Exploring the Non-ideal Characteristics of Transmission Lines

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PHYS 331

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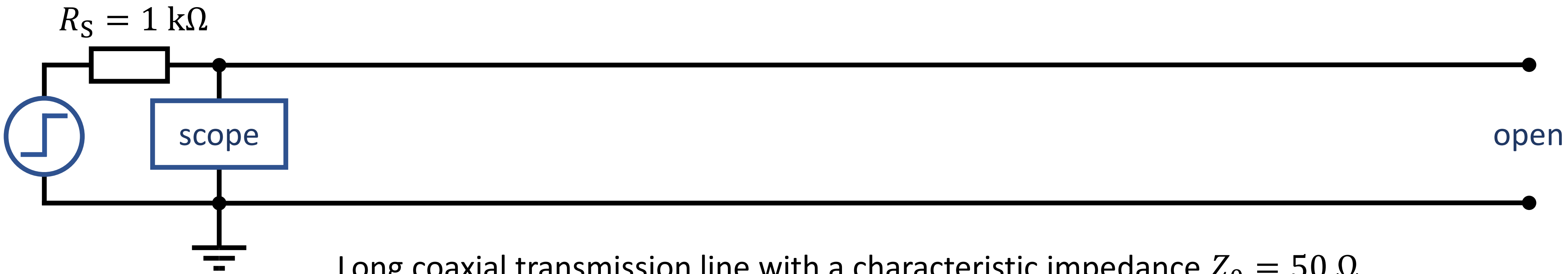
http://physics.ok.ubc.ca/welcome.html

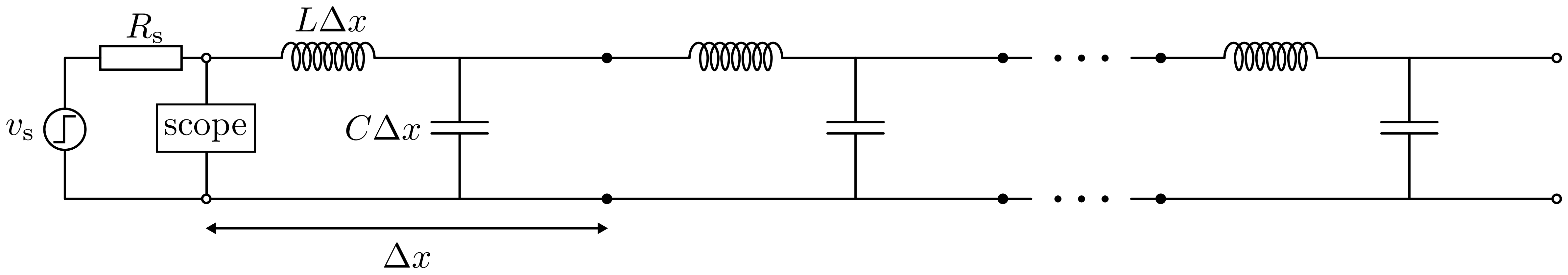
Transient response…



Long coaxial transmission line with a characteristic impedance $Z_0 = 50\ \Omega$.

If the output of the signal generator steps instantaneously from zero to V_0, what is the expected $v(t)$ measured by an oscilloscope at the transmission line input?

Transient response…



The case of an ideal (lossless) transmission line can be analyzed using a number of different methods:

- So-called “bounce diagrams”

(Transients on Bounded Transmission Lines - https://web.mit.edu/6.013_book/www/chapter14/14.4.html)

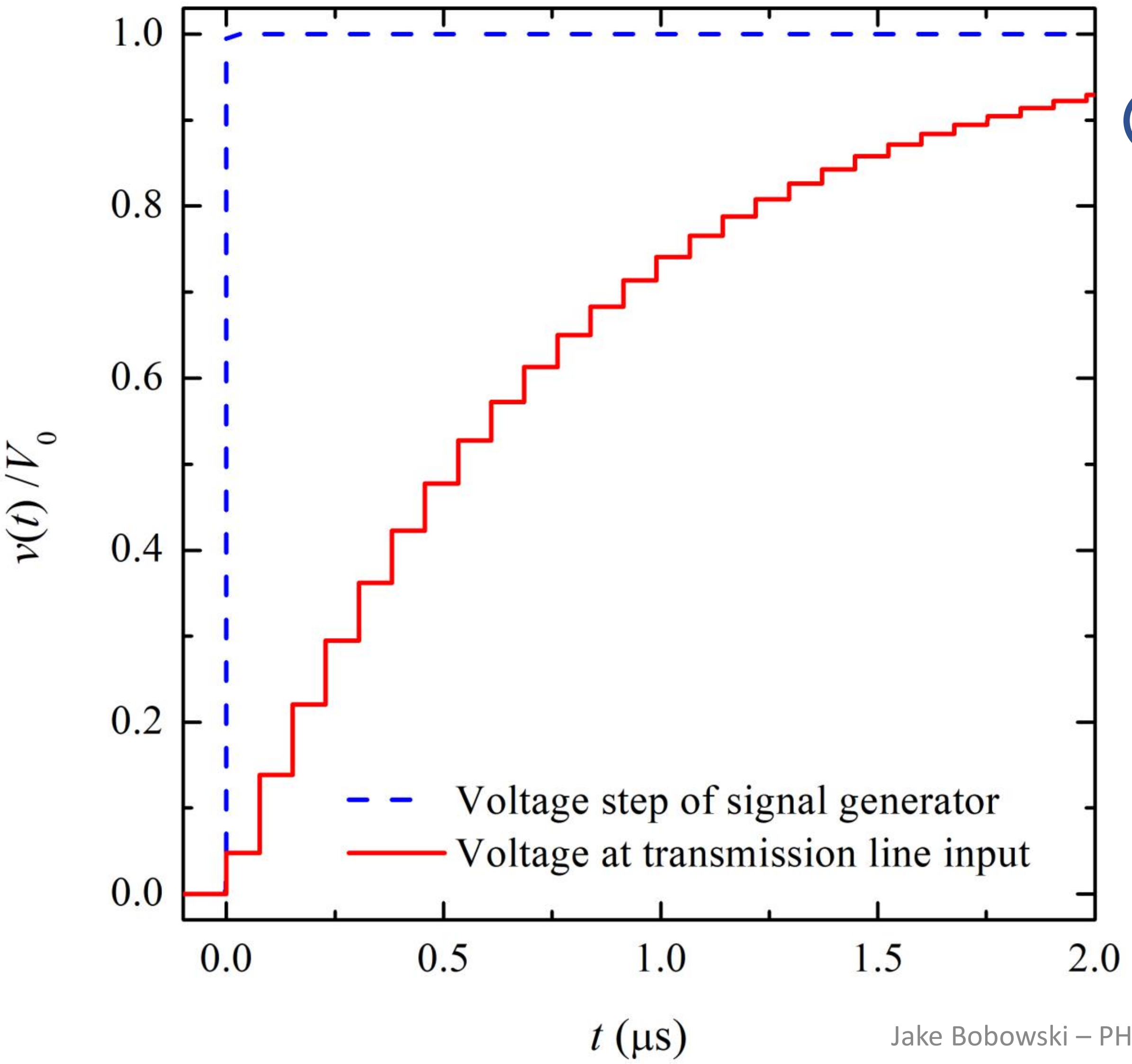
- Inverse Fourier transform of the equivalent frequency-domain analysis

