Determination of near-surface apparent resistivity by means of high frequency mutual impedance measurements

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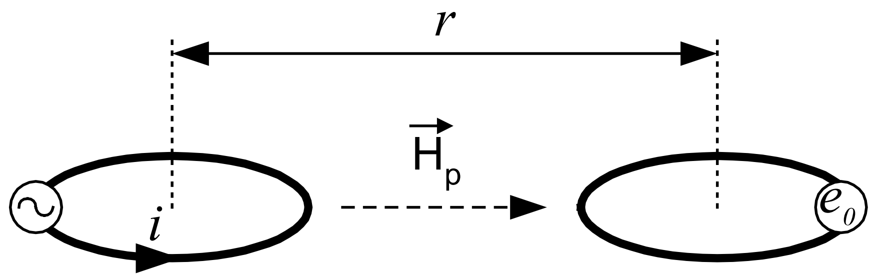
Presentation topics

- Introduction
- Choice of operating frequency
- Measuring System
- Interpretation of measurement results
- Field measurement results
- Conclusions

Introduction

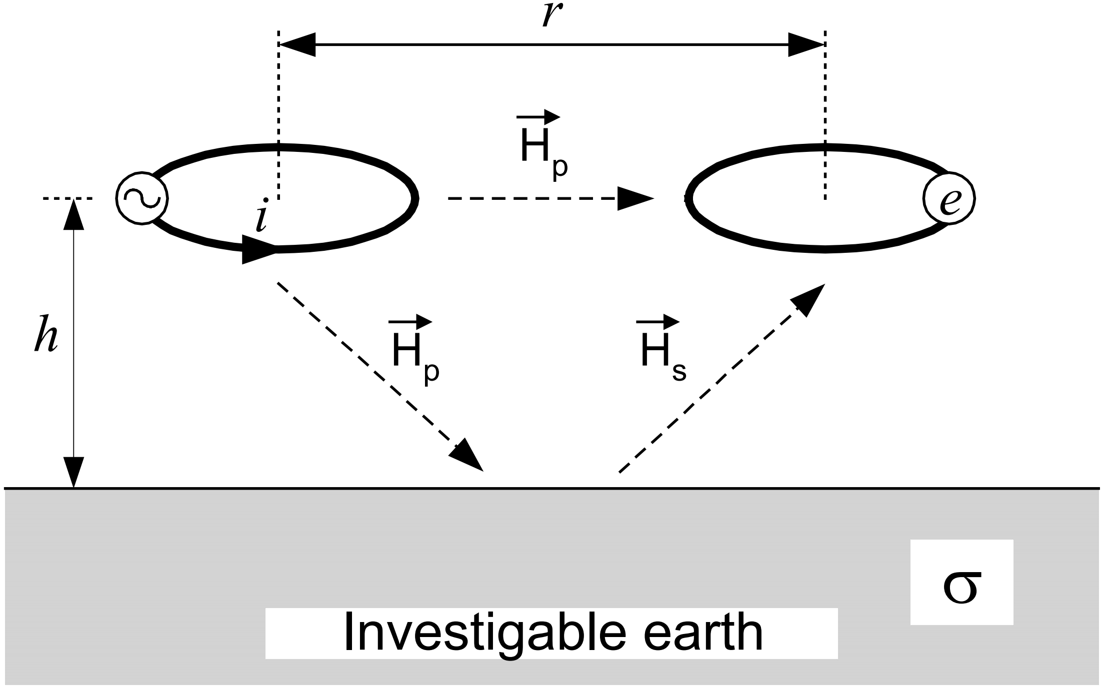
- Mutual impedance concept



In free space: $Z_0 = \frac{e_0}{i}$

Introduction

- Mutual impedance concept



In free space: $Z_0 = \frac{e_0}{i}$

In the presence of earth:

