltages
Requires information on $Z_e$




$$U_0 = \frac{Z_e + Z_c}{Z_c} U_m$$

- Estimation of contact impedances

**Method-1:**

Invert two-point impedance measurements

$$\begin{bmatrix}1 & \cdots & 1 & \cdots \\ \vdots & \cdots & \vdots & \cdots \\ \cdots & 1 & \cdots & 1\end{bmatrix}\begin{bmatrix}Z_{e\_1}\\ \vdots \\ Z_{e\_11}\end{bmatrix} = \begin{bmatrix}\frac{U_{1-8}}{I_s}\\ \vdots \\ \frac{U_{11-7}}{I_s}\end{bmatrix}$$

**Method-2:**

Use mean of recorded potentials to represent the ground potential

$$Z_{e\_i} = \frac{U_{c\_i} - mean(\boldsymbol{U_{m\_j}})}{I_{c\_i}}$$

$i$: electrode number used for current injection
$j$: electrode number used for potential record

## Results

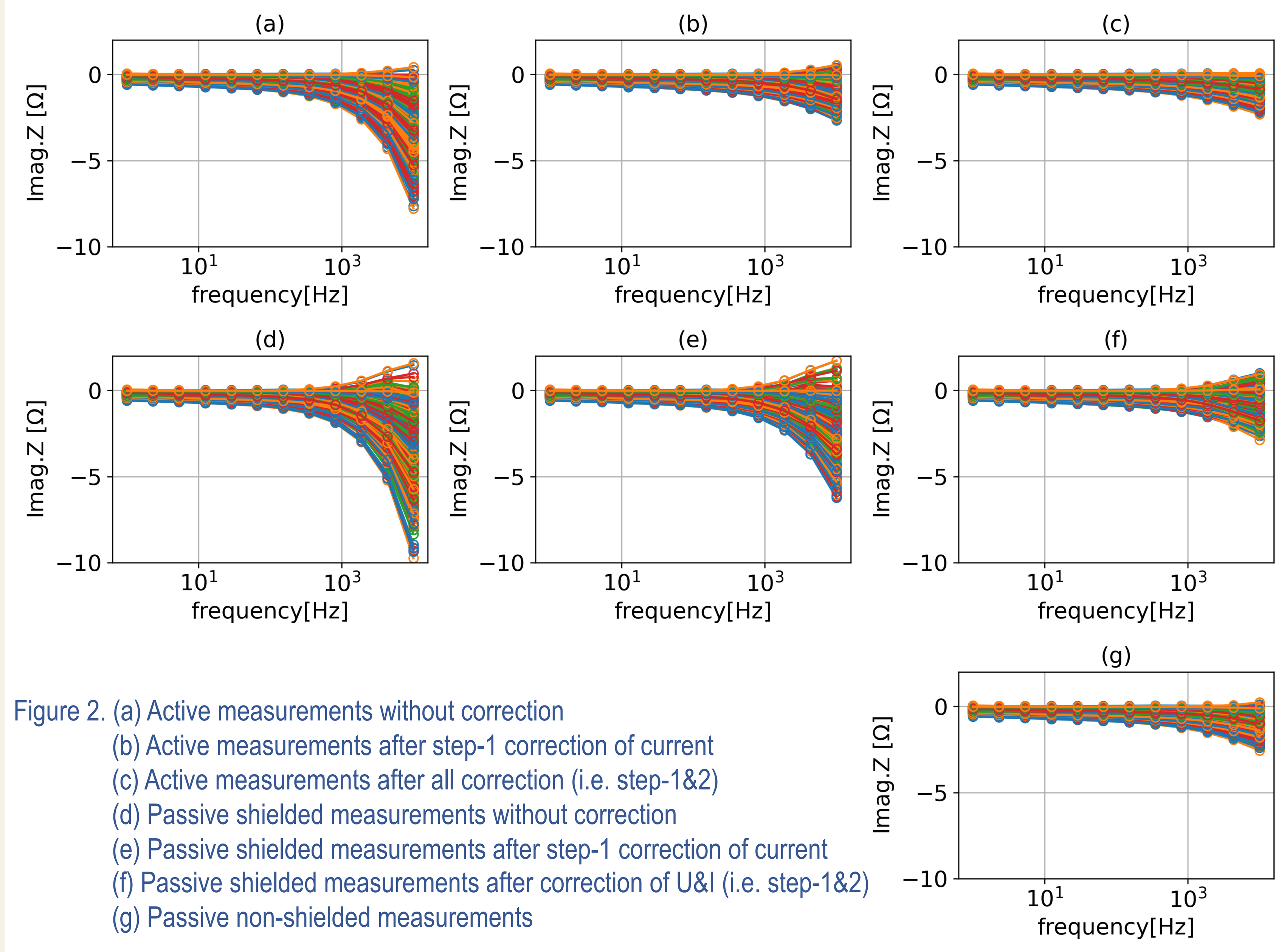



Figure 2. (a) Active measurements without correction
(b) Active measurements after step-1 correction of current
