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Horizontal Long Wire Antenna as an Atmospheric Electrical Instrument

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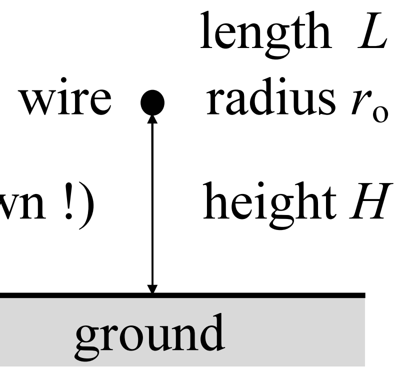
1. **Atmospheric electrical DC antennas**
2. **Geophysical problems**
3. **Technical problems**

Electrostatic model of the antenna



$$\boxed{I = S\, j}$$

(E & j +direction down !)

j

$$I = \iint \vec{j}\, \mathrm{d}\, S = \lambda \iint \vec{E}\, \mathrm{d}\, S = -\lambda Q / \varepsilon_\circ = \lambda EHC / \varepsilon_\circ = \left(HC / \varepsilon_\circ \right) j$$

$\lambda \vec{E}$ $\quad -Q/\varepsilon_\circ$ $\quad -CU$ $\quad S$

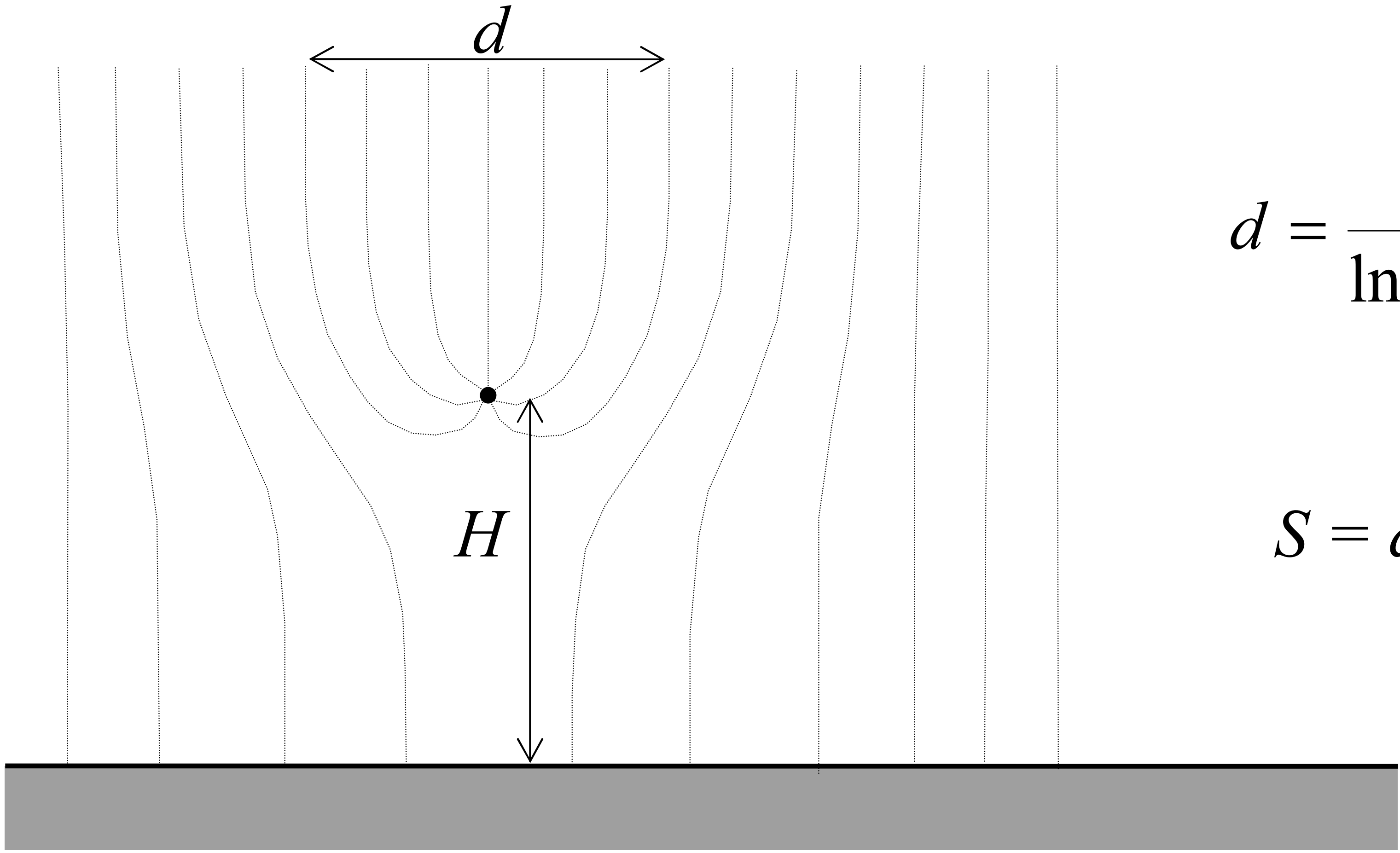
EH

$$C = \varepsilon_\circ \frac{2\pi}{\ln\left(2H/r_\circ\right)} L$$

$$\boxed{S = S_E = \frac{2\pi H}{\ln\left(2H/r_\circ\right)} L}$$

Kasemir, H.W., and L.H. Ruhnke, Antenna problems of measurement of the air-Earth current, in *Recent Advances in Atmospheric Electricity,* edited by L. G. Smith, pp. 137–147, Pergamon, New York, 1959.

"….only one class of ions is effective according to the sign of the field. …… But all the problems concerning the electrode effect …. will not discussed in this paper."



$$d = \frac{2\pi H}{\ln\left(2H/r_{\circ}\right)}$$

$$S = d \times L$$

Example: $H = 1000\ (2r_{\mathrm{o}}) \;\;\Rightarrow\;\; S = (0.76\ H)\ L$

Components of the vertical current and effective areas of an antenna

(fair-weather situation)