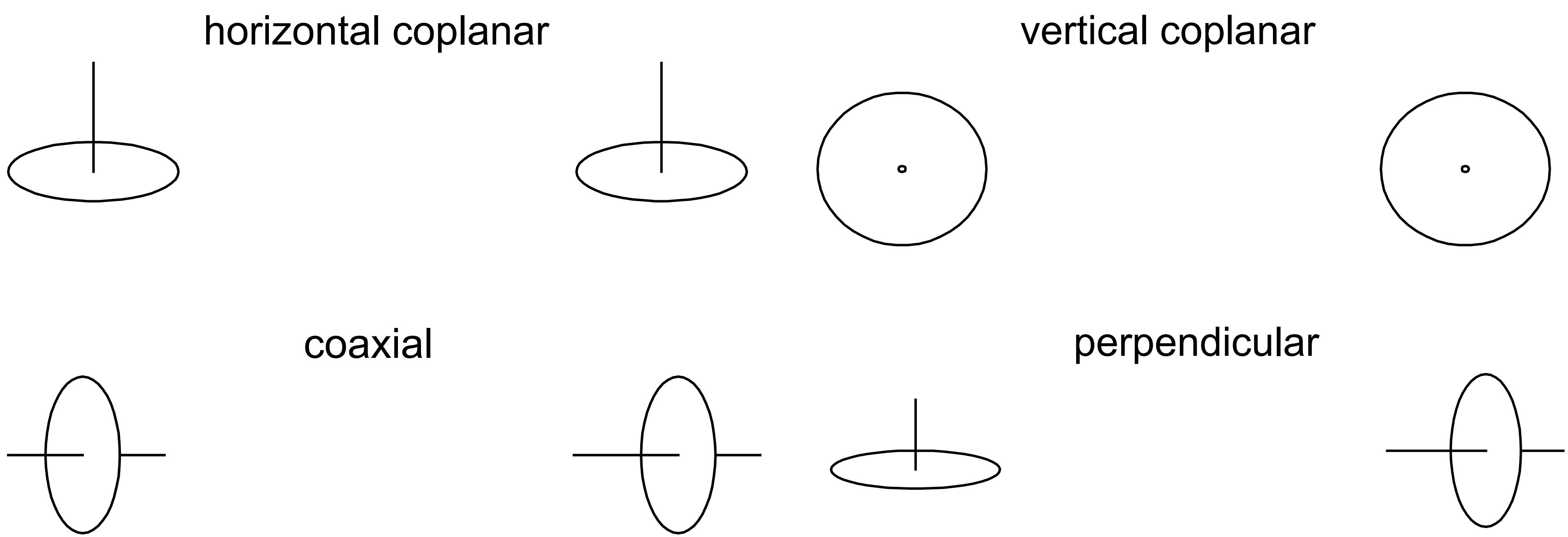
$$Z = \frac{e}{i}$$

Normalized mutual impedance:

$$\frac{Z}{Z_0} = \frac{\vec{H}_p + \vec{H}_s}{\vec{H}_p} = f(h, r, \omega, \sigma)$$

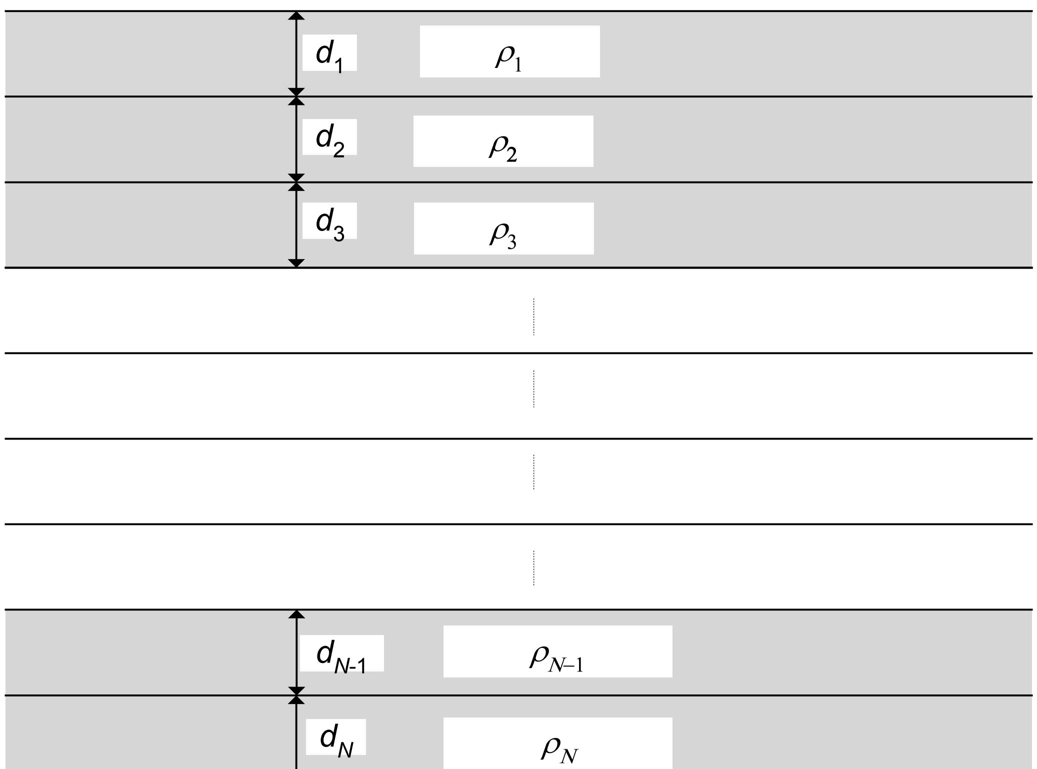
Introduction

- Antennas configuration



Introduction

- Concept of apparent resistivity



Definition:

$$\rho_a = f(\rho_1, \rho_2, .., \rho_m, d_1, d_2, .., d_m)$$

Conductivity and resistivity:

$$\rho_a = \frac{1}{\sigma_a}$$

Choice of operating frequency

- Sensitivity of mutual impedance function
- Neglecting displacement current

Choice of operating frequency

- Sensitivity of mutual impedance function

model

ρ_1, $d_1 = 1[m]$

$\rho_2 = \rho_1 \pm 0.1\rho_1$, $d_2 = 0.1[m]$

$\rho_3 = \rho_1$

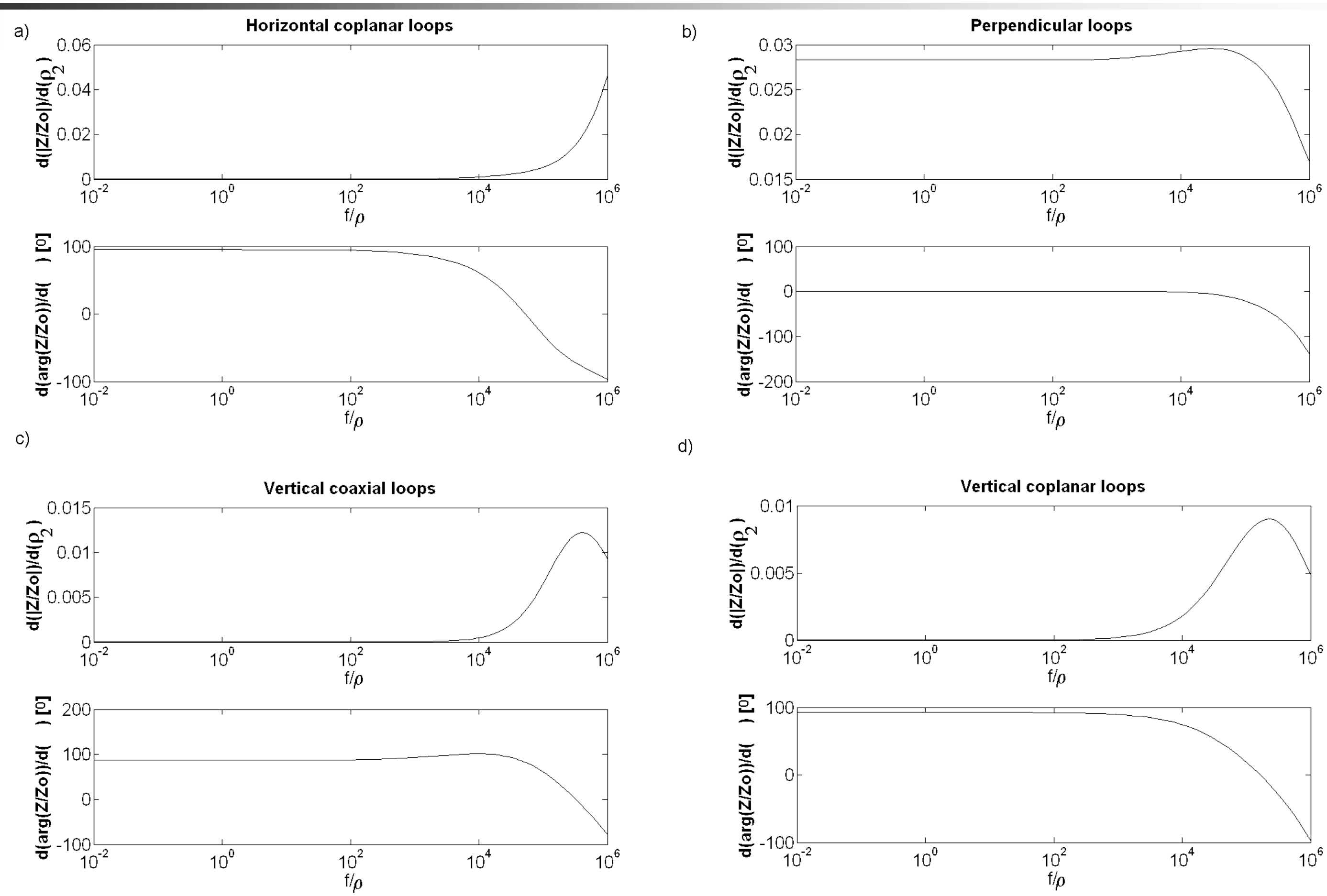
Sensitivity:

$$S = \frac{\sigma_2}{Z/Z_0} \frac{d(Z/Z_0)}{d\sigma_2}$$

Antennas: r = 5m, h = 1m

$$\rho = (1 \div 100)[\Omega m]$$

Choice of operating frequency



Sensitivity of mutual impedance as a function of frequency

Choice of operating frequency

- Neglecting displacement current

Wave number: $\gamma^2 = \omega^2 \mu_0 \varepsilon_r \varepsilon_0 - i\omega\mu_0\sigma = \alpha - i\beta$

