

Exploring the Non-ideal Characteristics of Transmission Lines

Jake Bobowski

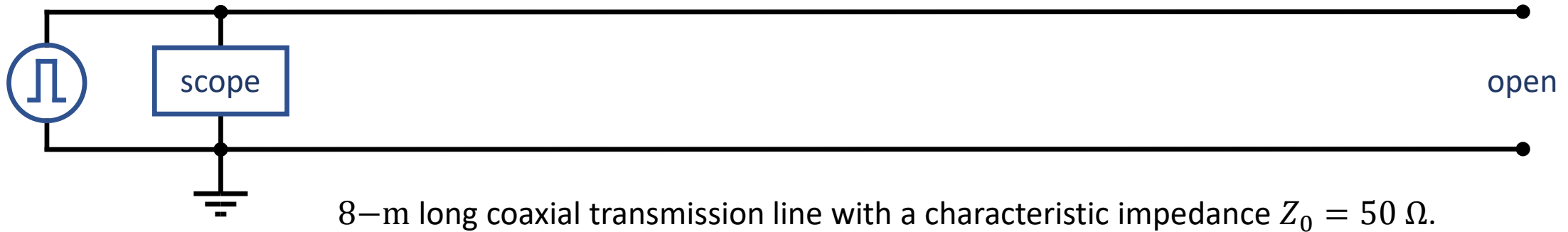
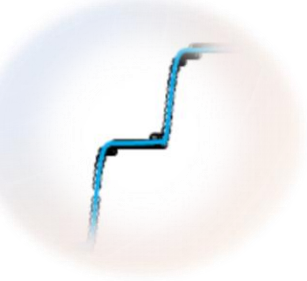


vBFY

Thursday, July 29, 2021

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<http://physics.ok.ubc.ca/welcome.html>

Pulse Propagation...



$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Pulse Propagation...

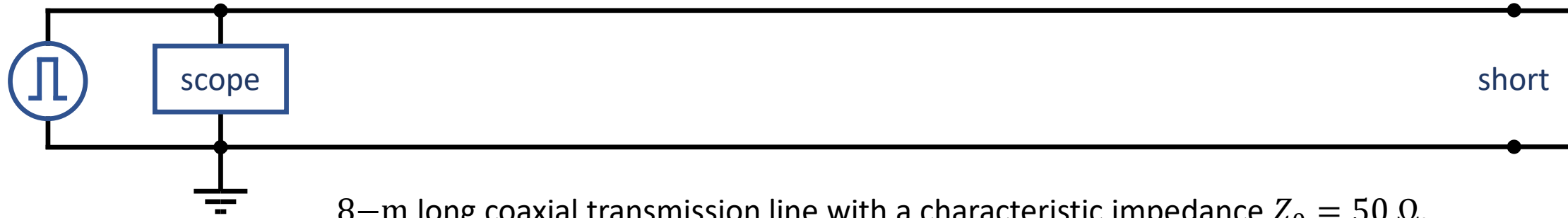
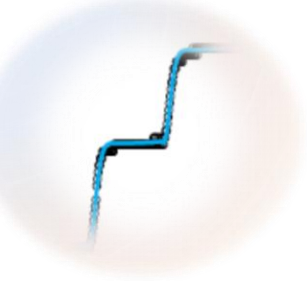
Pulse generator: HP 8011A
Pulse width: 25 ns

Oscilloscope: Tektronix
TDS 2002C (70 MHz)

Coax: UT-141 semi-rigid
copper outer conductor
SPCW inner conductor

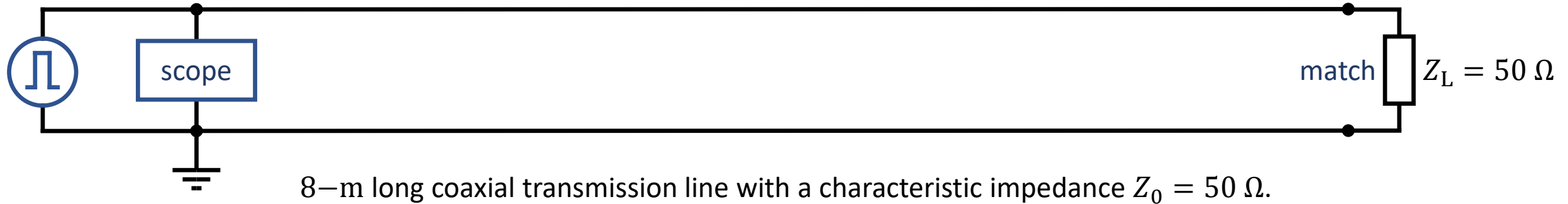
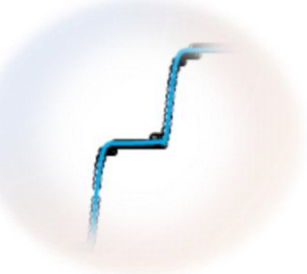


Pulse Propagation...



