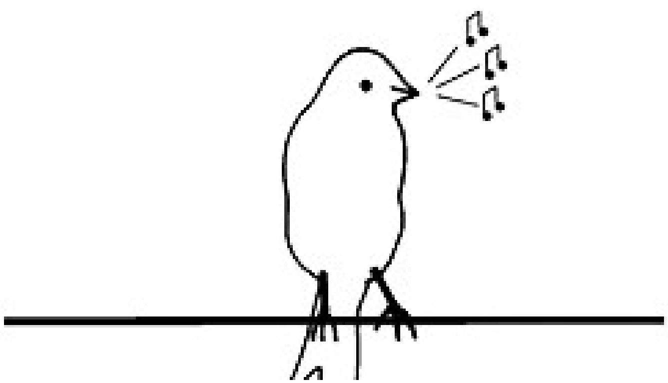
Journal Club

Birds on power lines

Jose Arnaldo Redinz, Am. J. Phys. 82, 691 (2014)



Presented by Simon Nigg

University of Basel, July 29 2014

Birds on power lines

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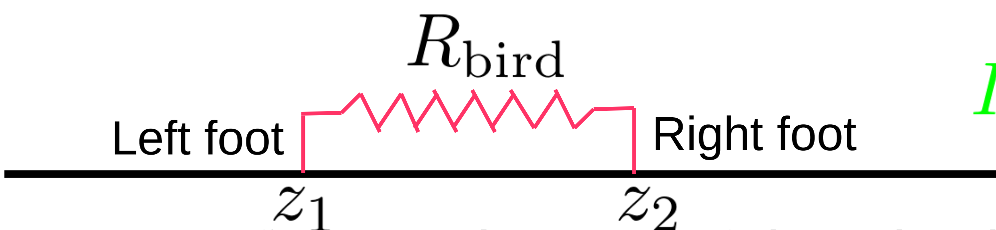
Why can a bird safely rest on a high-voltage power line? We discuss three effects that can lead to the development of voltages and currents in the bird's body. To explain the absence of electric shocks, we give numerical estimates of these voltages and currents obtained from the standard solution for the voltage along a two-wire transmission line.
[http://dx.doi.org/10.1119/1.4874259]

Summary and main results

- “Capacitive” (displacement) currents

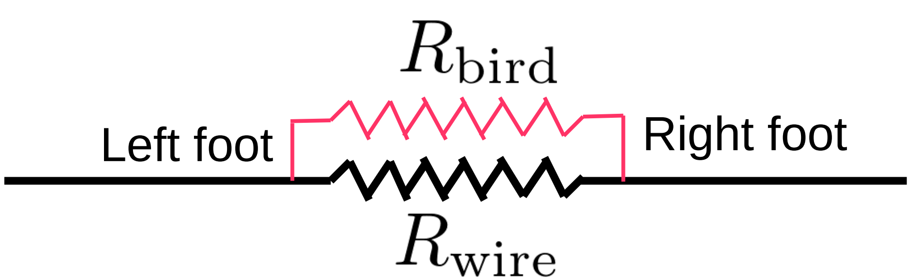
$$I_C = C\dot{V}(t)$$

- Closed circuit-currents from one foot to another
  - Due to phase difference of AC voltage between left and right foot



$$I_\beta = |V(z_1) - V(z_2)|/R_{\mathrm{bird}}$$

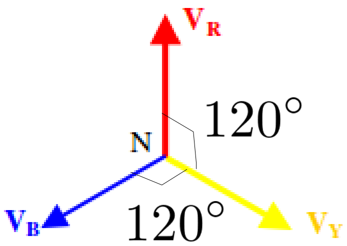
  - Due to finite resistance of the wire (most typical argument)