Vertical current density $j = j_d + j_\lambda + j_t$

Antenna current $I = I_d + I_\lambda + 0$

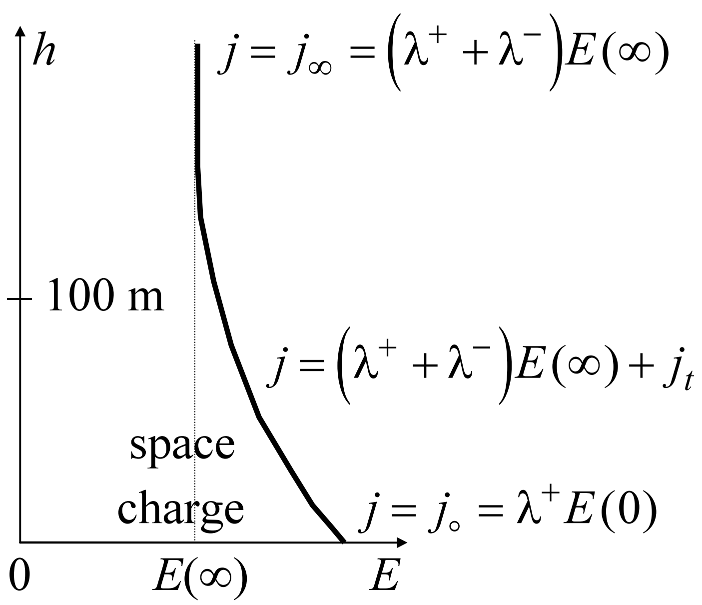
Plain effective area $S = I/j$

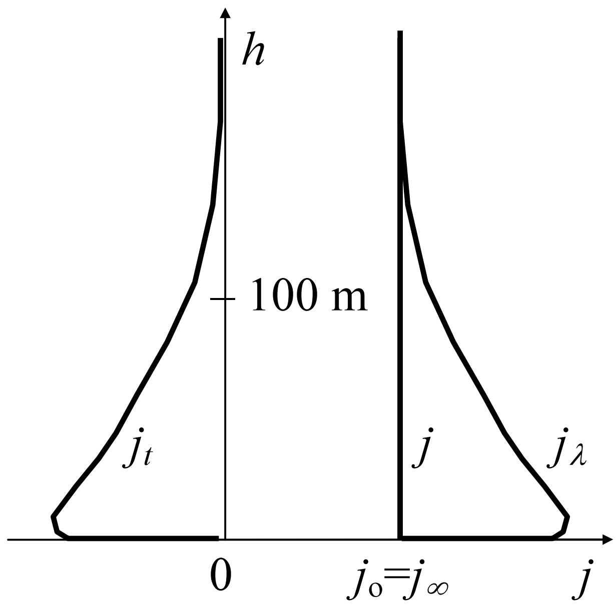
Dynamic effective area $S_d = I_d / j_d$

In case of rapid (compared with $\tau = \varepsilon_\circ/\lambda \approx 500...1000$ s) variations $S_d = S_E$.

Static effective area $S_s = I_\lambda / \left(j_\lambda + j_t\right)$

Origin of j_t $(\partial E/\partial t = 0)$





$j_\circ = j_\infty \quad \Rightarrow \quad E(0) \approx 2E(\infty)$

Static effective area

Classic assumption: $S = S_E \quad \Rightarrow \quad S_s = S_E$

Dolezalek, H., Zur Berechnung des luftelektrischen Stromkreises III: Kontrolle des Ohmschen Gesetzes durch Messung, *Geofis. Pura Appl.*, *46*, 125–144, 1960.

The Wilson plate is expected as a standard instrument when measuring j. Measurements are assumed to be processed according to the classic assumption $j = I / S_E$. j, λ, and E should be simultaneously measured and the conformity of measurements tested according to the Ohm's law $j = E\lambda$. A violation of the Ohm's equation is interpreted as an indication of an important convection current, and/or errors in vertical current measurements.