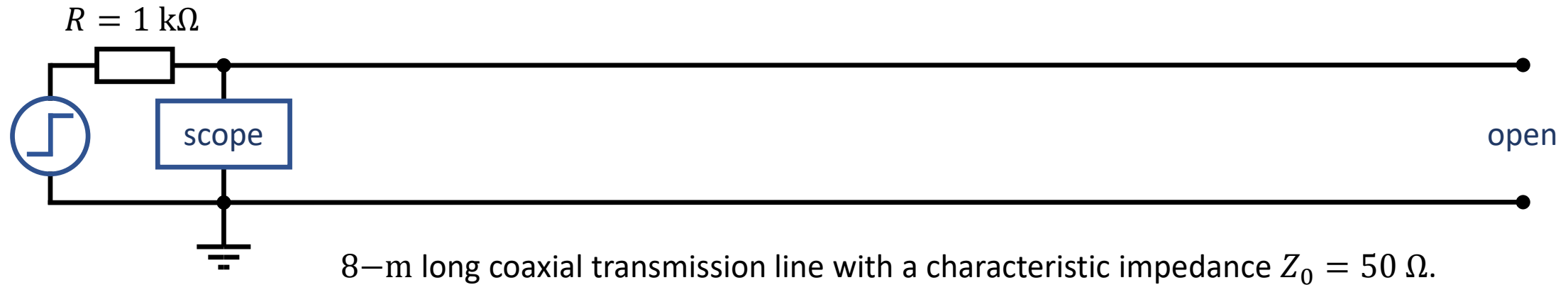
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Pulse Propagation...



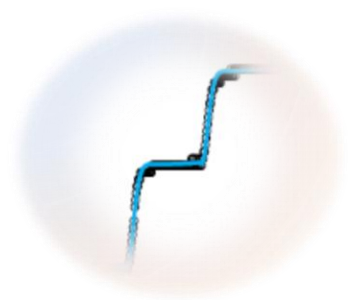
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Transient Response...



Modeling and measuring the non-ideal characteristics of transmission lines, Am. J. Phys. **89**, 96—104 (2021).
 Transients in lossy transmission lines, arXiv:2011.00430.

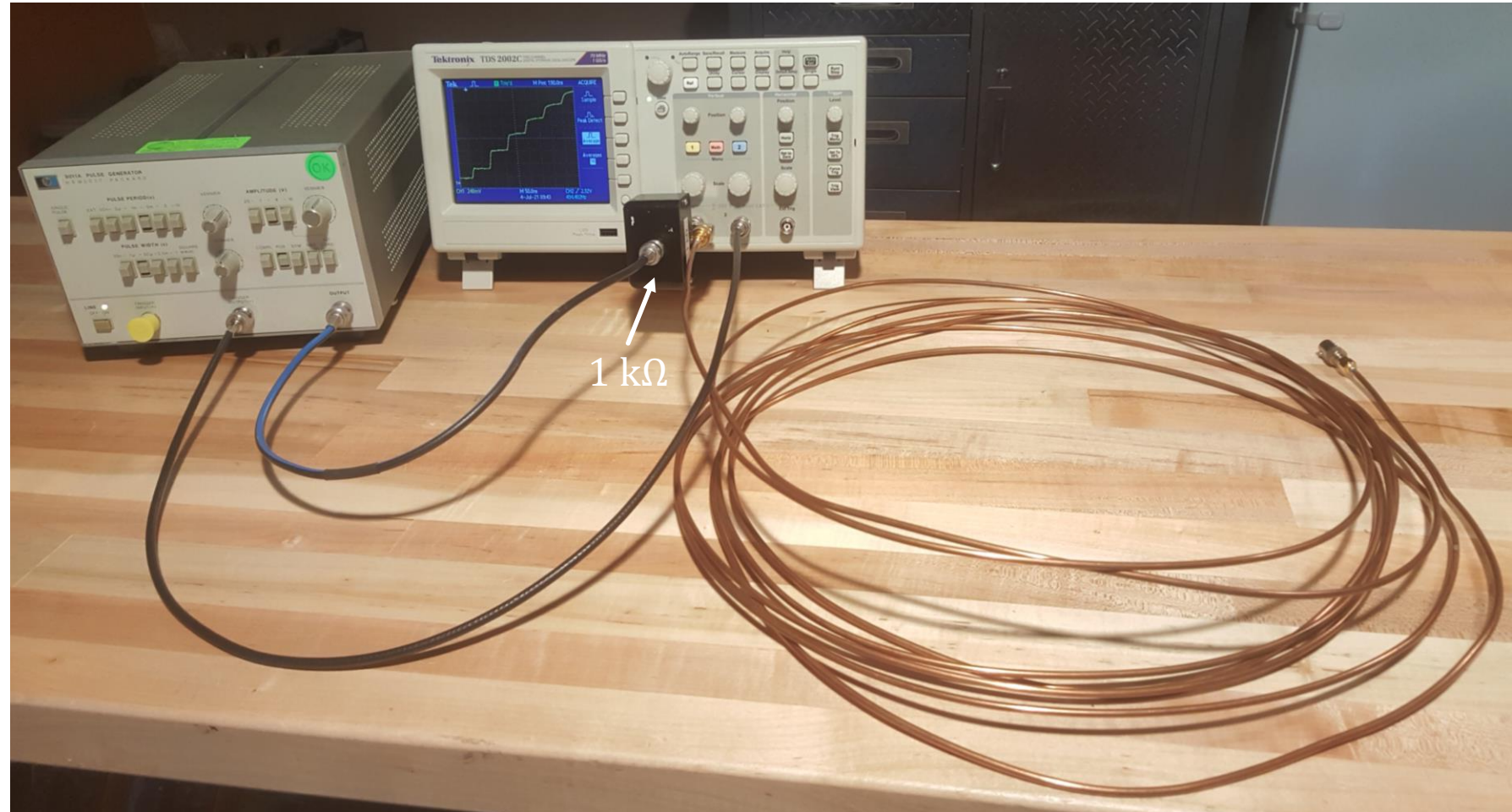
Pulse Propagation...