Conducting - displacement current ratio: $\dfrac{\alpha}{\beta} = \dfrac{\omega\varepsilon_0\varepsilon_r}{\sigma} = \omega\varepsilon_0\varepsilon_r\rho$

Maximum influence of displacement current - 5%.

For typical ground parameters: $\varepsilon_r = 10 \;\; \rho = 100[\Omega m]$

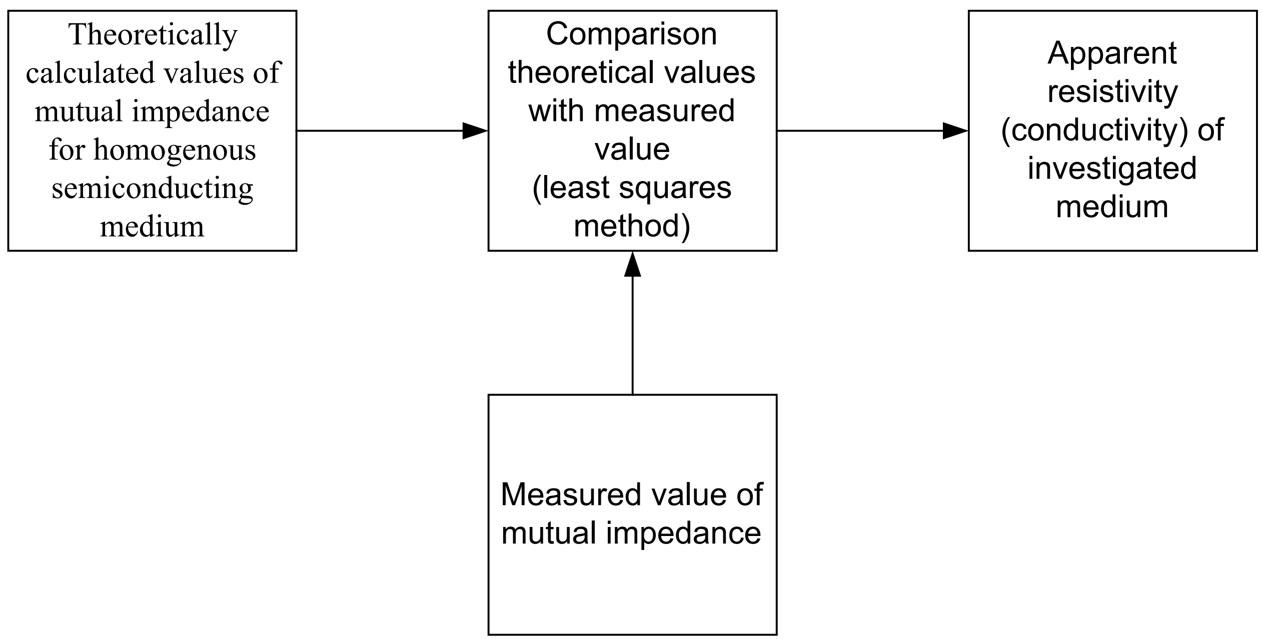
Maximum frequency: $f_{\max} = \dfrac{0.05}{2\pi\varepsilon_0\varepsilon_r} = 898kHz$

Measuring System

Parameters of the System:

- source magnetic moment: 0.17 - 3.6 [Am^2]
- receaving antenna diameter: 0.5 [m]
- elevation: 0.5 [m]
- loop antennas separation: 2 – 6 [m]
- measurements for any configuration of antennas
- measuring step: 0.05 – 1.6 [m]