Rosen, J.M., D.J. Hofmann, W. Gringel, J. Berlinski, S. Michnowski, Y. Morita, T. Ogawa, and D. Olson, Results of an international workshop on atmospheric electrical measurements, *J. Geophys. Res.*, *87*, 1219–1227, 1982.

Vertical current was measured using balloon-borne antennas. Technical measuring errors were low and convection current was negligible. However, $I / S_E \neq \lambda E$, and the disagreement was big, up to twice.

Few, A.A., and A.J. Weinheimer, Factor of 2 in balloon-borne atmospheric conduction current measurements, *J. Geophys. Res.*, *91*, 10,937–10,948, 1986.

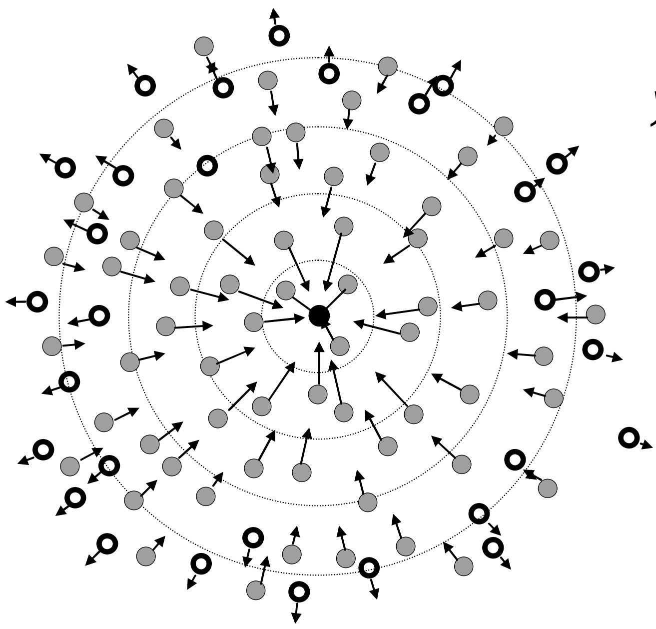
Improved theoretical model and explanation of the results by *Rosen et al.* Explanation: j is determined by $\lambda^+ + \lambda^-$ but I by λ^+ only. Thus the antenna current should be about half as calculated according to the classic model and the data should be processed using the advanced model

