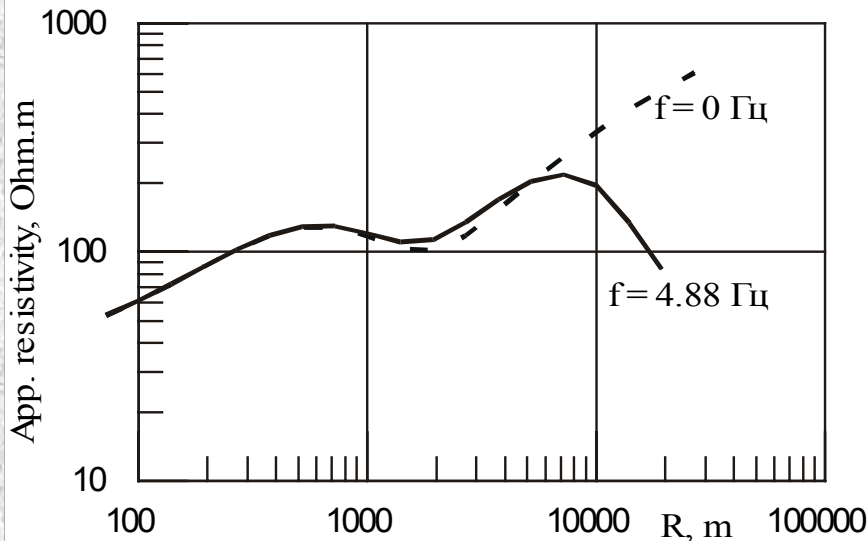
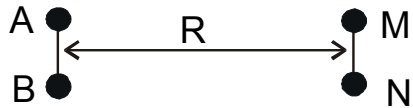


# Low-frequency non-contact resistivity method

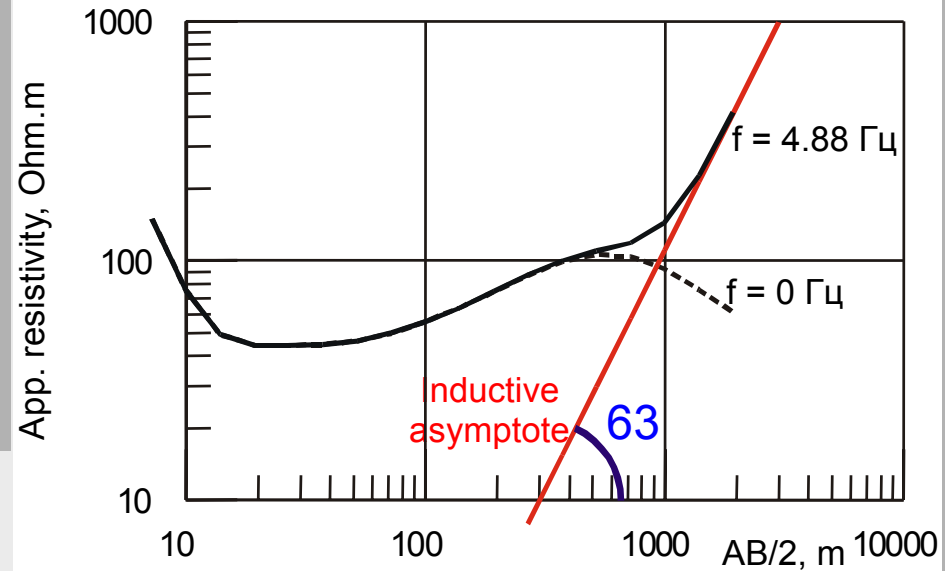
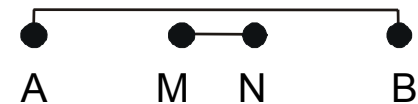
1. Low frequency AC field
2. Inductive coupling effect
3. Non-contact measurements
4. Theory of electrical field in the air