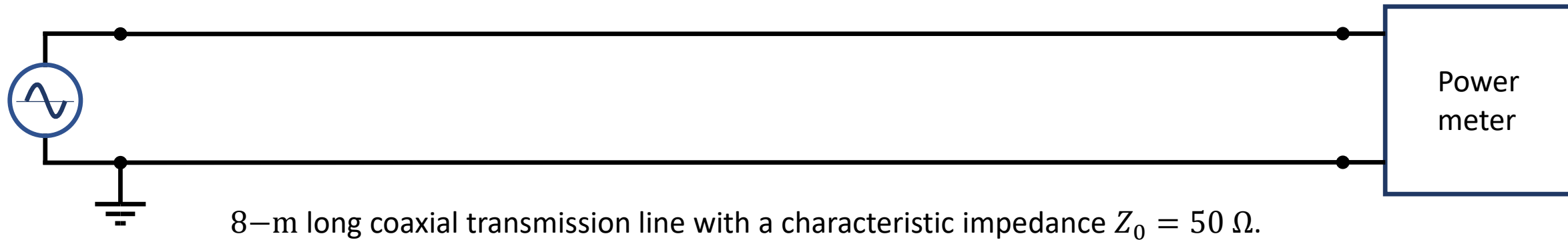
Pulse generator: HP 8011A
Pulse width: 10 μ s

Oscilloscope: Tektronix
TDS 2002C (70 MHz)

Coax: UT-141 semi-rigid
copper outer conductor
SPCW inner conductor

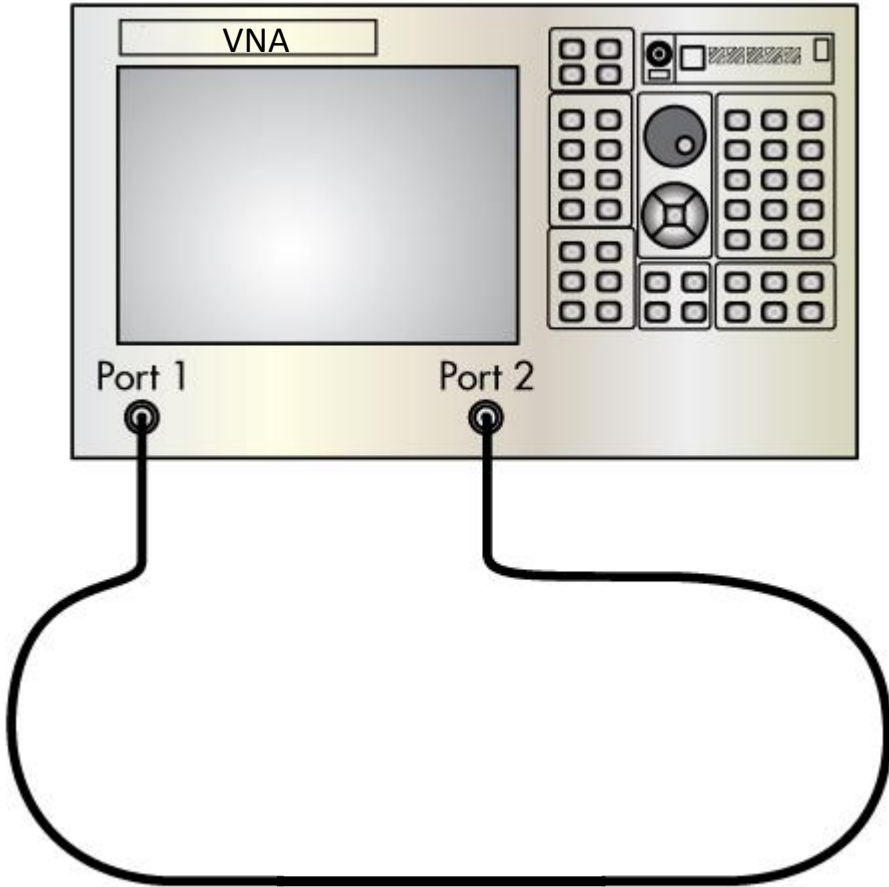


Frequency Response...



Modeling and measuring the non-ideal characteristics of transmission lines, *Am. J. Phys.* **89**, 96—104 (2021).
 Transients in lossy transmission lines, arXiv:2011.00430.