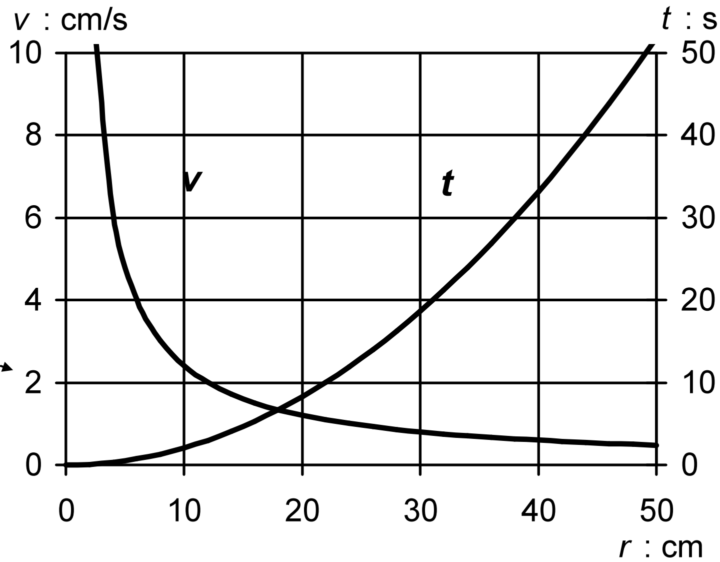
$$j = f \times I / S_E \qquad \text{or} \qquad I = (1/f)\, S_E j\ ,$$

where the factor $f = 2$ for a balloon-borne antenna.

According to our terminology, $f = S_E / S$. {Example 88.08.Dolezalek}

Antenna in calm air



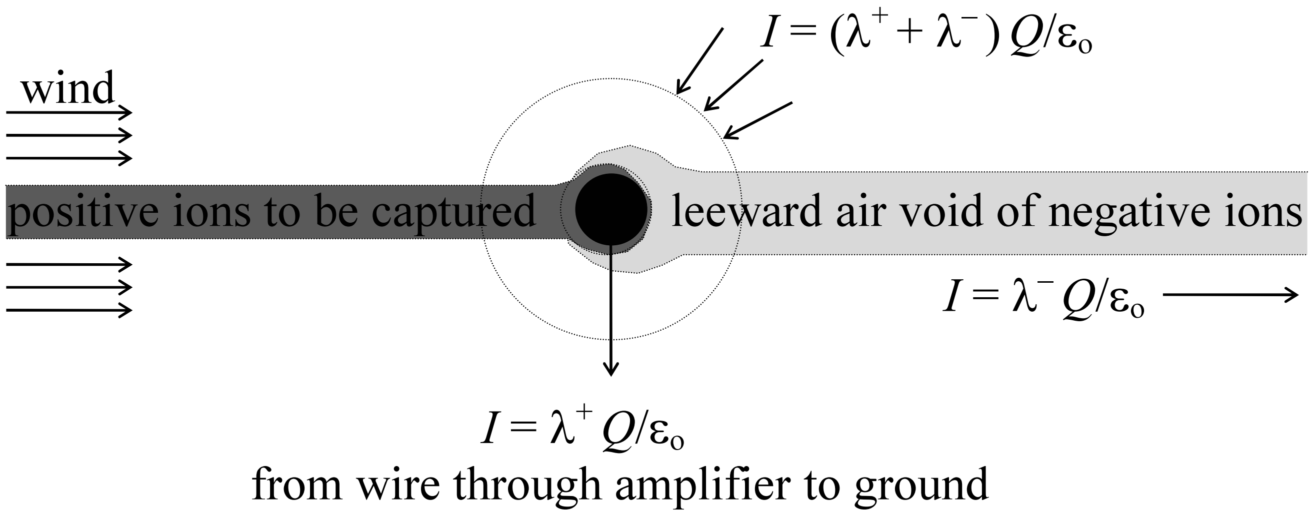


The velocity and time of the drift of an air ion to a charged wire with 1-mm radius. The air ion mobility is assumed to be 1 $cm^2V^{-1}s^{-1}$, and the charge equal to that of an antenna at a height of 2 m in an ambient electric field of 100 V m^{-1} .