# Low frequency AC field

dipole-dipole

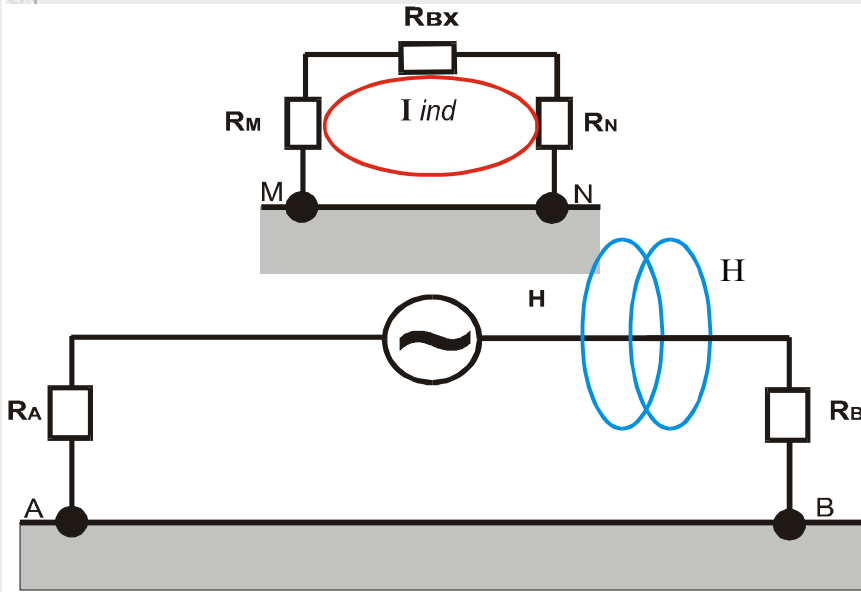


Schlumberger array

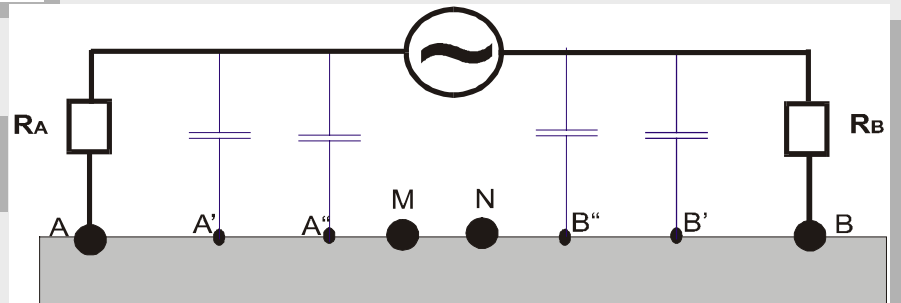


# EM effects concerned with wires

Inductive coupling effect

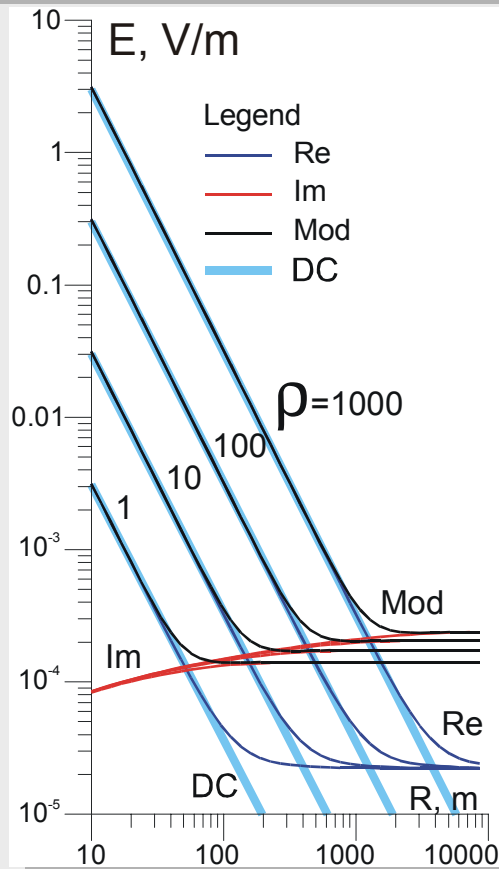


Capacity leakage

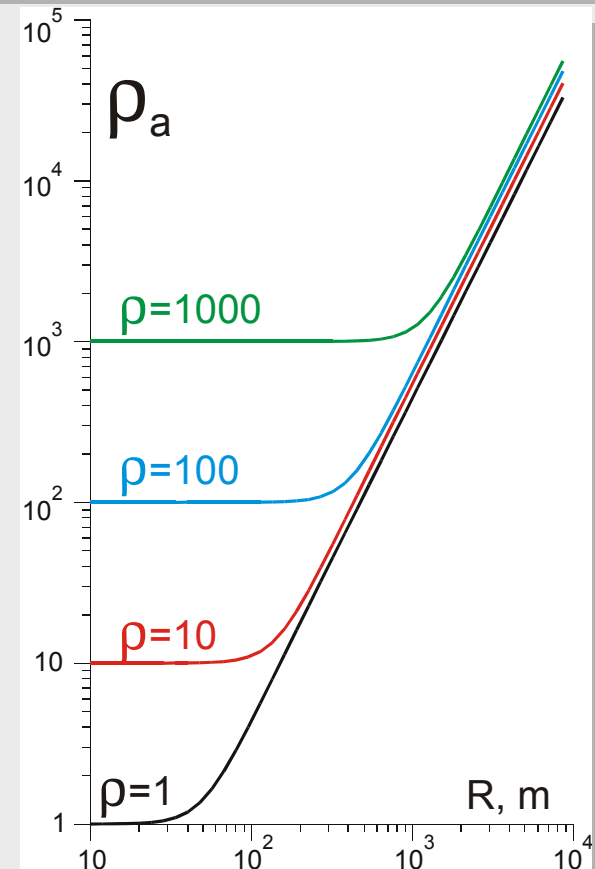


# Dependence of inductive asymptote from resistivity of ground ( $f = 4.88 \text{ Hz}$ )

Changes of Re, Im,  $E_x$  AC modulus and  $E_x$  DC from AB/2 spacing for Schlumberger array.



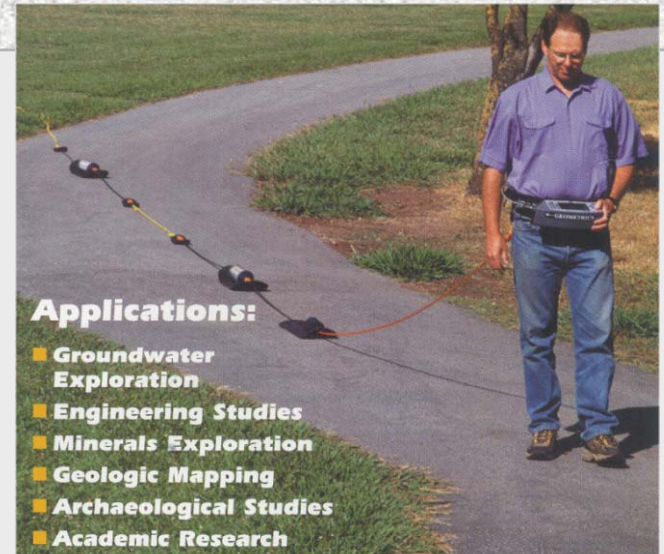
Dependence of inductive asymptote's position from halfspace resistivity for modulus  $E_x$ .



# Non-contact measurements



**OhmMapper**  
**f=16.5 kHz**



## Applications:

- Groundwater Exploration
- Engineering Studies
- Minerals Exploration
- Geologic Mapping
- Archaeological Studies
- Academic Research

*Iris Instruments*

**Corim, f=12 kHz**

**CONTINUOUS ELECTRICAL PROFILING**



## CORIM, CONTINUOUS ELECTRICAL PROFILING SYSTEM

- Set of carpets pulled on the surface of the ground
- 1 transmitting dipole, 6 receiving dipoles, 1 m spacing
- Continuous measurement of impedance at 12 kHz frequency
- Pseudo section of apparent resistivity, underground imaging
- Logging speed from 0.5 to a few km/h depending on field conditions
- Depth of investigation down to 3-5 m
- **Applications:** subsurface investigation for trench layout, soil studies, etc.