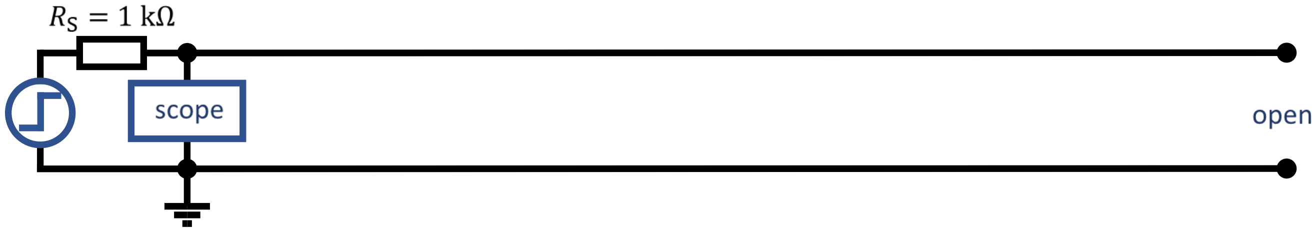
(A Fourier Transform Approach to Transmission-Line Analysis - **DOI:** 10.1109/TE.1970.4320549)

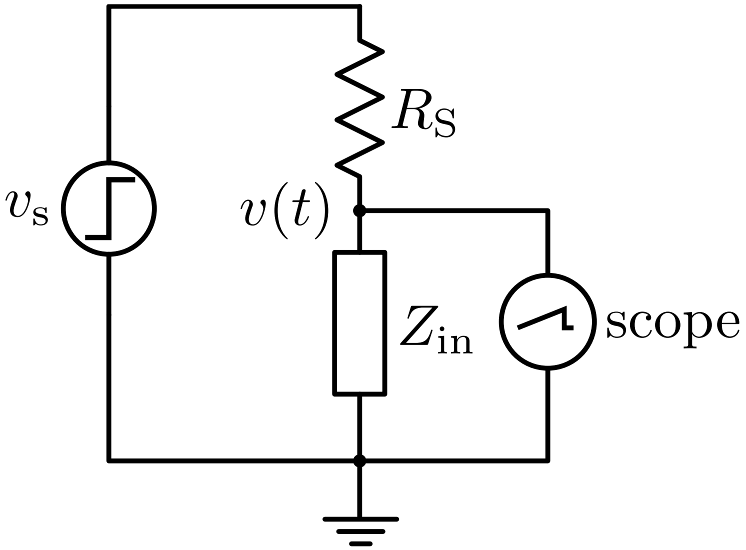
- Inverse Laplace transform

(Modeling and Measuring the Non-ideal Characteristics of Transmission Lines – **DOI:** 10.1119/10.0001896)

Transient response…





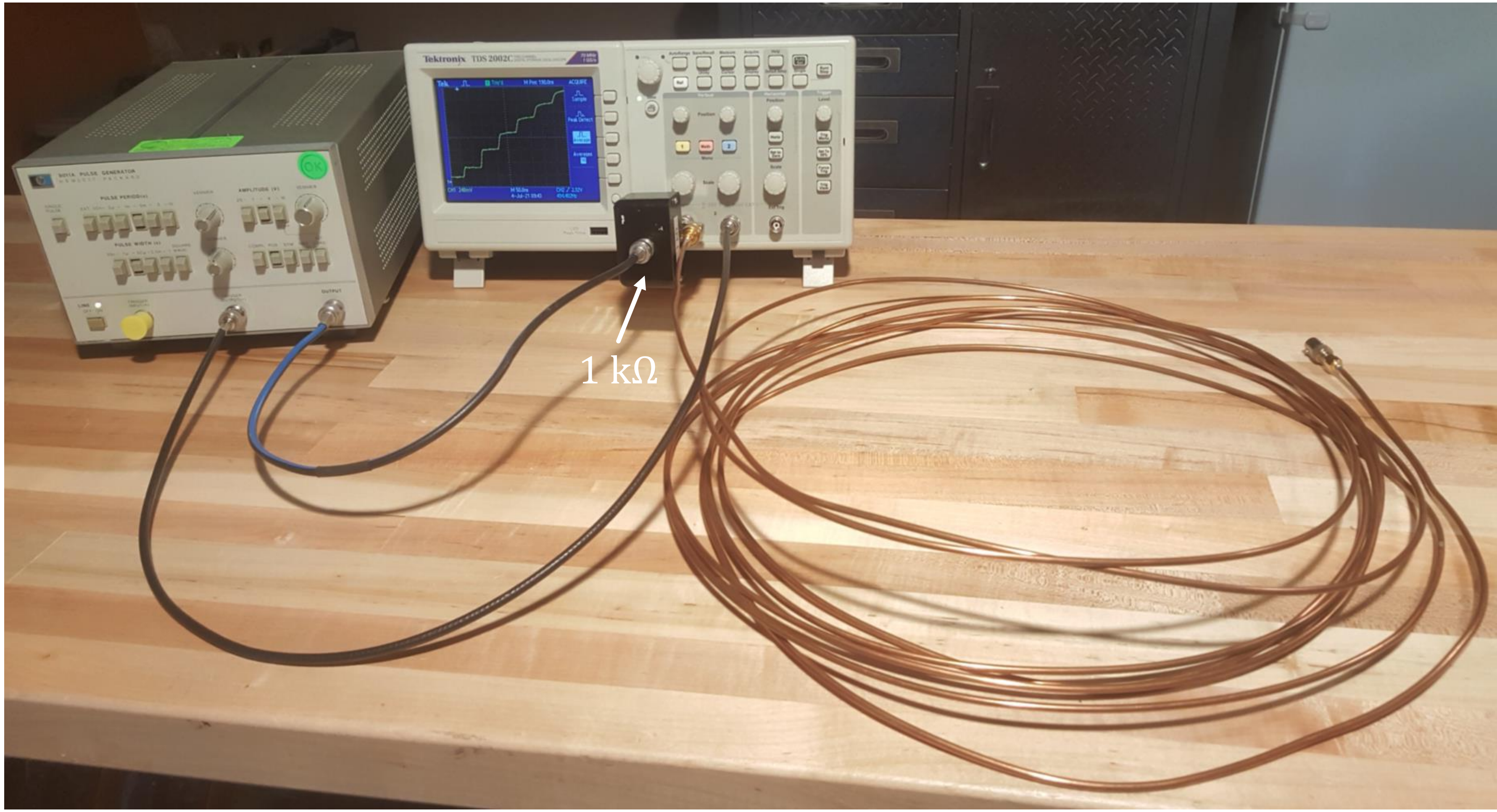


Transient response…

Pulse generator: HP 8011A

Oscilloscope: Tektronix
TDS 2002C (70 MHz)