Conclusions:

1. The conduction current to the wire surface is $I_\lambda = (\lambda^+ + 0)\, Q/\varepsilon_o$.
2. The wire charge is doubled when compared with the situation without space charge.
3. Two effects exactly compensate each other and the electrostatic model $S_s = S_E$ is valid.

Antenna in wind



Conclusion:

Assuming the wire charge $Q = E_\infty HC$, we get the collected current $S_E\, j\,/\,2$ and $S_s = S_E\,/\,2$.

The assumption above is correct only if the antenna is placed above the near-ground electrode effect layer.

If the antenna is close to the ground, we get $E = 2E_\infty$ and $S_s = S_E$.

Antenna in the electrode effect layer

A simple model of the near-ground electrode effect:

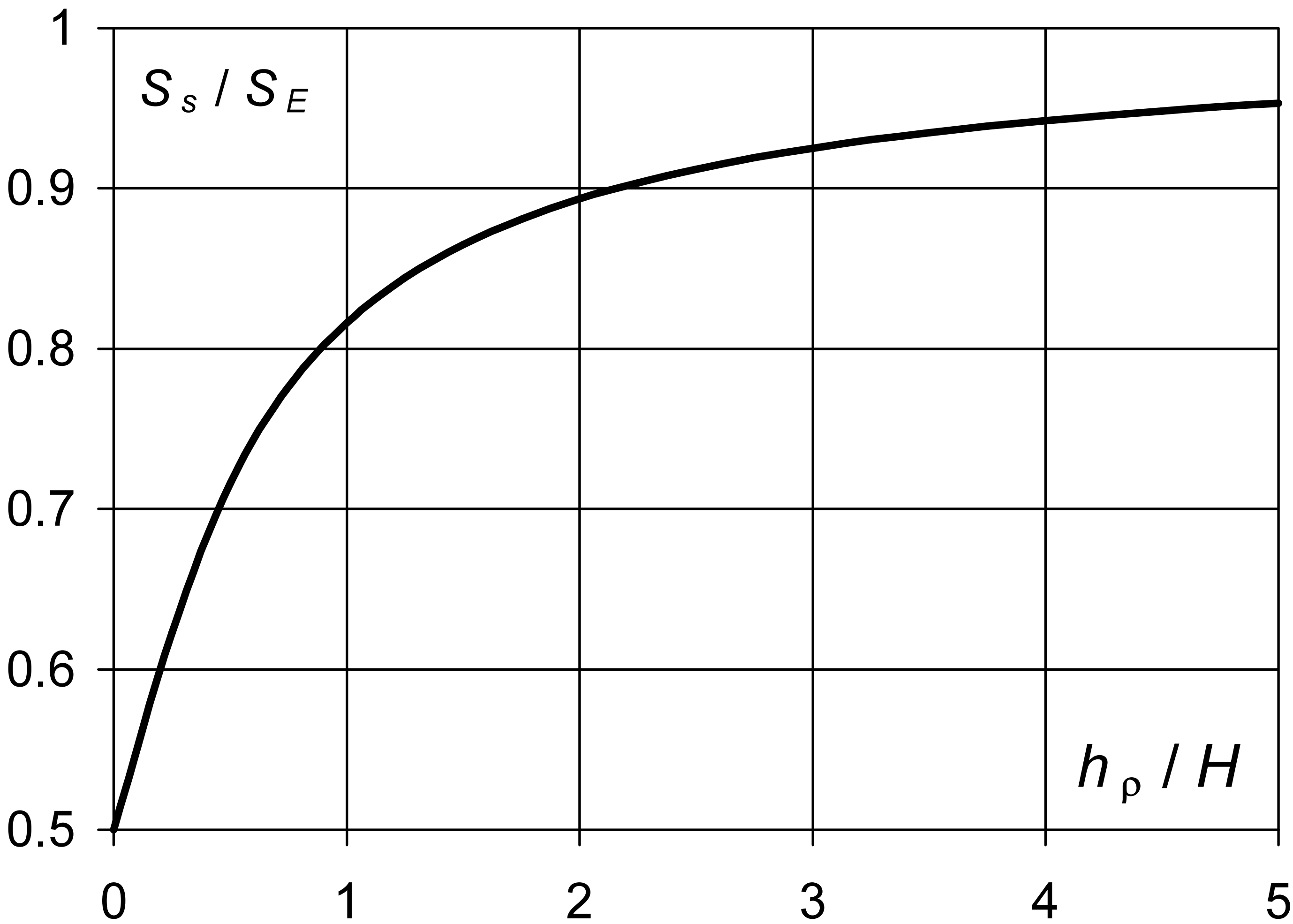
$$E(h) = E_\infty\left(1 + \exp(-h / h_\rho)\right),$$