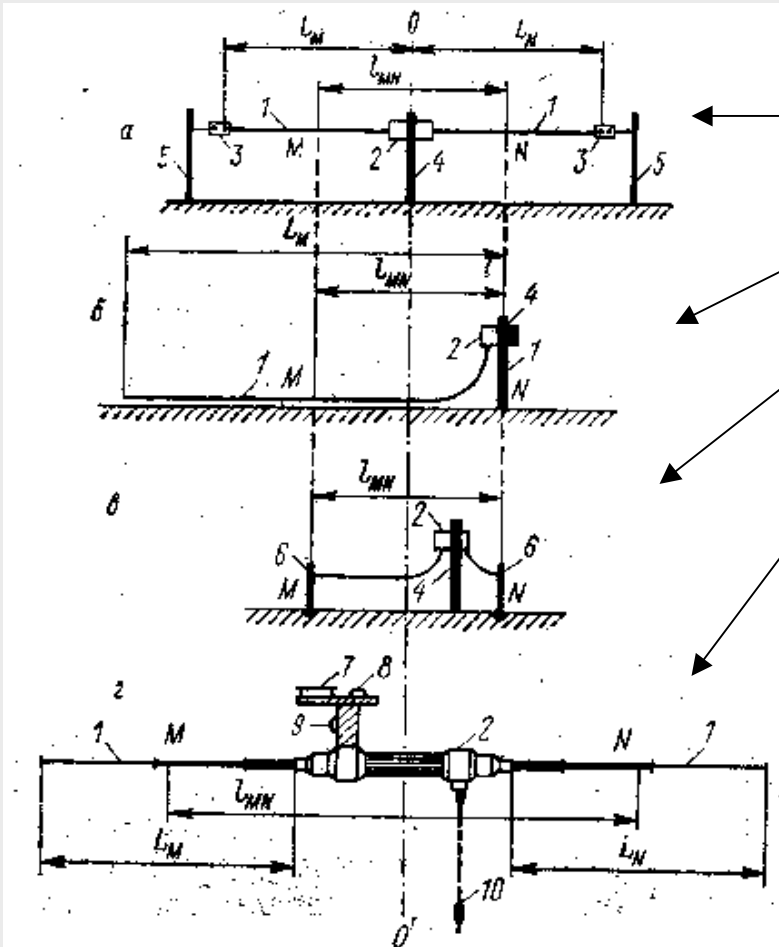
# ERA equipment, $f=625\text{Hz}$



# Types of source

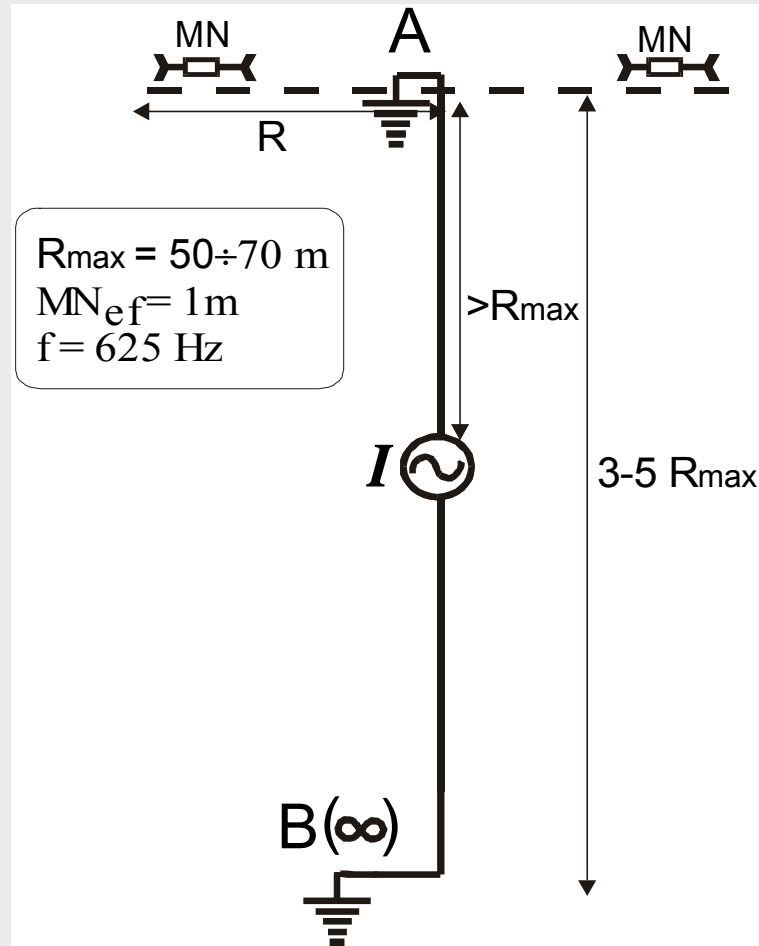
- Classical galvanic grounding
- Capacity electrode with big area
  - flat electrode
  - long wire
- Non grounded loop

# Types of receiver



- Antenna (wire)
- Long wire + operator
- Grounded electrodes
- Antenna
- Active electrodes with high input impedance ( $\sim 50\text{G}\Omega\cdot\text{m}$ )