(c) Active measurements after all correction (i.e. step-1&2)
(d) Passive shielded measurements without correction
(e) Passive shielded measurements after step-1 correction of current
(f) Passive shielded measurements after correction of U&I (i.e. step-1&2)
(g) Passive non-shielded measurements

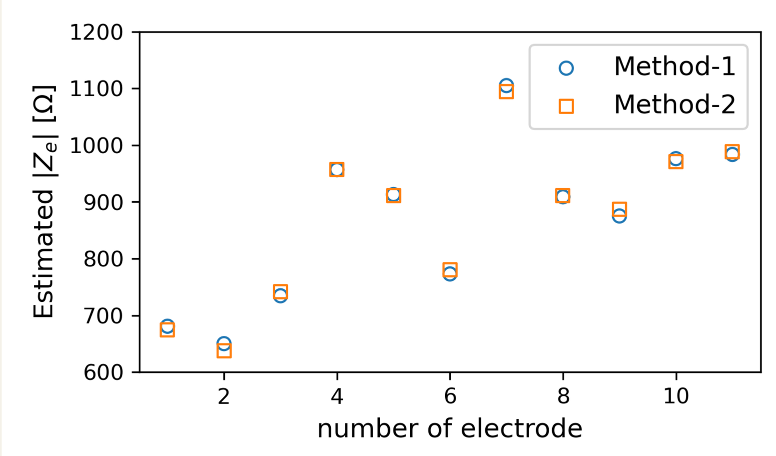



Figure 3. Estimated electrode impedances using two different methods

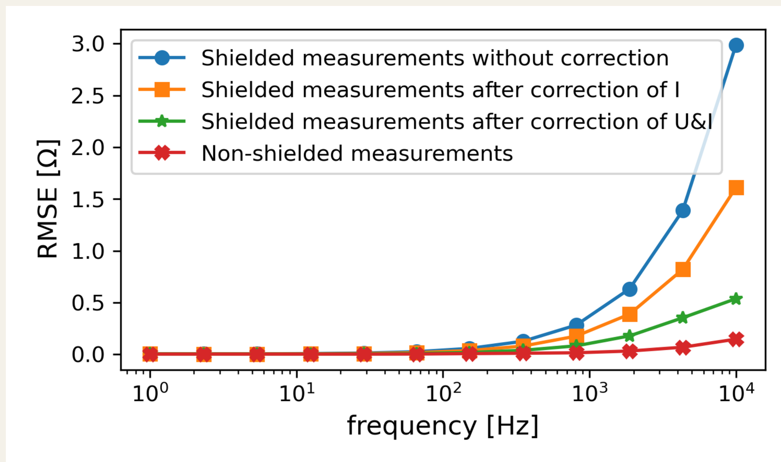



Figure 4. RMSE of different datasets reference to active measurements

- Improvement can be observed after each step of correction for both active and passive shielded measurements.
- Passive non-shielded measurements presented insignificant capacitive coupling because wires were largely separated with the use of the fan-shaped cable layout and lifted in the air by the lush grass in the field.