Coax: UT-141 semi-rigid (8-m long)
copper outer conductor
SPCW inner conductor



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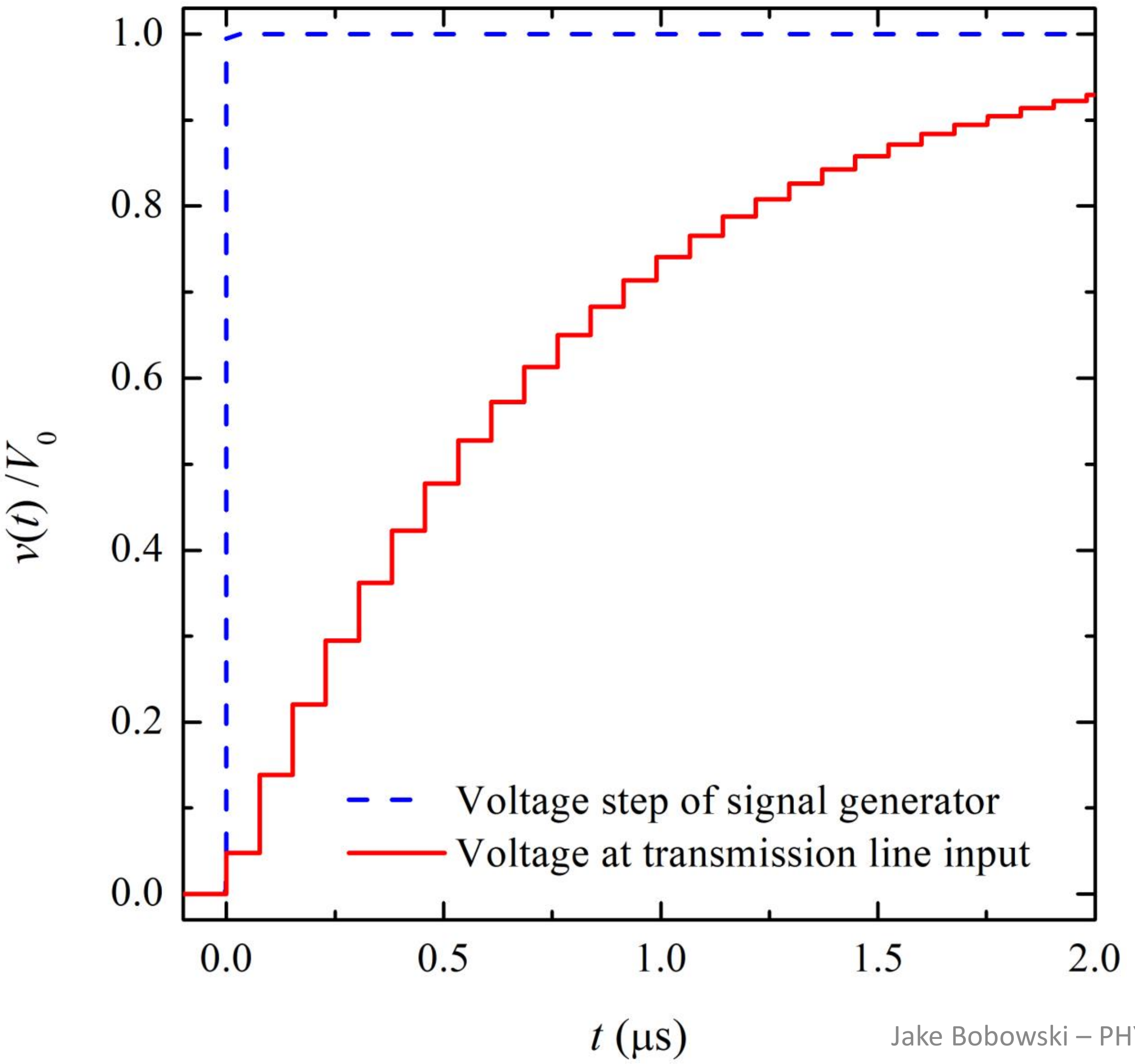
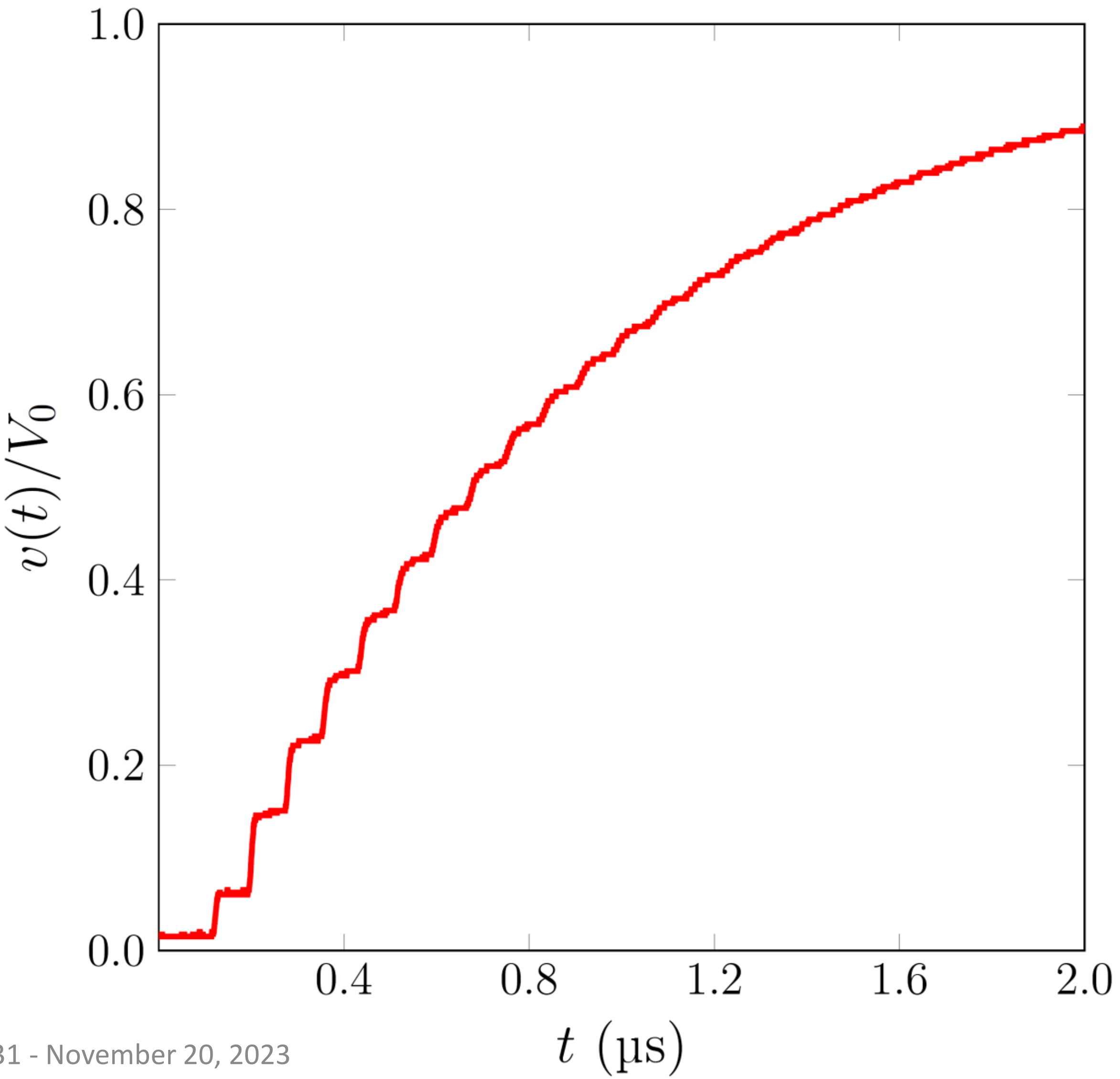
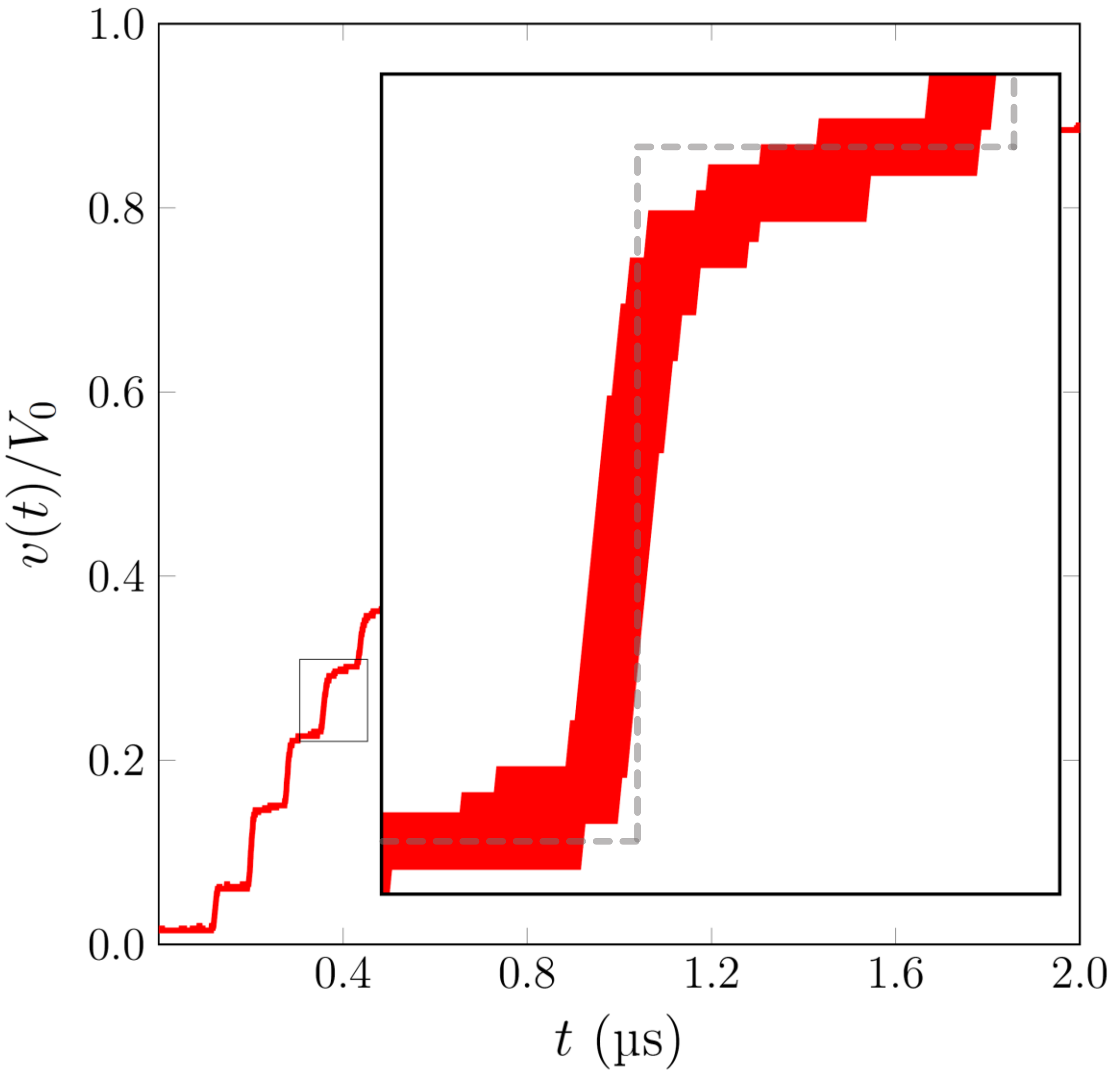