# Array for non-contact soundings



# Limits of maximal resistance for electrodes

## **Current electrodes**

Minimal suitable current

## **Potential electrodes**

Maximal input impedance of receiver

# Theory of electrical field in the air

$$\begin{aligned}\operatorname{rot} \mathbf{H} &= (\sigma - i\omega\epsilon\epsilon_0)\mathbf{E} \\ \operatorname{rot} \mathbf{E} &= i\omega\mu\mathbf{H}\end{aligned}$$

$$\begin{aligned}\mathbf{E}_{ind} &= i\omega\mu\mathbf{A} \\ \mathbf{E}_q &= -\operatorname{grad} U\end{aligned}$$

$$\begin{aligned}\mathbf{H} &= \operatorname{rot} \mathbf{A} \\ \mathbf{E} &= i\omega\mu\mathbf{A} - \operatorname{grad} U\end{aligned}$$

$$\begin{aligned}\mathbf{E} &\approx \mathbf{E}_q \\ \operatorname{div}(\sigma - i\omega\epsilon\epsilon_0)\operatorname{grad} U &= 0\end{aligned}$$

$$\operatorname{div} \mathbf{A} = 0$$

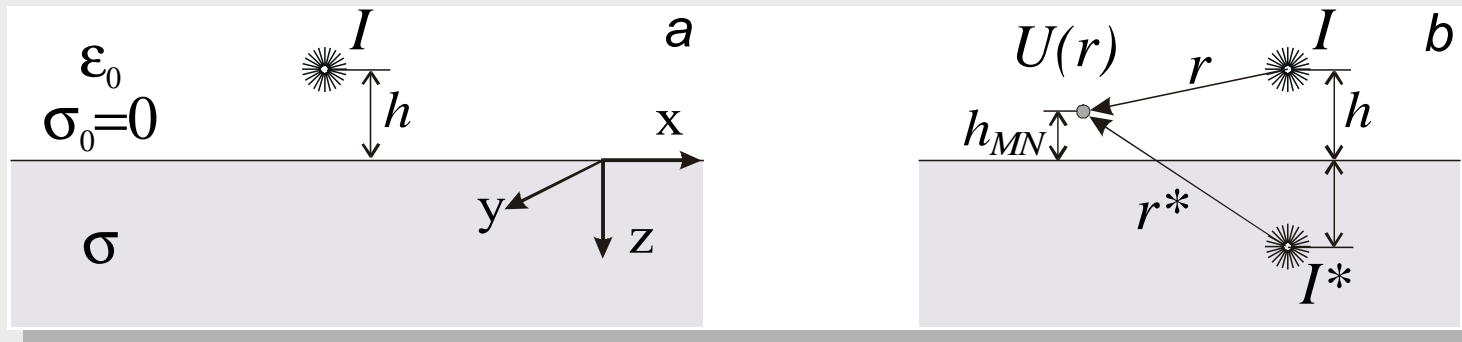
# Complex resistivity

$$\mathbf{E} \approx \mathbf{E}_q$$
$$\operatorname{div}(\sigma - i\omega\epsilon\epsilon_0) \operatorname{grad} U = 0$$

$$\epsilon_0 = 9e^{-12}$$

f, Hz	4.88	625	15000
Resistivity of the air	3.7 GOhm.m	29 MOhm.m	1.2 MOhm.m

# Field of static electrode

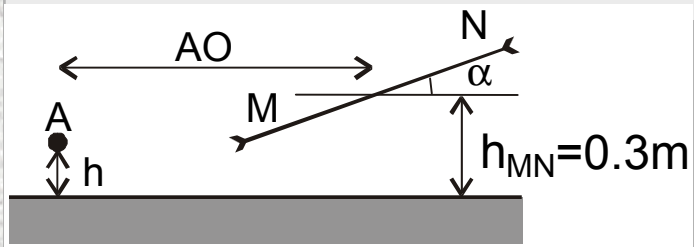


$$U_0(r) = \frac{1}{4\pi r} \frac{I}{\hat{\sigma}} = \frac{1}{4\pi r} \frac{I}{i\omega\epsilon_0}$$