Frequency Response (S_{21})...



<https://www.mwrf.com/>



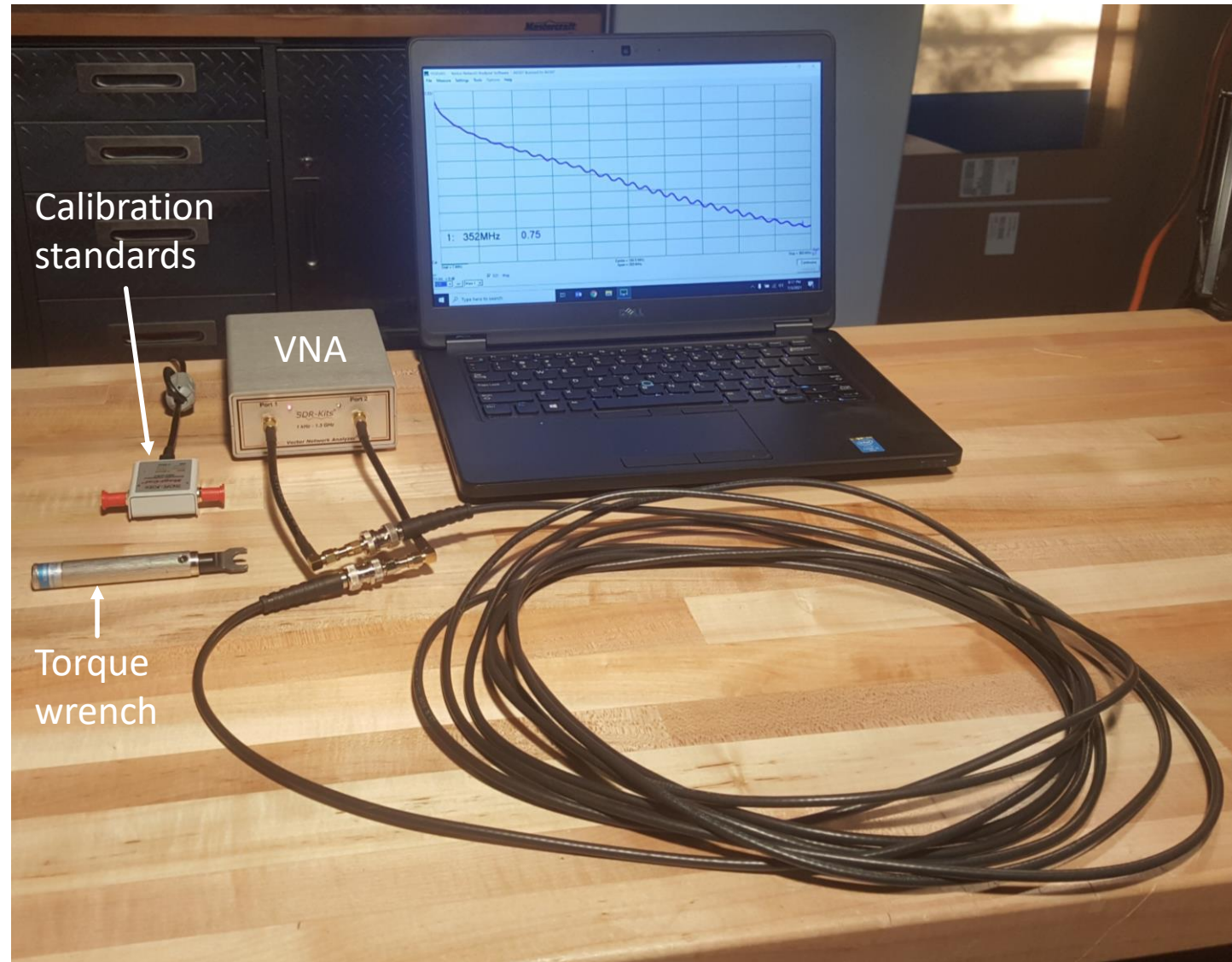
<https://www.sdr-kits.net/>

Pulse Propagation...

VNA: SDR-Kits DG8SAQ VNWA 3SE

Calibrator: Magi-Cal[®] Automatic Calibrator

Coax: RG-58 BNC



Transmission line losses...