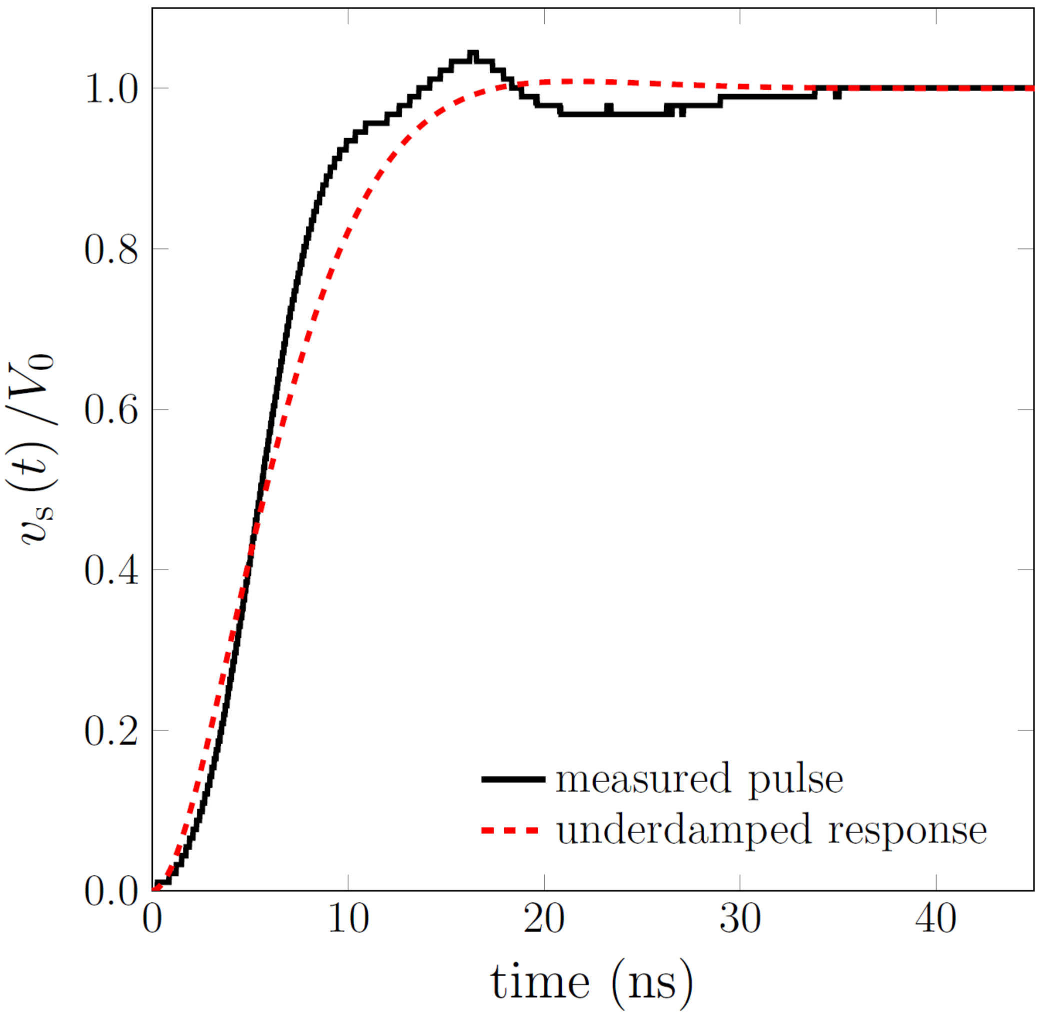
Transient response…



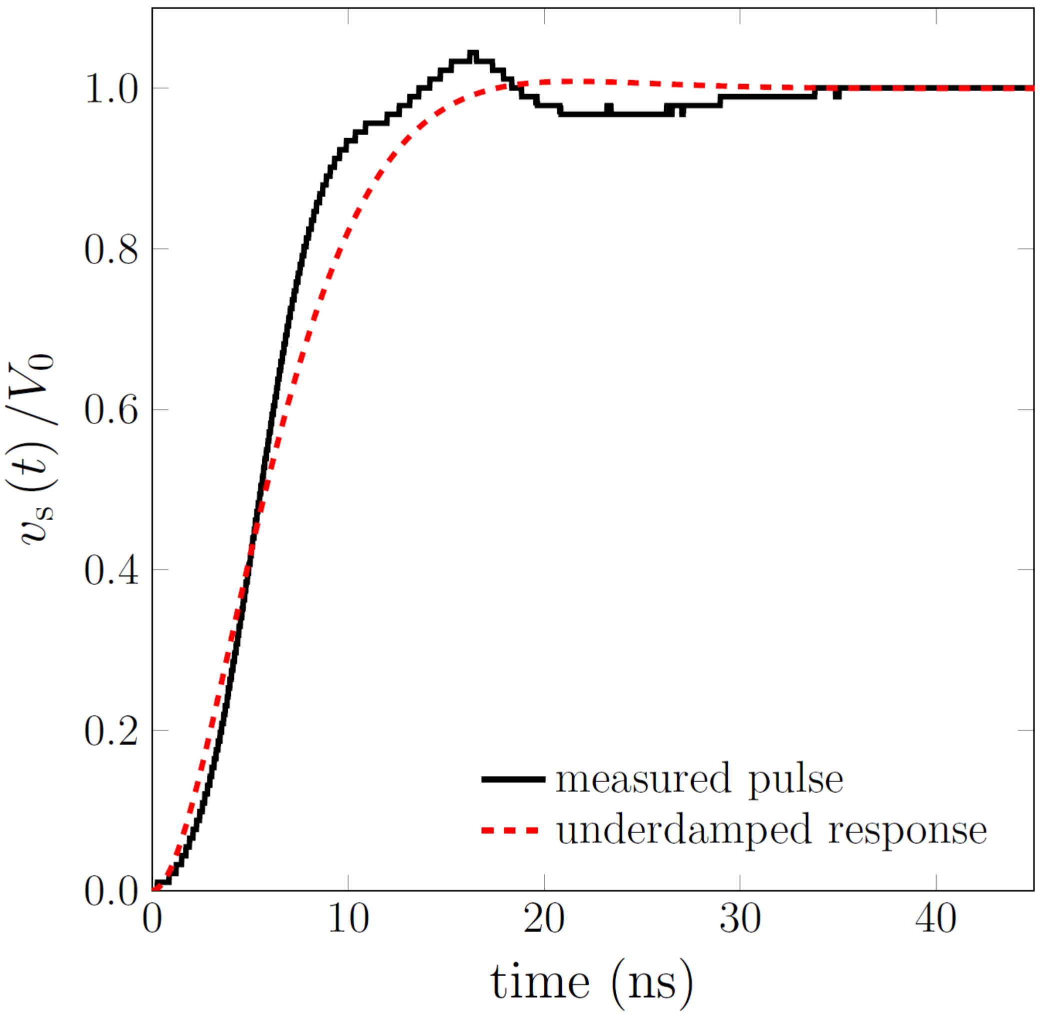
Non-ideal features:

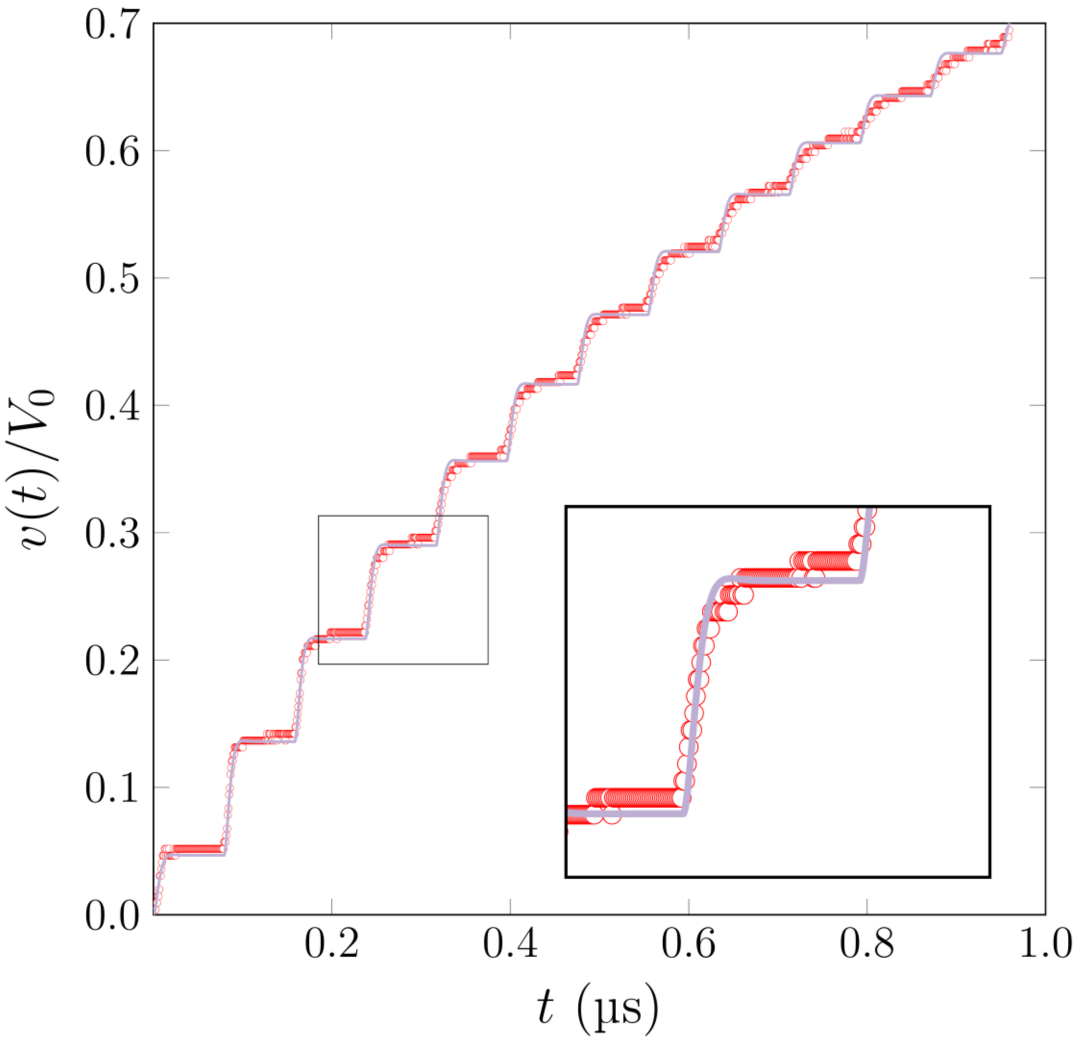
- Finite slope of vertical part of step
- Non-zero slope of horizontal part of the step
- Rounded corners