Interpretation of measurement results



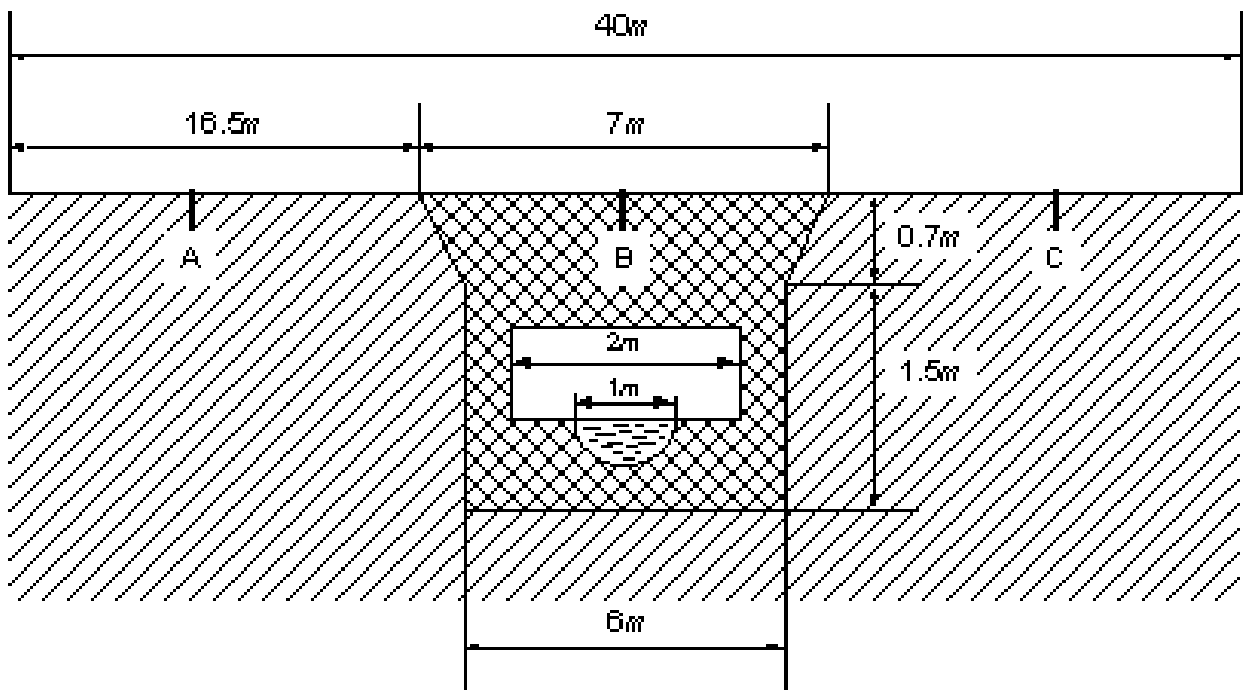
Block diagram of interpretation method

Field measurement results

Case History 1 – two section the embankment of Odra River with a culvert, Poland

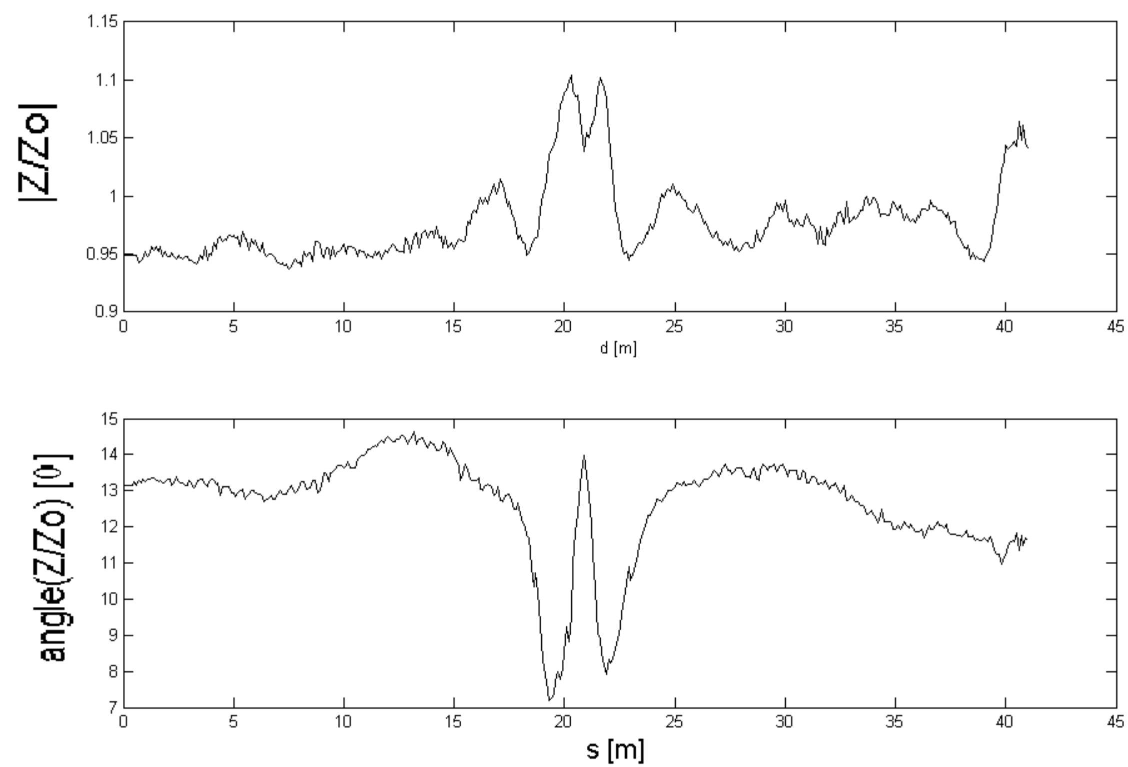
EM method: coplanar horizontal, antennas separation 2 [m], measuring step 0.05 [m]