$$\lambda^+ = \text{const},$$

$$\lambda^-(\infty) = \lambda^+.$$

The solution:

$$S_s / S_E = 0.5\left[1 + (h_\rho / H)\left(1 - \exp(-H / h_\rho)\right)\right].$$



Ratio of two effective areas of a long-wire antenna, S_s/S_E , as a function of the relative height of the ambient electrode effect space charge layer h_ρ/H
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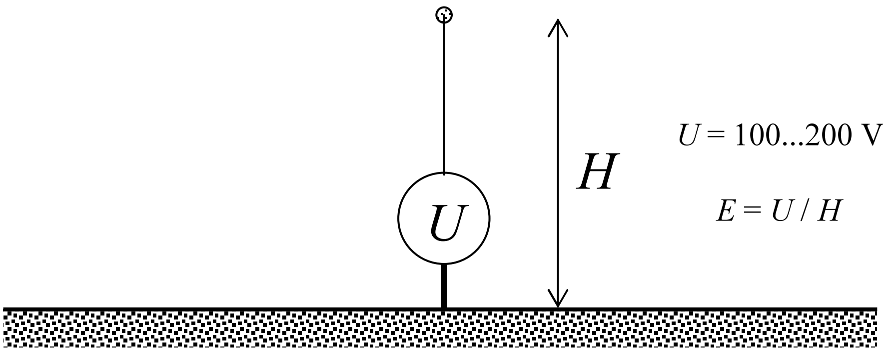
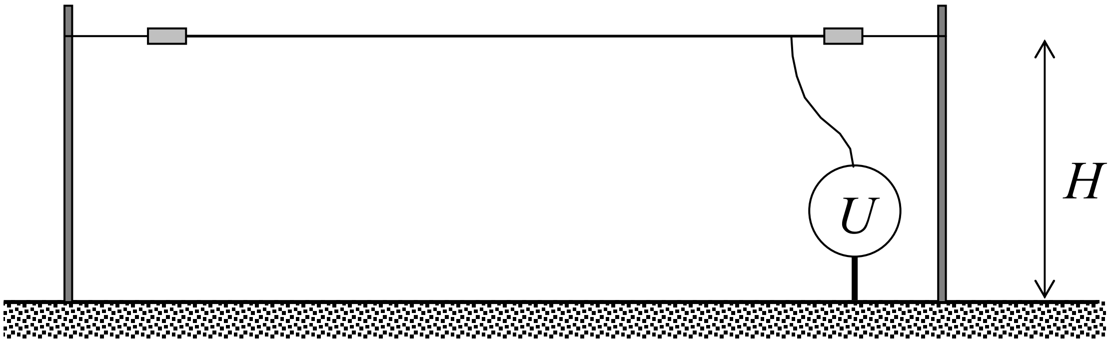
1. Atmospheric electrical DC antennas