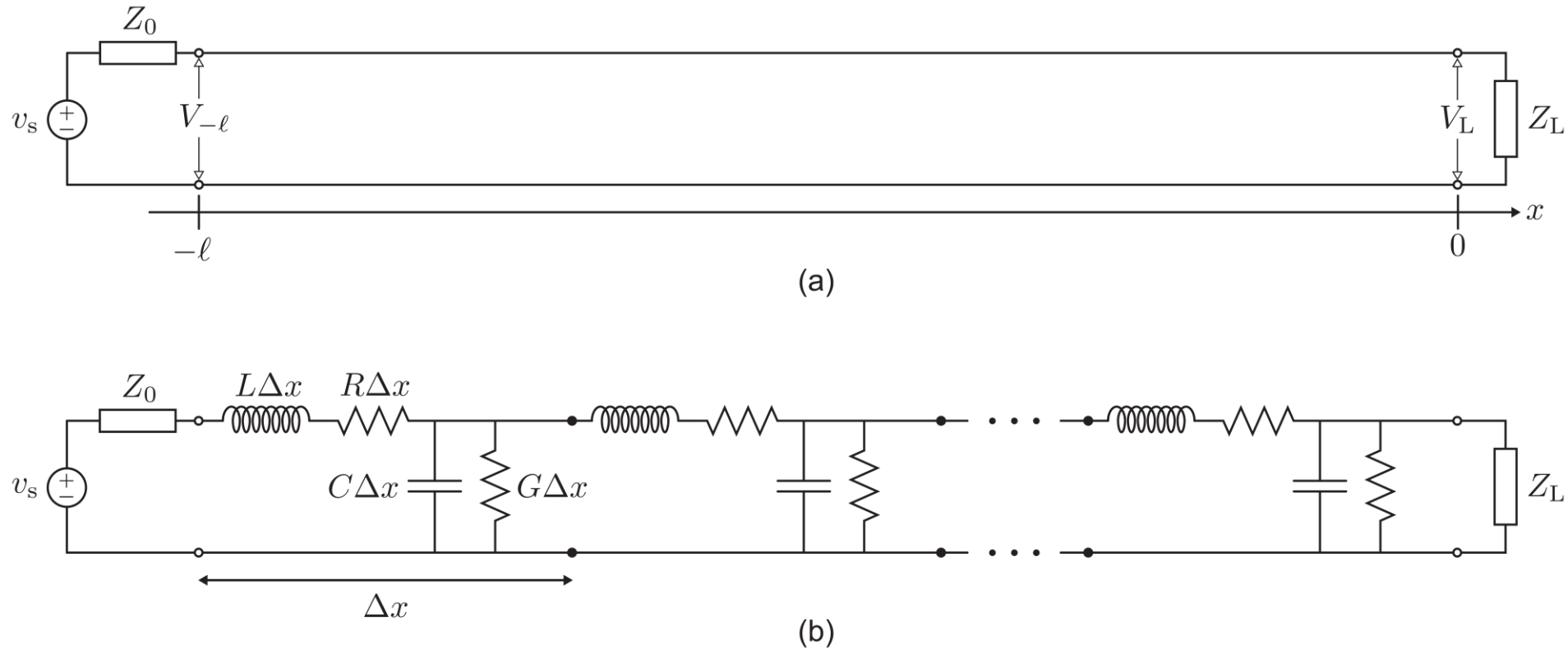
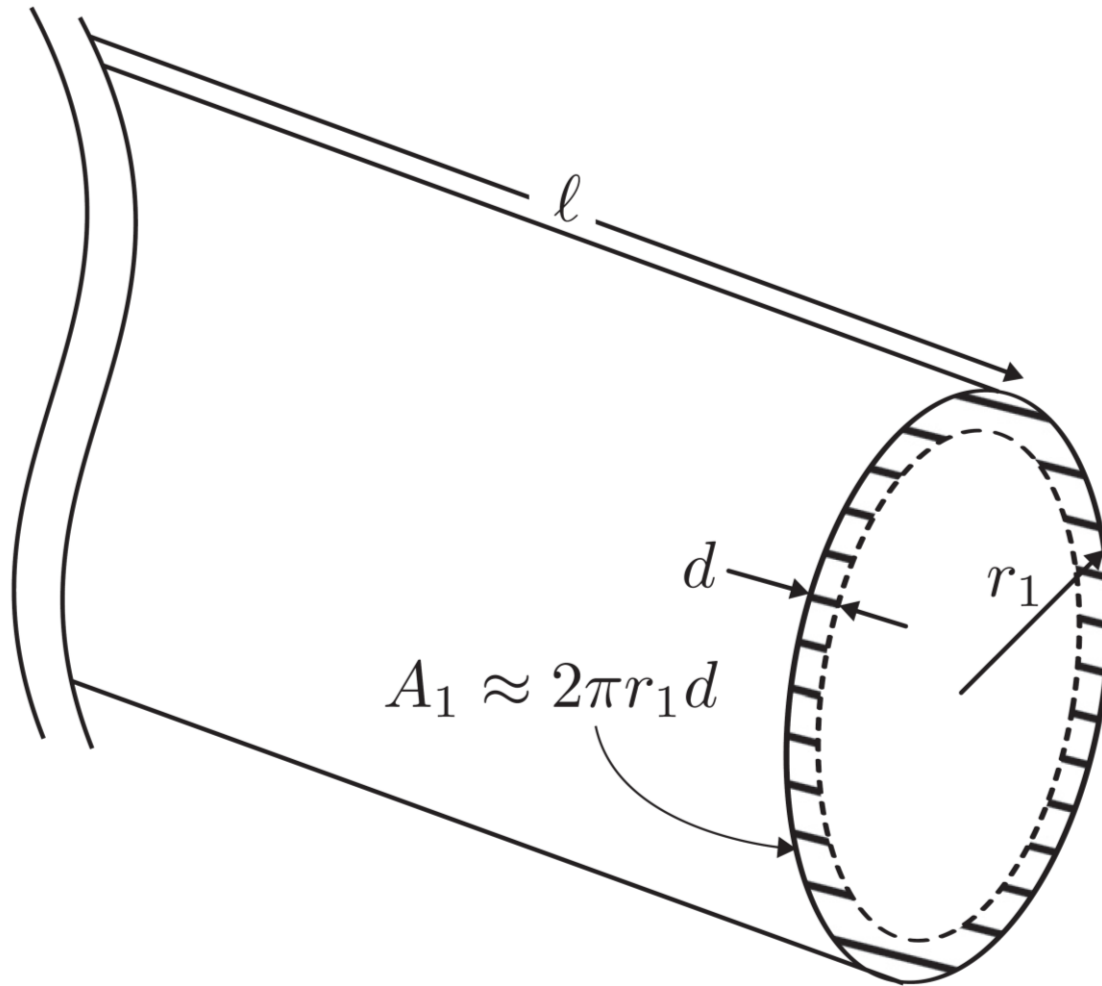