Field measurement results



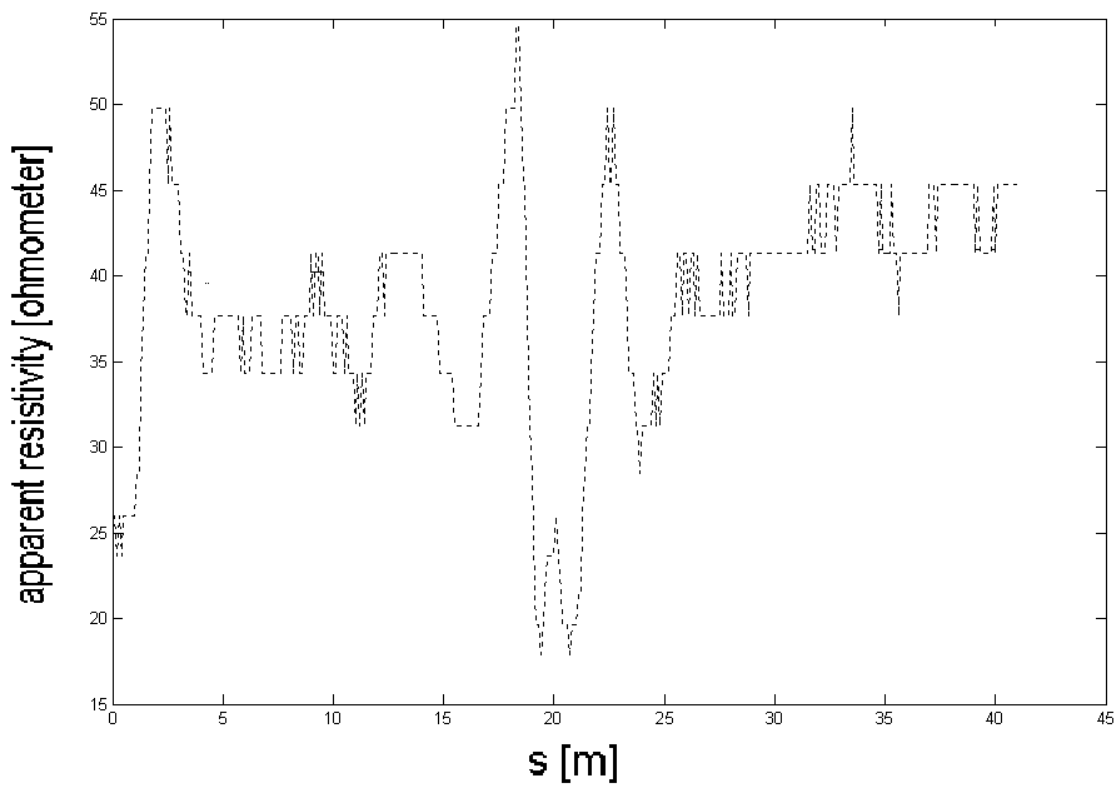
Sketch of investigated section of the Odra River's levee in Wrocław, Poland

Field measurement results



Measured curves of absolute value and phase of mutual impedance

Field measurement results



Traces of apparent resistivity obtained by mutual impedance and galvanic resistivity measurements