Collector antenna



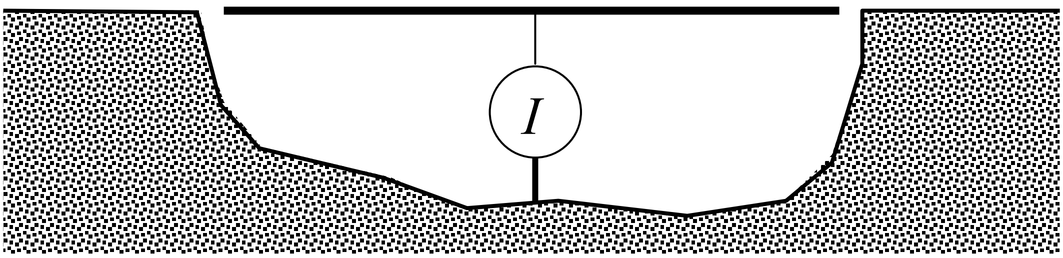
Passive potential antenna (Crozier, Harrison,...)



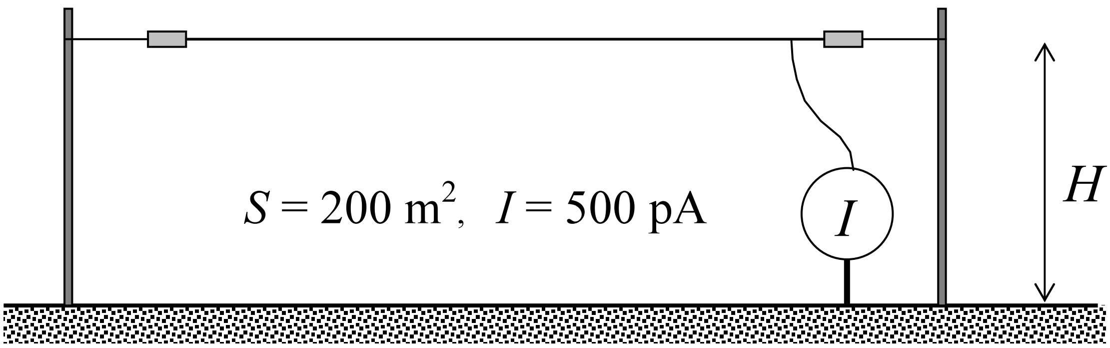
Wilson plate

$S = 4\ \mathrm{m}^2$

$I = 10\ \mathrm{pA}$



Grounded horizontal wire antenna



DC effective area of a wire antenna

2. Geophysical problems

Global parameters of atmospheric electricity

$$U = 250\ \text{kV}, \qquad I = 1250\ \text{A}, \qquad R = 200\ \Omega$$

Atmospheric electricity and global change

Williams, E. (1994) Global circuit response to seasonal variations in global surface air temperature. *Monthly Weather Review* **122,** 1917−1929.

Measuring of global parameters

- **Carnegie curve**
- **Ionospheric potential**
- **Schumann resonance noise**
- **Vertical current**

  Ruhnke, L.H. (1969) Area averaging of atmospheric electric currents. *J. Geomagn. Geoelectr.* **21**, 453−462.

- **Waldorf-Vilsandi experiment**

  Ruhnke, L.H., Tammet, H.F., and Arold M. (1983) Atmospheric electric currents at widely spaced stations. In *Proc. in Atmos. Electr.*, A. Deepak Publs., Hampton, VA.

Mapping of ionospheric potential variations

3. Technical problems

- **Wire material**
- **Wire height and diameter**

Electrostatic effective area of 1 km antenna, m^2

Height m	Diameter : mm		
	1	**2**	**3**
1	**758**	**827**	**873**
2	**1398**	**1515**	**1593**
3	**2007**	**2167**	**2273**

- **Configuration and length of the antenna**
- **Supports and tightening**

Standard tension F_o – 2-mm aluminium : 11 kG,
1.5 mm steel : 18 kG.

Sag at standard tension $(l\text{:m} / 10)^2$ cm

Eigenfrequency $\dfrac{56\text{m}}{l}\sqrt{\dfrac{F}{F_\circ}}$ Hz

l is the distance between supports

- **Insulators**
- **Insects and spiders**
- **Electrolytic currents**
- **Amplifier and recorder**
- **Data analysis**