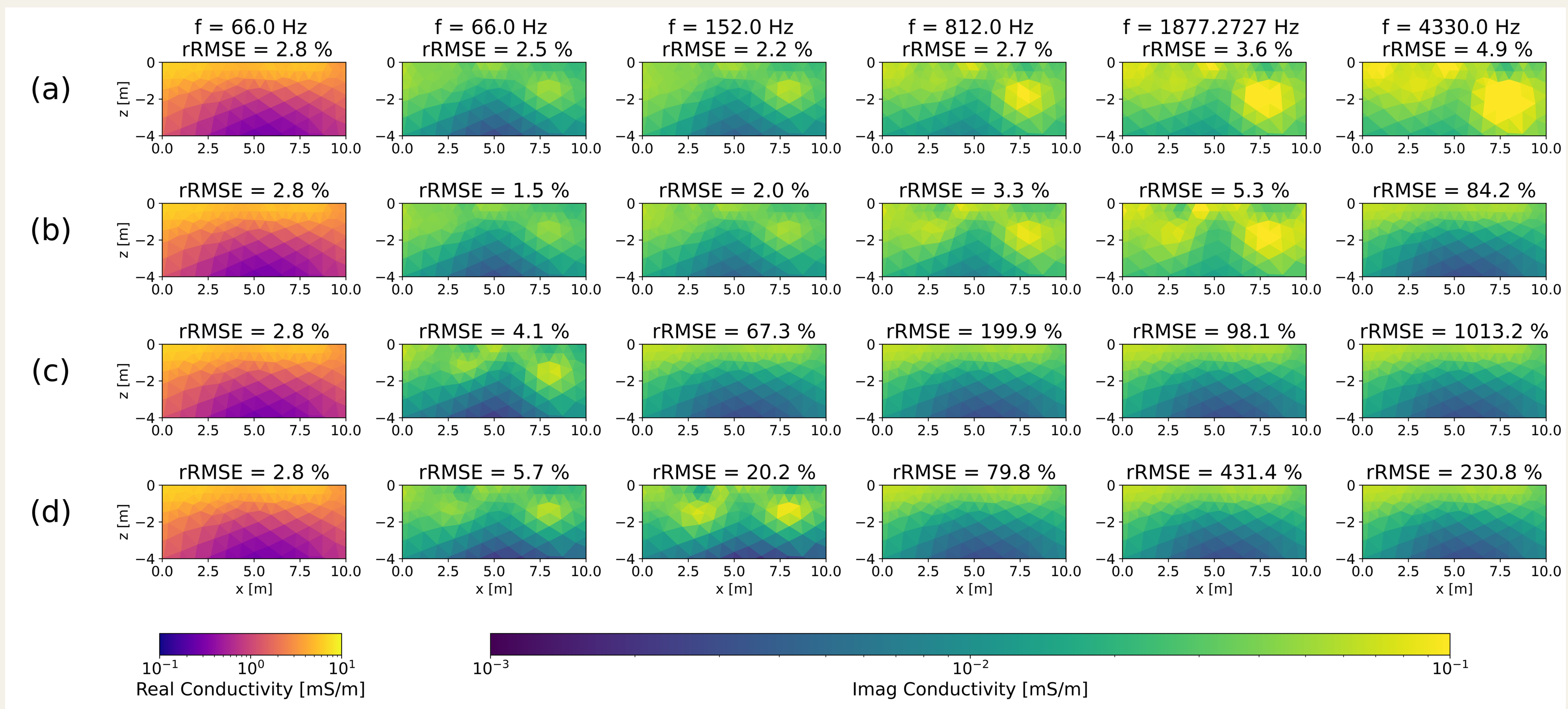



Figure 5. Inversion results of (a) Reference active measurements, (b) Passive non-shielded measurements, (c) Passive shielded measurements without correction, and (d) Passive shielded measurements after all correction

## Summary and outlook

- sEIT measurements acquired using a centralized multiplexer were compared with measurements acquired using distributed amplifiers.
- Correction methods were developed for measurements obtained using coaxial cables and a centralized multiplexer.
- Measurements using non-shielded cables showed good data quality compared to reference active measurements because wires are well separated by the fan-shaped cable layout and lifted in the air by the lush grass in the field.
- Implementing different types of capacitive coupling and electrode impedance in 3D modelling would allow for more advanced analyses and corrections.

## References

Wang, H., Huisman, J.A., Zimmermann, E. and Vereecken, H., 2024. Tackling capacitive coupling in broadband spectral electrical impedance tomography (sEIT) measurements by selecting electrode configurations. Geophysical Journal International, p.ggae154.
Zimmermann, E., Kemna, A., Berwix, J., Glaas, W. and Vereecken, H., 2008. EIT measurement system with high phase accuracy for the imaging of spectral induced polarization properties of soils and sediments. Measurement Science and Technology, 19(9), p.094010.