Transient response with finite rise time…



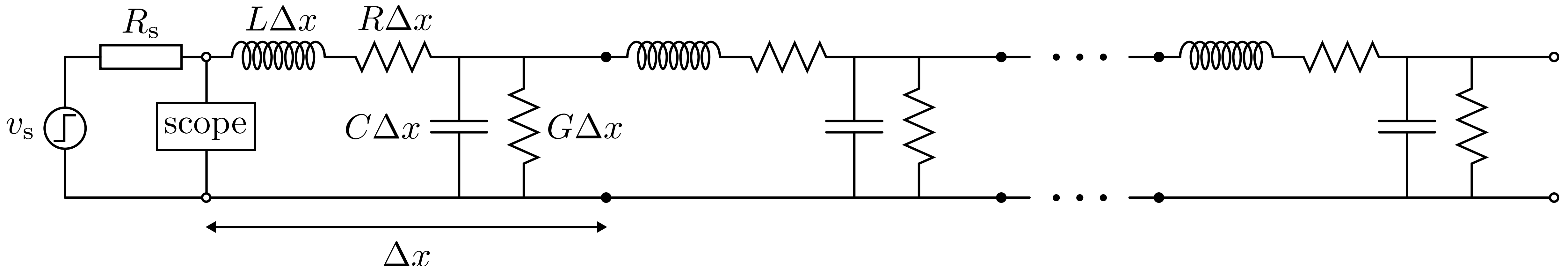
Transient response with finite rise time…





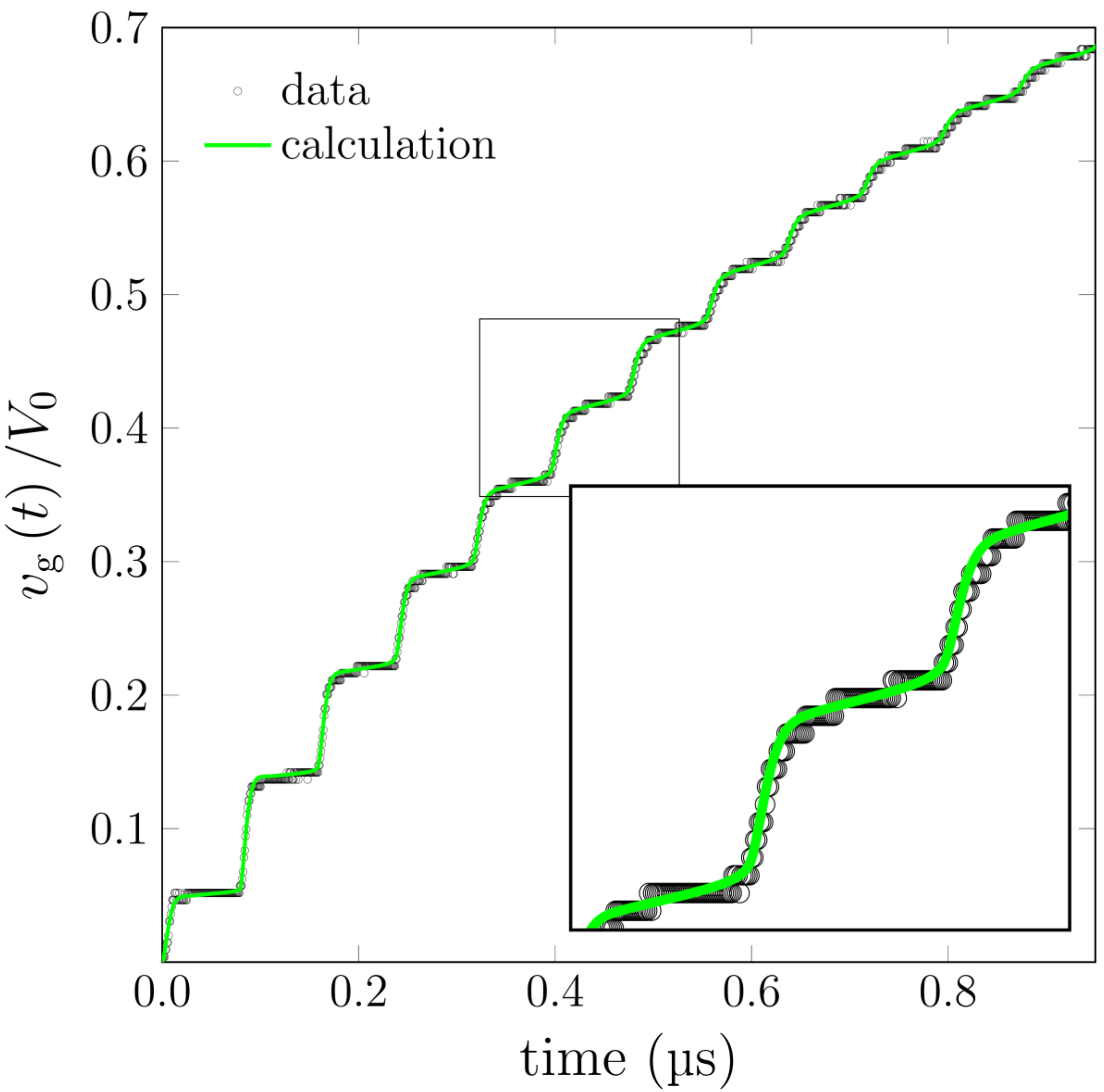
Transmission line losses…

Model both the dielectric and conductor losses of a coaxial transmission line.
Include these effects in the calculated transient response.



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

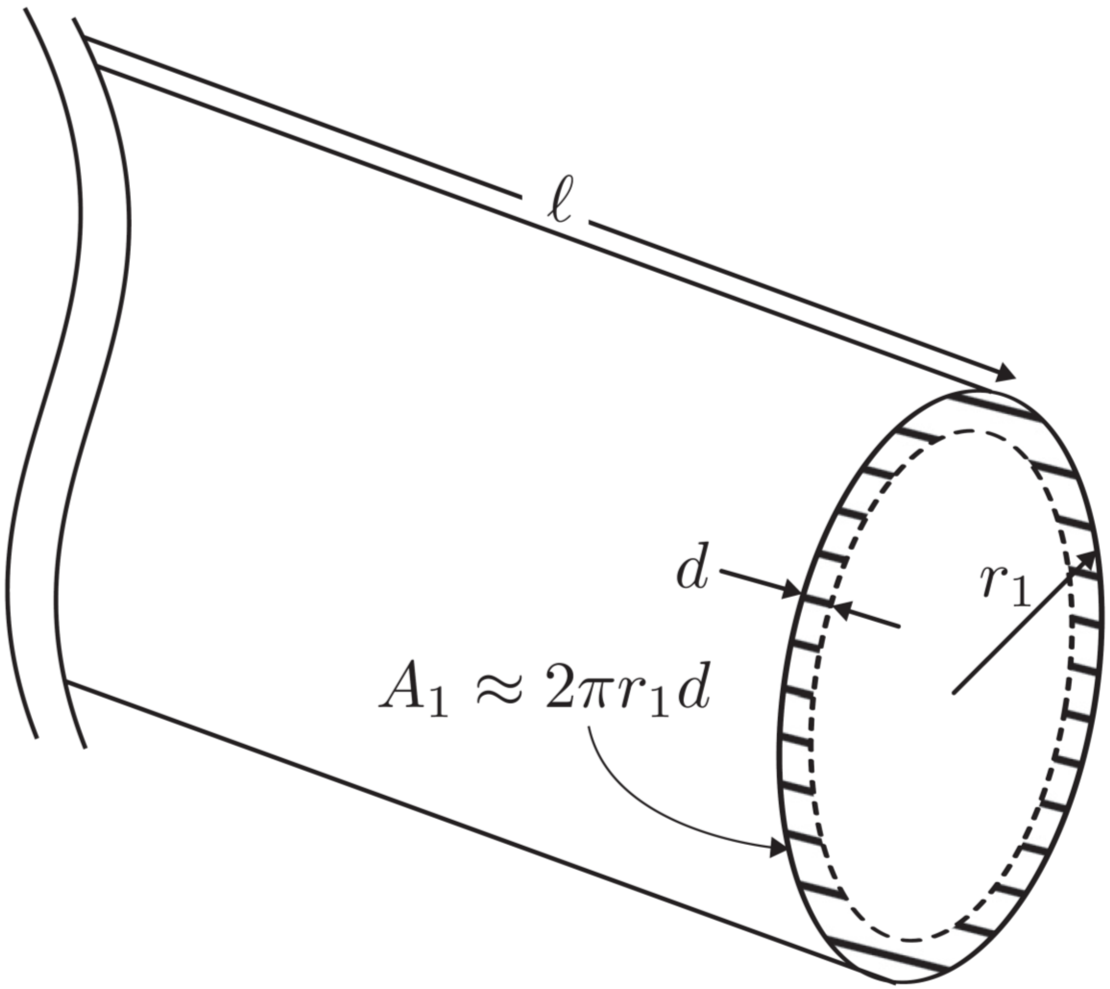
Transients in a lossy transmission line…