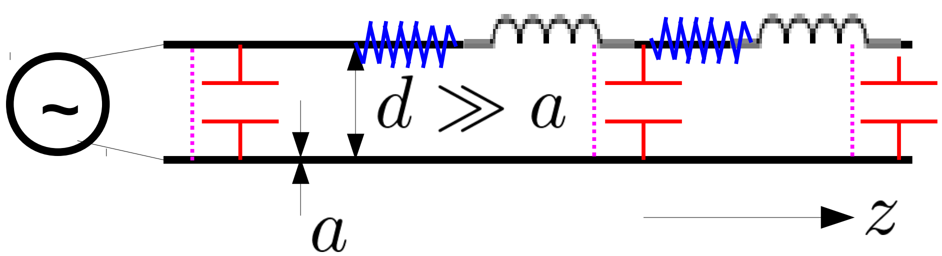
$$I_\alpha \sim R_{\mathrm{wire}}/R_{\mathrm{bird}}$$

$$\boxed{I_C > I_\beta > I_\alpha}$$

Some details on the models and calculations



- Power line modeled as a 3-phase system
- 1 phase = transmission line of two parallel wires



$$L = \frac{\mu_m}{\pi}\left[\frac{1}{4} + \ln\left(\frac{d}{a}\right)\right]$$

$$C = \frac{\pi \epsilon_m}{\ln(d/a)}$$

$$R = \frac{2}{\sigma_w \pi a^2} \qquad G = \frac{\pi \sigma_m}{\ln(d/a)}$$

Voltage between two wires:

$$V(z,t) = V_0 e^{-\alpha z} \cos(\omega t - \beta z)$$

$$\alpha = \frac{R}{2\sqrt{L/C}} + \frac{G\sqrt{L/C}}{2} \qquad \beta = \omega\sqrt{LC}$$

$$\mu_m \approx \mu_0 = 4\pi \times 10^{-7}\,\mathrm{N/A^2}$$

$$\epsilon_m \approx \epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$$

N.B. Bird size is < d

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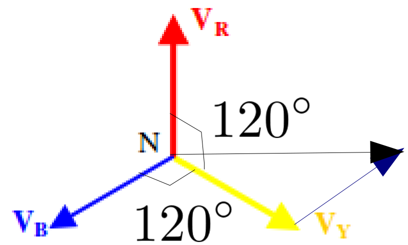

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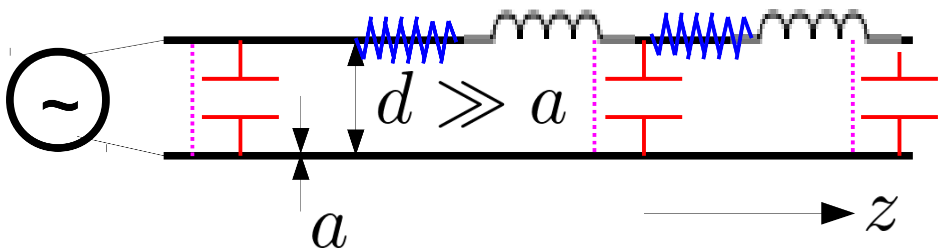

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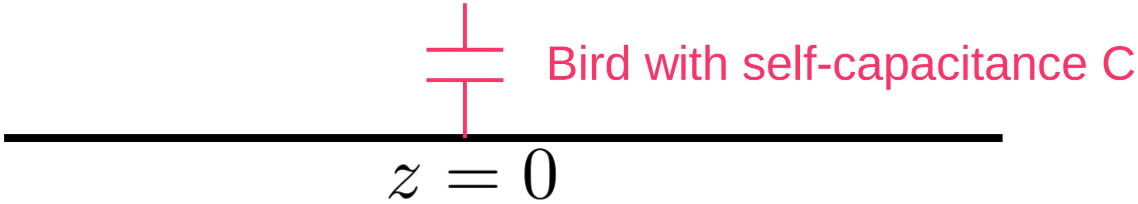
Phase-to-neutral voltage: $V(z,t)/\sqrt{3}$

Estimates of capacitive current

- **Single point of contact** (only contribution for a bird standing on one foot...e.g. flamingo on a power line !?)