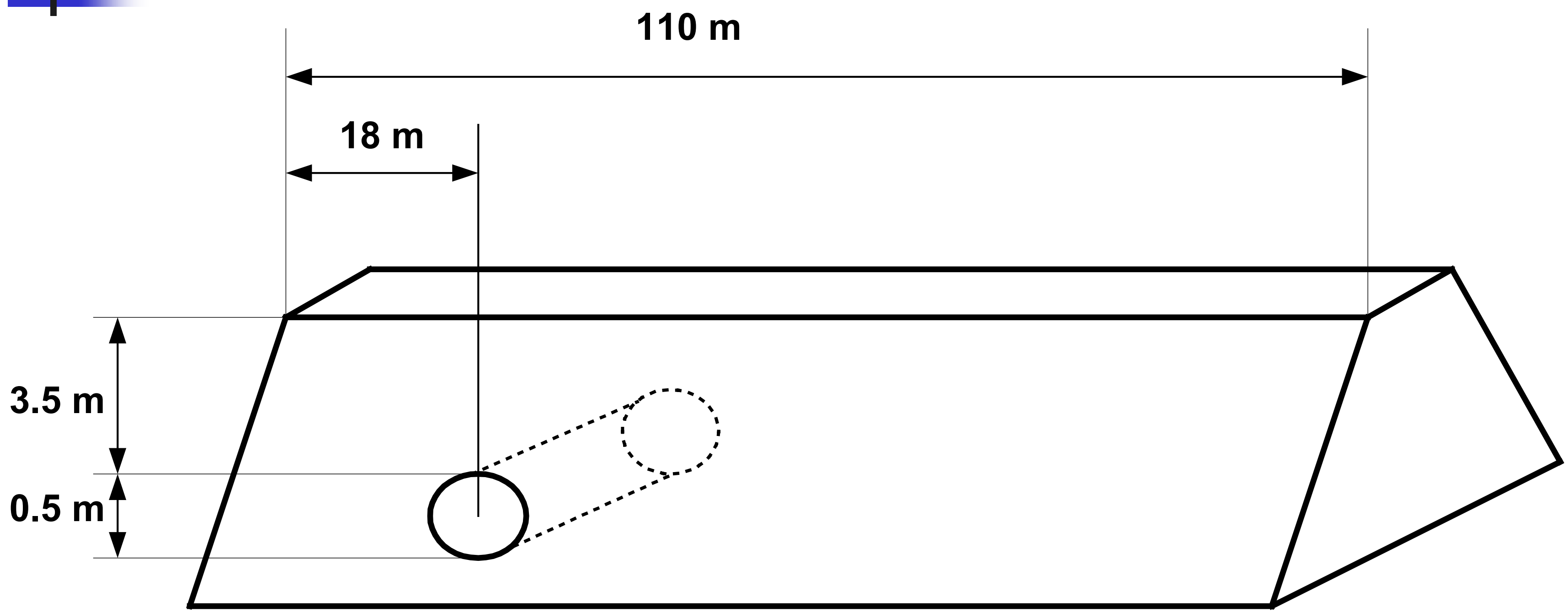
Field measurement results

Case History 2 – section the embankment with pipe culvert, Bystrzyca River, Poland

EM method:

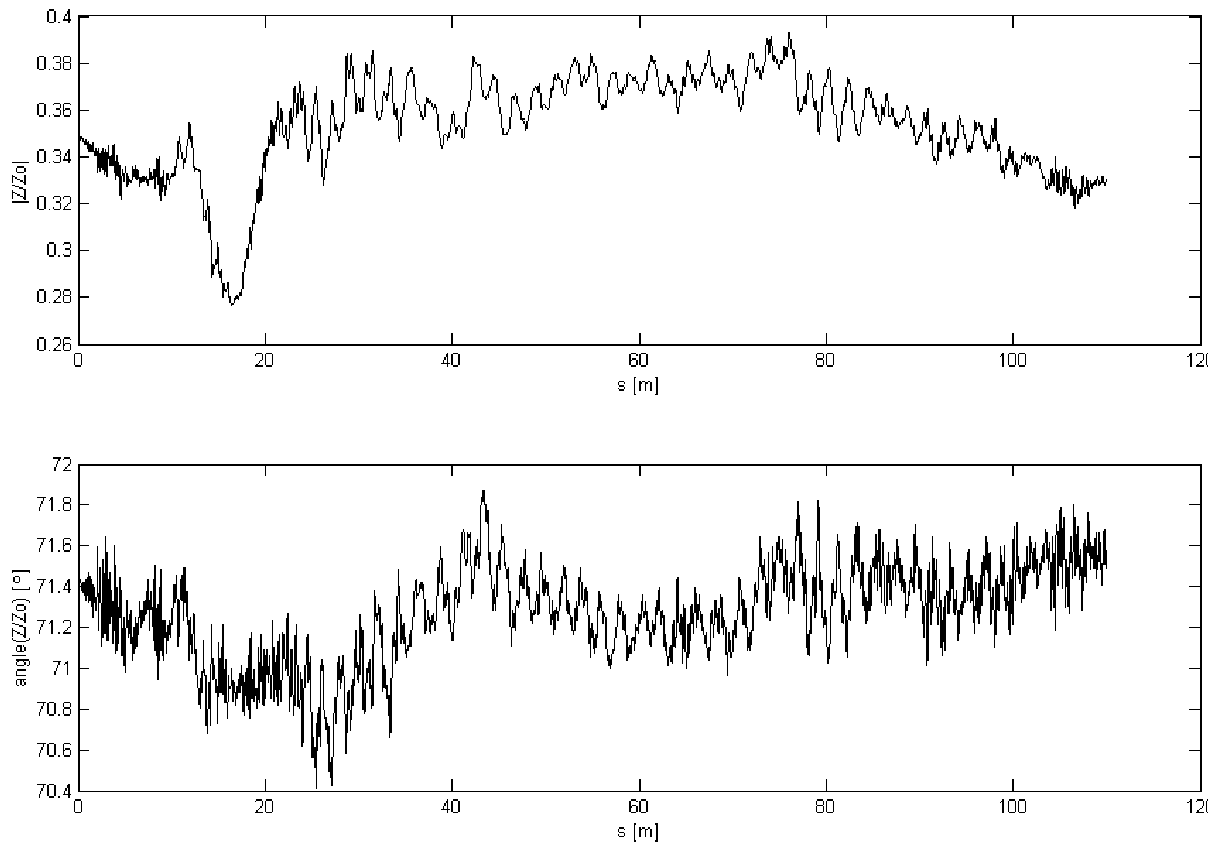
- **perpedicular loops, antennas separation 6 [m], measuring step 0.05 [m]**