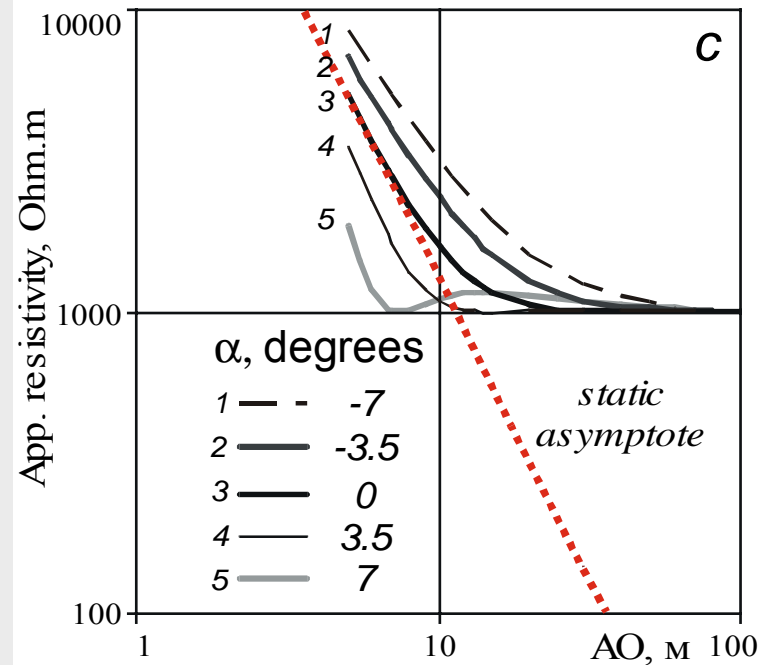
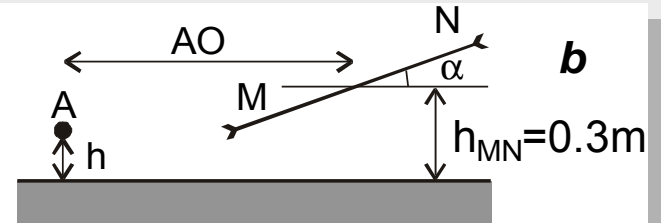
$$K_{12} = \frac{-(\omega\epsilon_0)^2 + \sigma^2 - 2i\omega\epsilon_0\sigma}{-(\omega\epsilon_0)^2 - \sigma^2} \approx \frac{\sigma^2 - 2i\omega\epsilon_0\sigma}{-\sigma^2} = \frac{2i\omega\epsilon_0}{\sigma} - 1$$

$$\begin{cases} U(r) = \frac{I}{i\omega\epsilon_0} \left( \frac{1}{4\pi r} + K_{12} \frac{1}{4\pi r^*} \right) \approx \frac{I}{2\pi r^* \sigma} + i \frac{I}{\omega\epsilon_0 4\pi} \left( \frac{1}{r} - \frac{1}{r^*} \right), & z \leq 0, \\ U(r) = \frac{I}{i\omega\epsilon_0} \frac{1}{4\pi r} (1 + K_{12}) \approx \frac{I}{2\pi r \sigma}, & z \geq 0. \end{cases}$$

# Electrostatic asymptote



$h = 5\text{ mm}, f = 625\text{ Hz}$



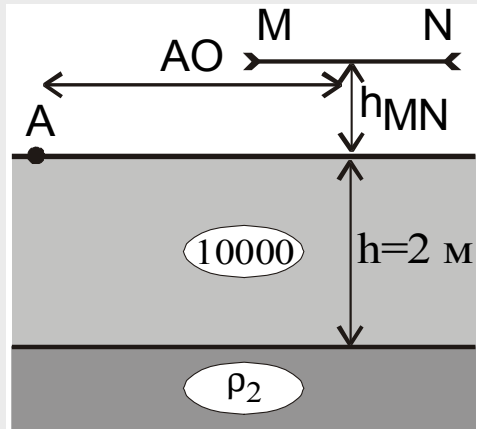
# Electrical field in the air from grounded electrode

Halfspace:

$$U(r) = \frac{I}{\sigma} \frac{1}{4\pi r} (1 + K_{12}) \approx \frac{I}{2\pi r \sigma} \left( 1 - \frac{i\omega \epsilon_0}{\sigma} \right) \approx \frac{I}{2\pi r \sigma}$$