$$I_C(z=0,\omega) = i\omega C V(z=0,\omega)$$



Estimates of capacitive current

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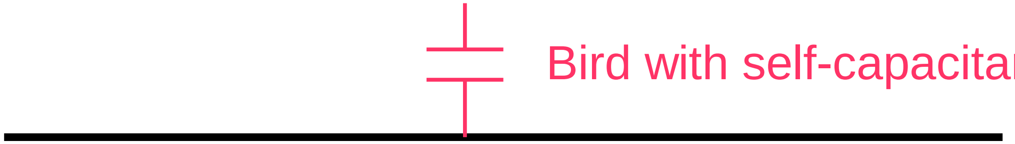
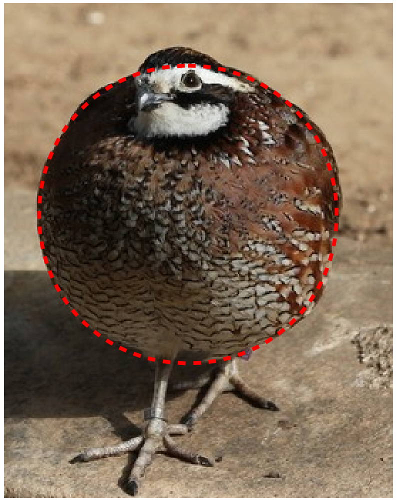


$z = 0$

Bird = conducting sphere with radius r: $C = 4\pi\epsilon_m r$

$$I_C^{\rm rms} = \frac{4\pi}{\sqrt{6}}\epsilon_m r\omega V_0$$



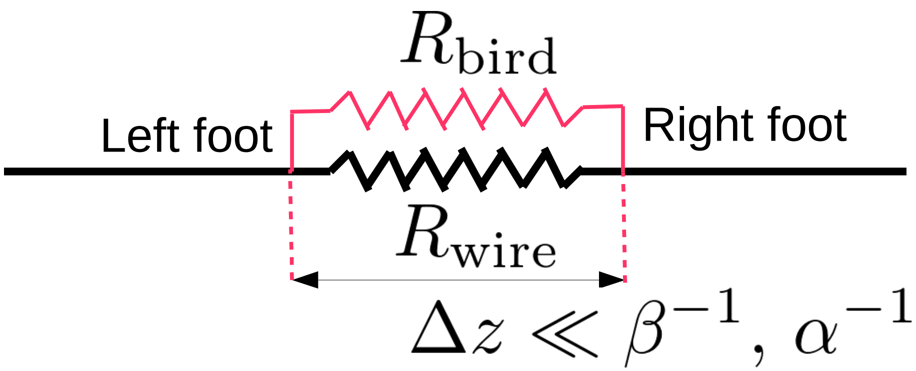
and ...conducting (?)

$$\left.\begin{array}{l} 2\pi\omega = 60\,\mathrm{Hz} \\ r = 0.1\,\mathrm{m} \\ V_0 = 500\,\mathrm{kV} \end{array}\right\} \quad I_C \approx 0.9\,\mathrm{mA}$$

N.B. Perception current: $1.1\,\mathrm{mA}$ (men), $0.7\,\mathrm{mA}$ (women)

Estimates for the resistive currents

- Assume low loss and long wavelength:



$$I_\beta = |V(z_1) - V(z_2)|/R_{\text{bird}}$$

$$I_\alpha \sim R_{\text{wire}}/R_{\text{bird}}$$

$$V(z,t) \approx V_0(1-\alpha z)[\cos(\omega t) + \beta z \sin(\omega t)]$$

Estimates based on TL data:

$$V_\alpha = \alpha \Delta z V_0/\sqrt{6} \approx 0.5 - 0.9\,\text{mV}$$

$$V_\beta = \beta \Delta z V_0/\sqrt{6} \approx 26\,\text{mV}$$

→ Phase current should dominate

No good data on bird resistance ---> estimate for resistive currents for humans!

$$\Delta z = 1\,\text{m},\ V_0 = 500\,\text{kV},\ R_{\text{power line maintenance MAN}} = 535\,\Omega$$

$$I_\alpha \approx 0.02\,\text{mA} \qquad I_\beta \approx 0.5\,\text{mA}$$

Conclusion & Corollary

The sum of all three currents is probably below the perception current for birds owing to their high resistivity and small size.

When lightning strikes:

- Wear a Faraday cage outfit

$$\Delta V(t) = 0 \Rightarrow I_C = 0$$

- Hop to safety on one foot :)

$$\Delta z = 0 \Rightarrow I_\alpha = I_\beta = 0$$

Thanks for your attention!

An other interesting recent paper:
Why do Earth satellites stay up ?
Am. J. Phys **82**, 769 (2014)