Field measurement results



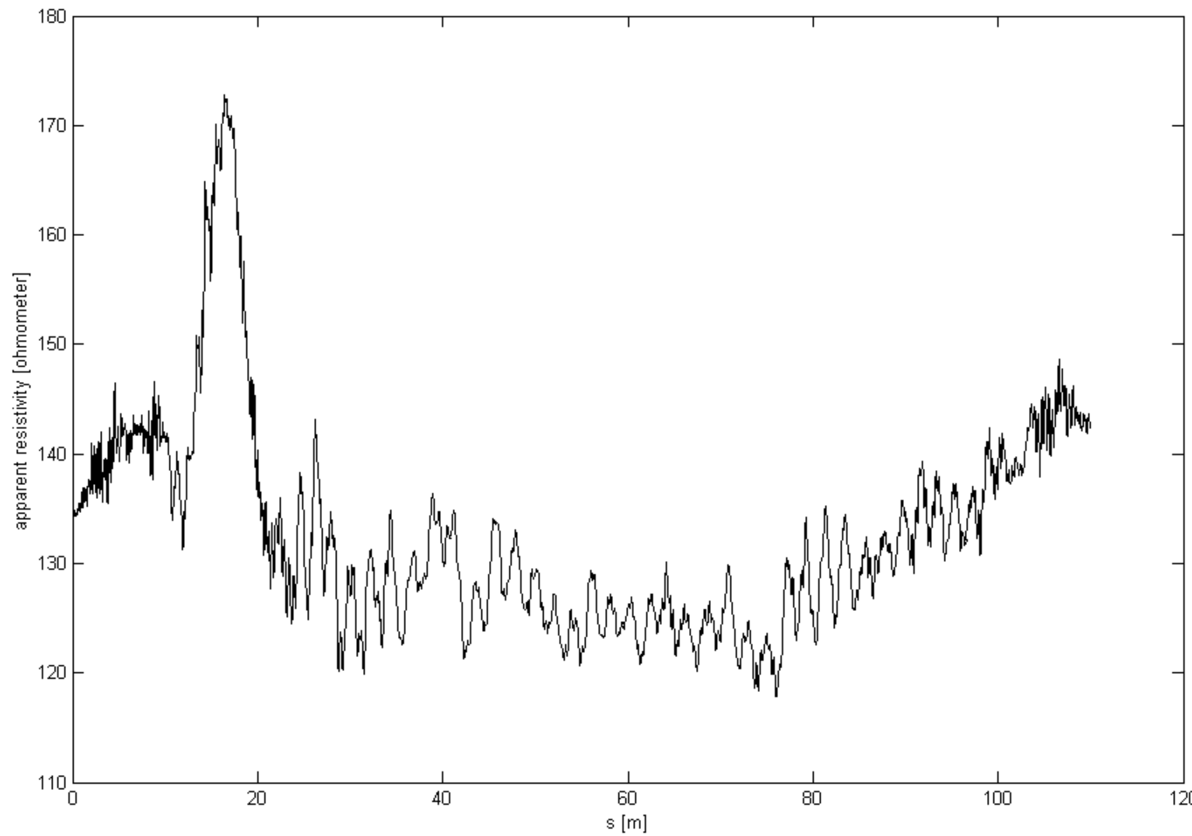
Location plan of measured embankment section

Field measurement results



Measured curves of absolute value and phase of mutual impedance

Field measurement results



Traces of apparent resistivity obtained by mutual impedance measurements

Conclusions

Advantages of described method :

- high speed of carrying out measurements
- noninvasive mesurements
- Application: embankments examination, road building a.s.o.

Thank you for your attention