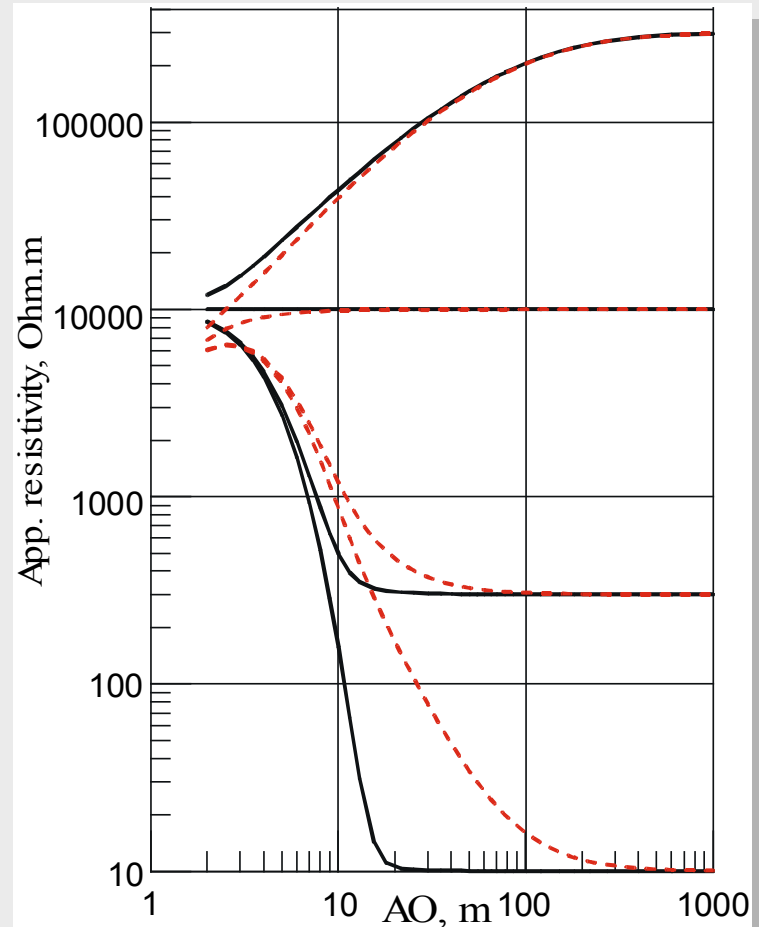
# Electrical field in the air from grounded electrode