Fig. 1. (a) A transmission line of length ℓ connected to a signal source with output impedance Z_0 at $x = -\ell$ and a load impedance Z_L at $x=0$. (b) The distributed circuit model of a transmission line.

Modeling and measuring the non-ideal characteristics of transmission lines, Am. J. Phys. **89**, 96–104 (2021).

Transmission line losses...



Skin depth:

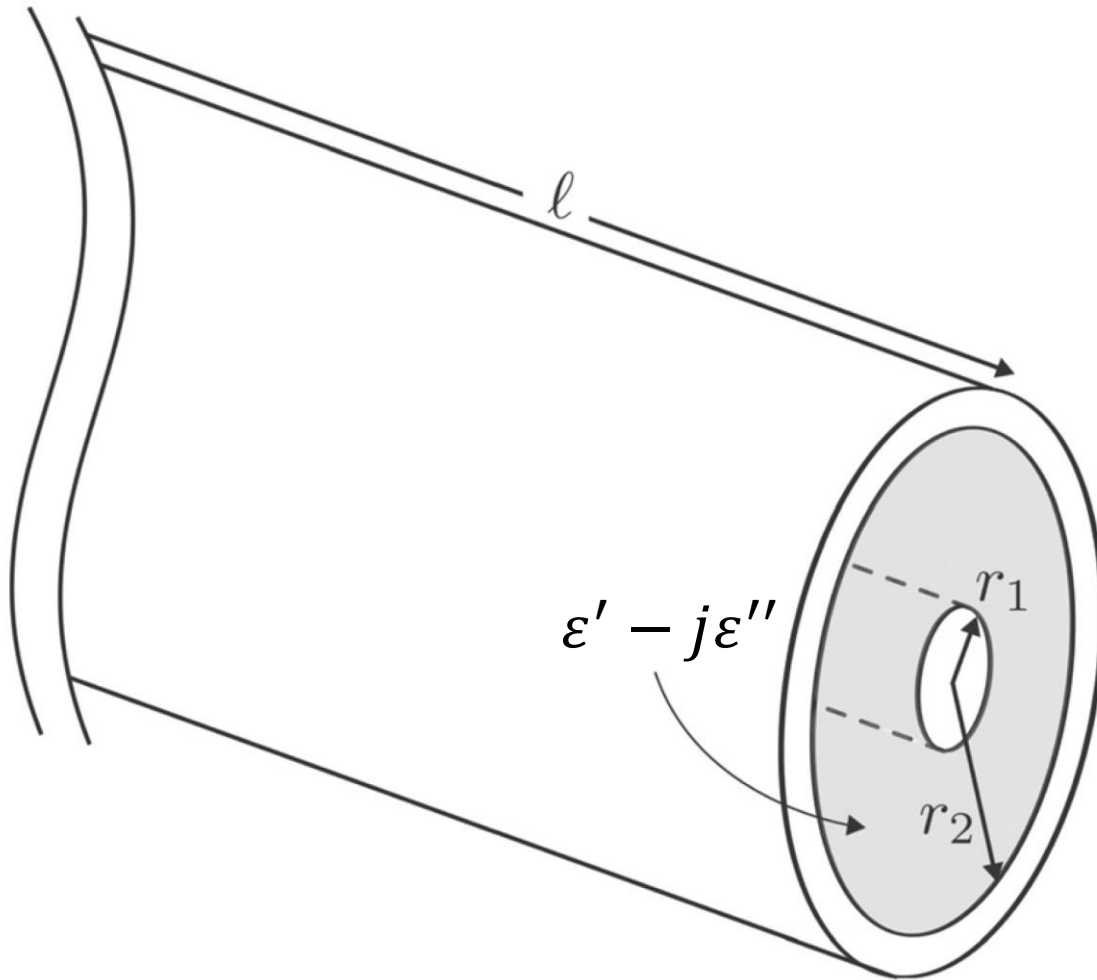
$$d = \sqrt{\frac{2\rho}{\mu_0\omega}}$$

Resistance per unit length:

$$R = \frac{\rho}{2\pi r_1 d} = \frac{1}{2\pi r_1} \sqrt{\frac{\mu_0 \rho \omega}{2}}$$

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Transmission line losses...