Includes:

- Finite rise time
- Conductor losses
- Dielectric losses had no effect

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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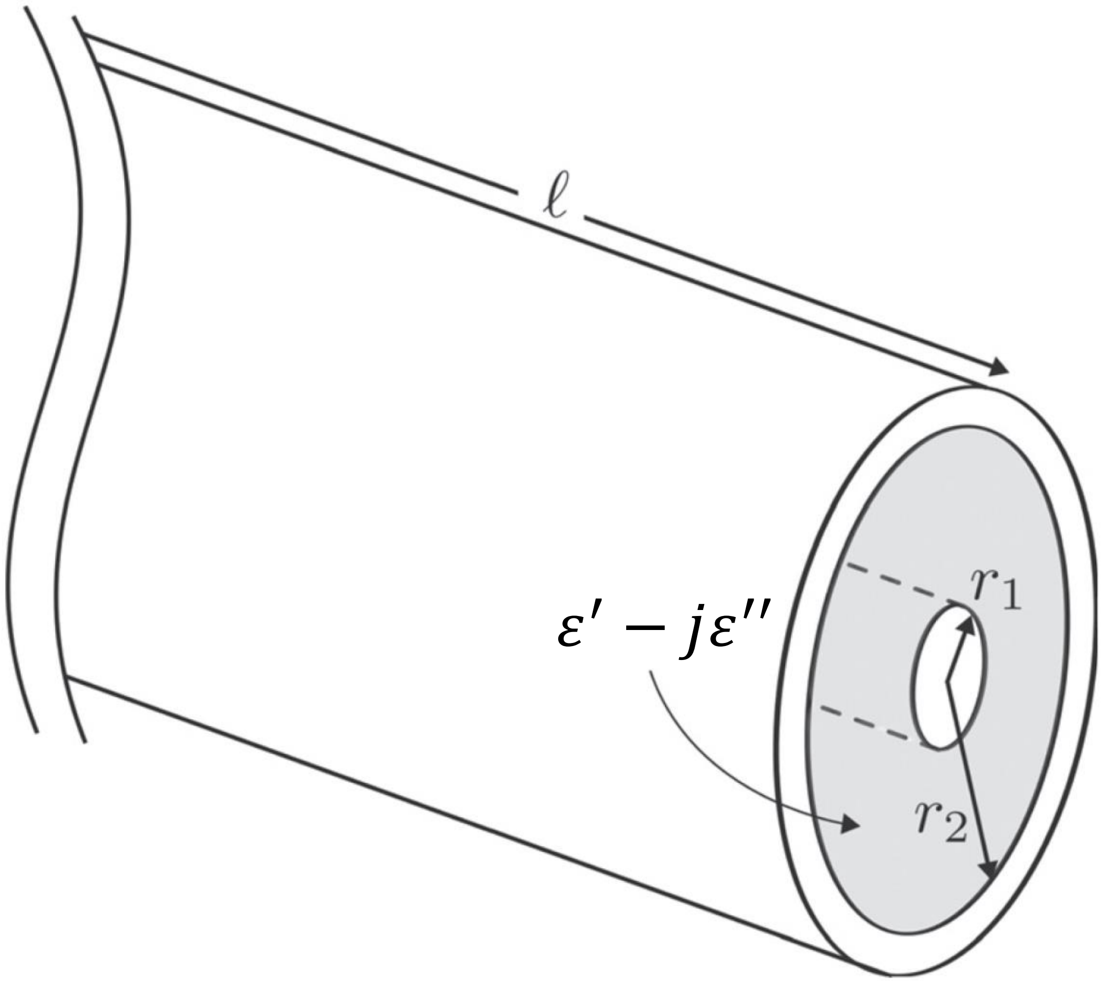
Transmission line losses…



Admittance per unit length:

$$j\omega C = j\omega\left[\frac{2\pi\varepsilon_{\mathrm{r}}\varepsilon_0}{\ln(r_2/r_1)}\right]$$

Conductance per unit length:

$$G = \frac{2\pi\omega\varepsilon''\varepsilon_0}{\ln(r_2/r_1)}$$

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Transmission line losses… cooling to 77 K