2 layers

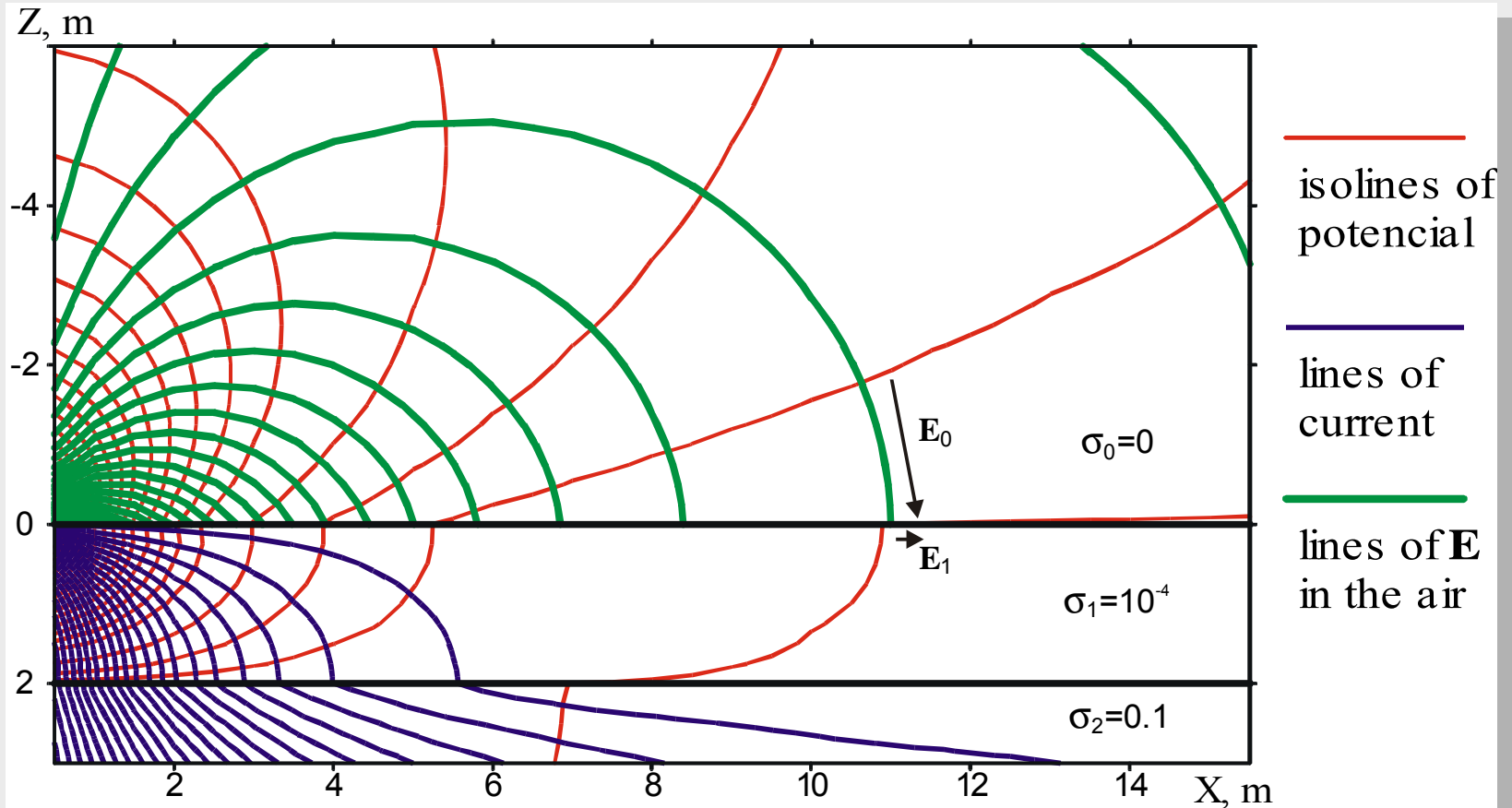


—  $h_{MN}=0$

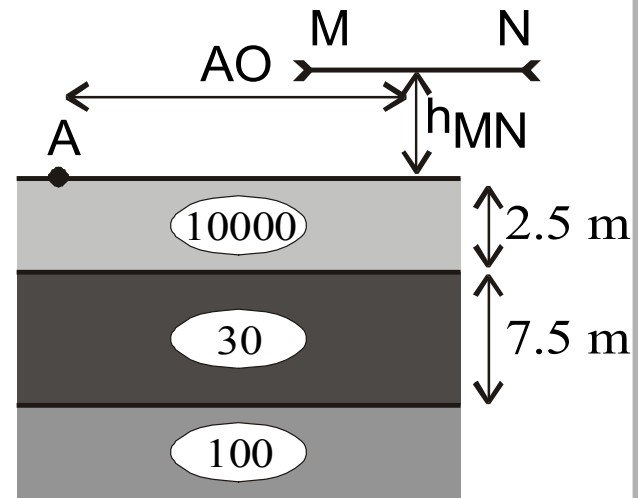
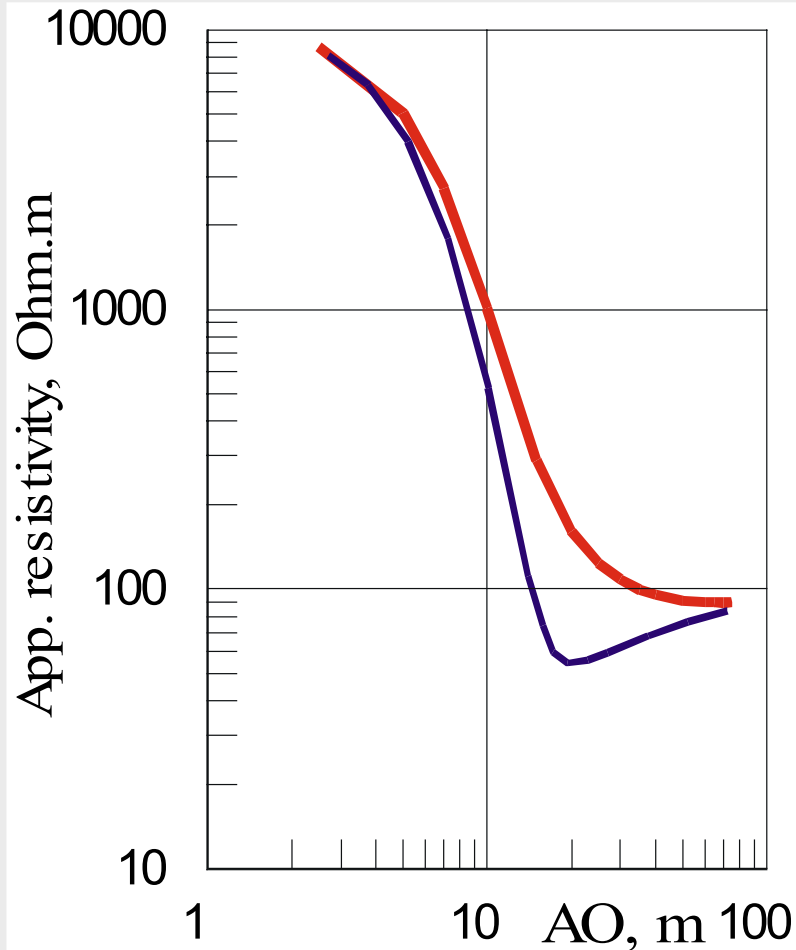
- - -  $h_{MN}=1\text{ M}$



# Structure of electrical field for two-layer model



# Three-layers model



$h_{MN}$ , m

- 0.5
- 0