Admittance per unit length:

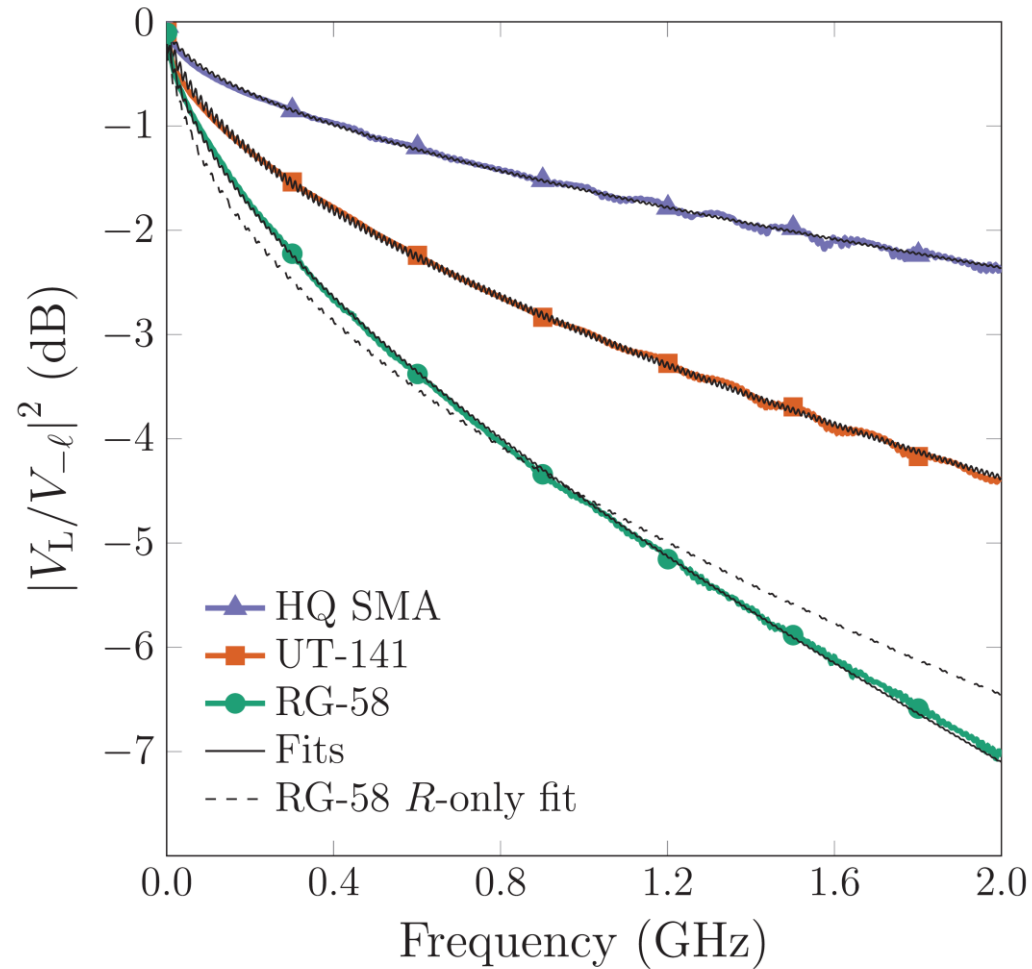
$$j\omega C = j\omega \left[\frac{2\pi\epsilon_r\epsilon_0}{\ln(r_2/r_1)} \right]$$

Conductance per unit length:

$$G = \frac{2\pi\omega\epsilon''\epsilon_0}{\ln(r_2/r_1)}$$

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Transmission line losses...