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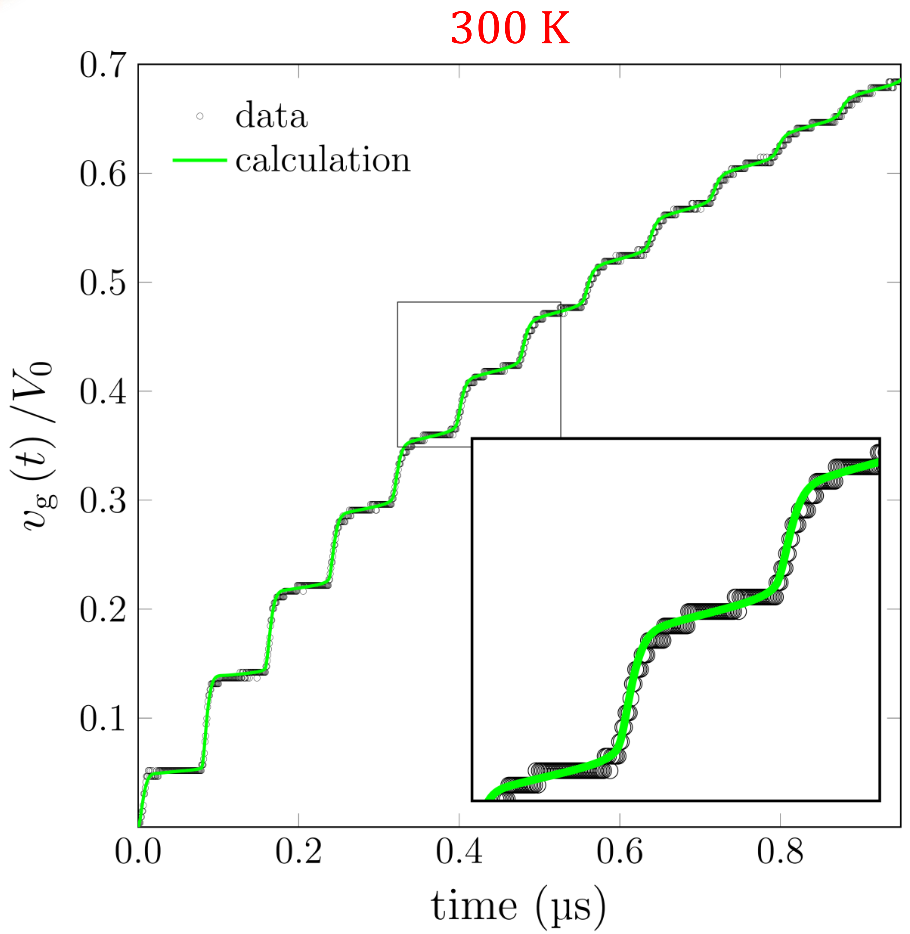
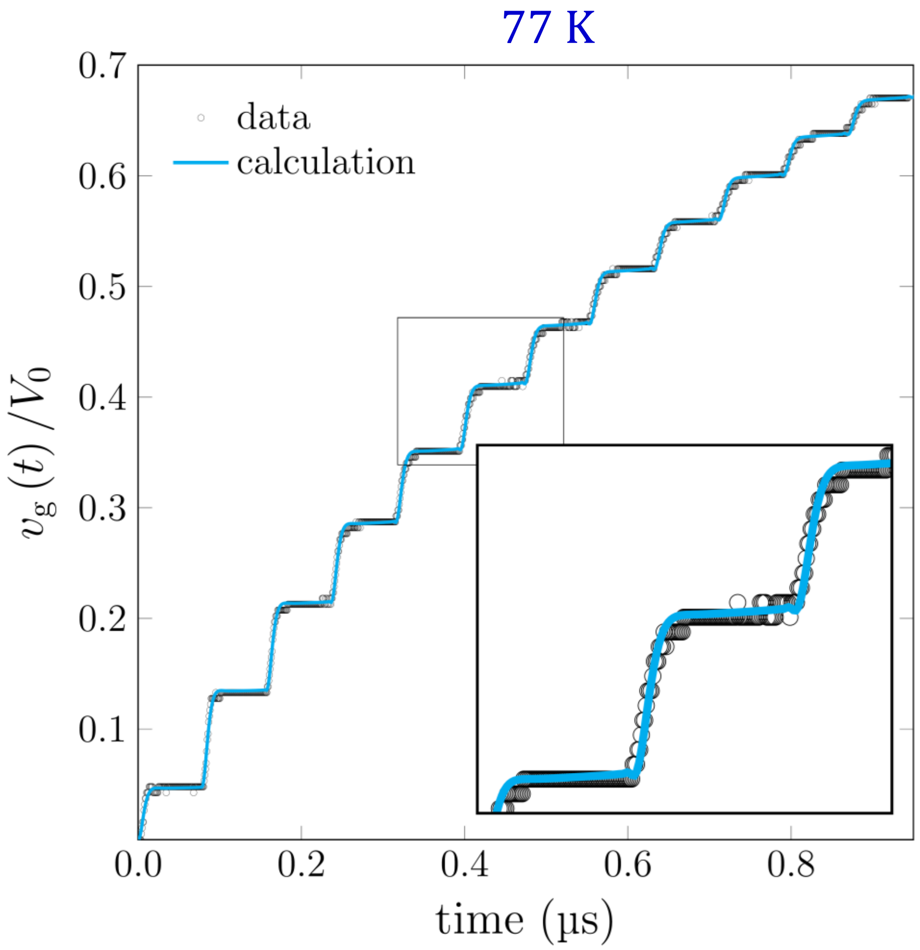
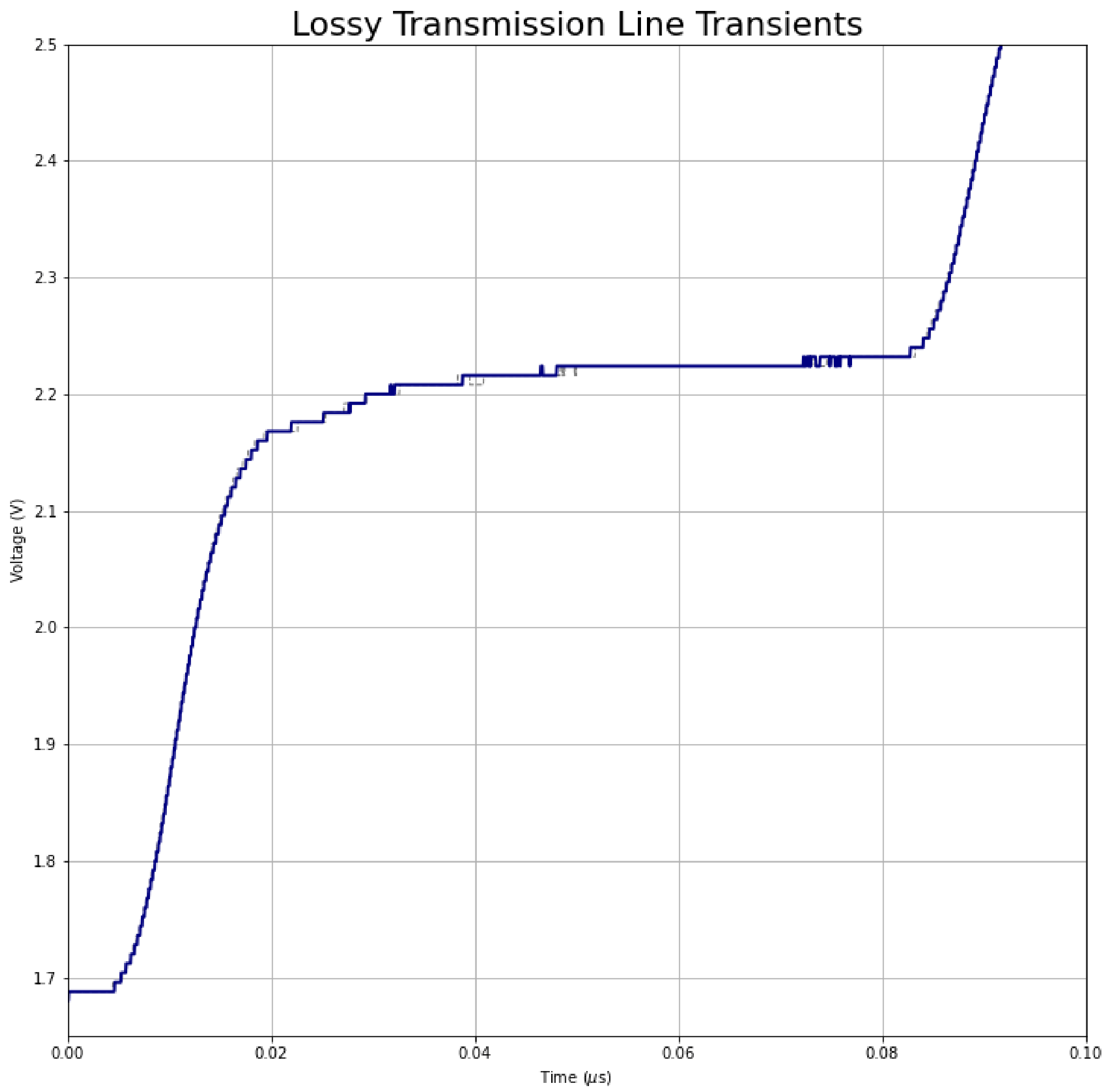




Transients in lossy transmission lines, arXiv:2011.00430.


Lossy Transmission Line Transients
Voltage (V)
Time (μs)
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
0.00
0.02
0.04
0.06
0.08
0.10

Link to gif.