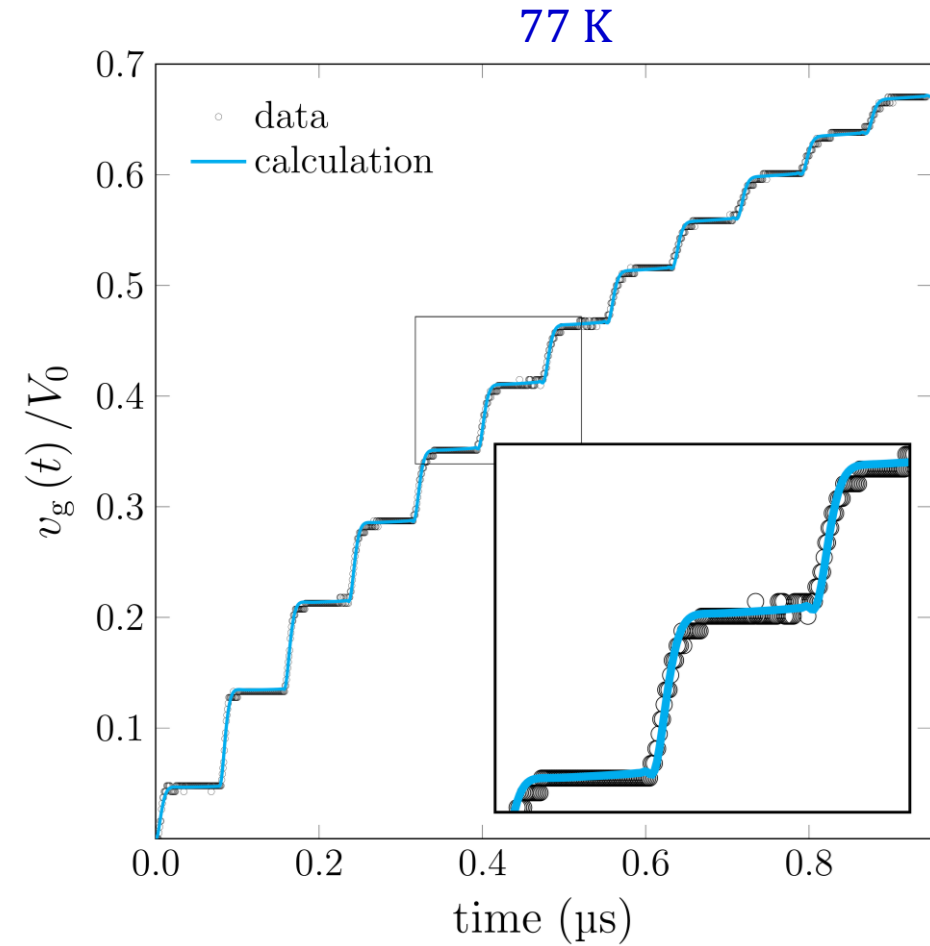
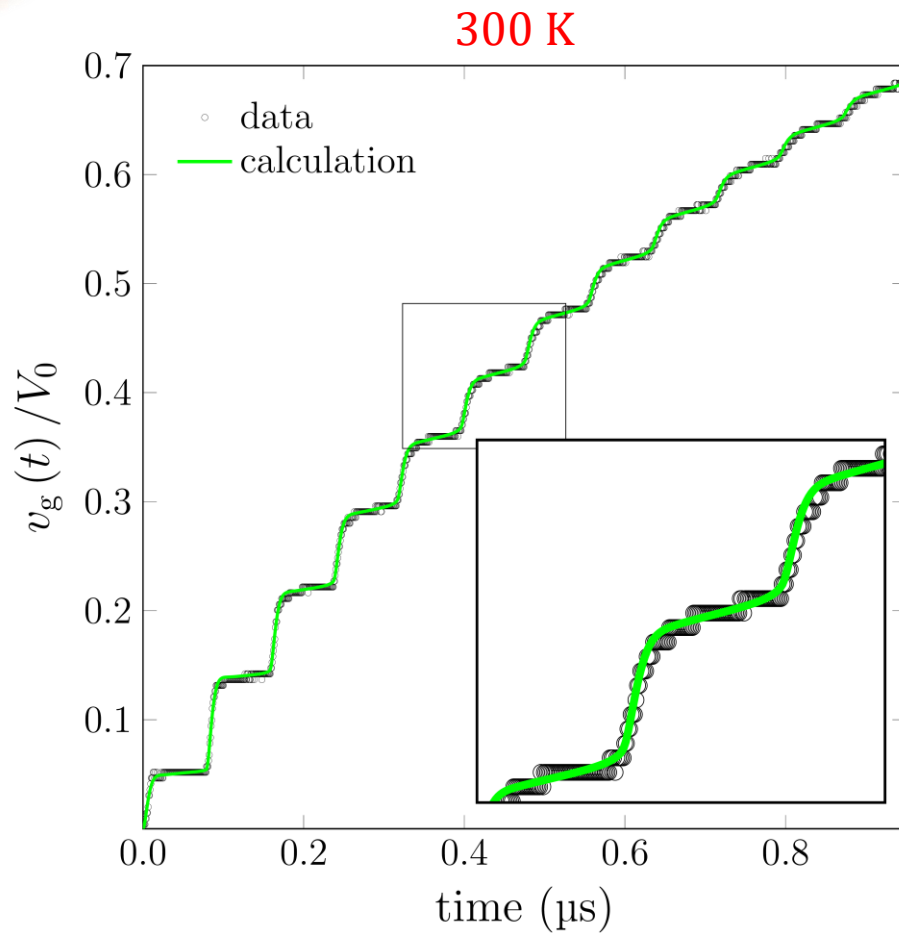
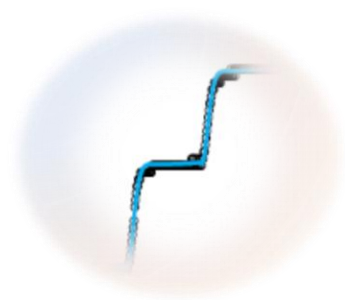


Modeling and measuring the non-ideal characteristics of transmission lines, Am. J. Phys. **89**, 96—104 (2021).

Transmission line losses... cooling to 77 K



Transmission line losses... cooling to 77 K



Transients in lossy transmission lines, arXiv:2011.00430.