

EE 3113

INTRODUCTION INTO RF

CIRCUIT DESIGN

Lecture Notes for A-term 1999

LECTURE 3

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Transmission Line Analysis

- Propagating electric field

$$E_x = E_{0x} \cos(\omega t - kz)$$

Space factor
↙



Time factor

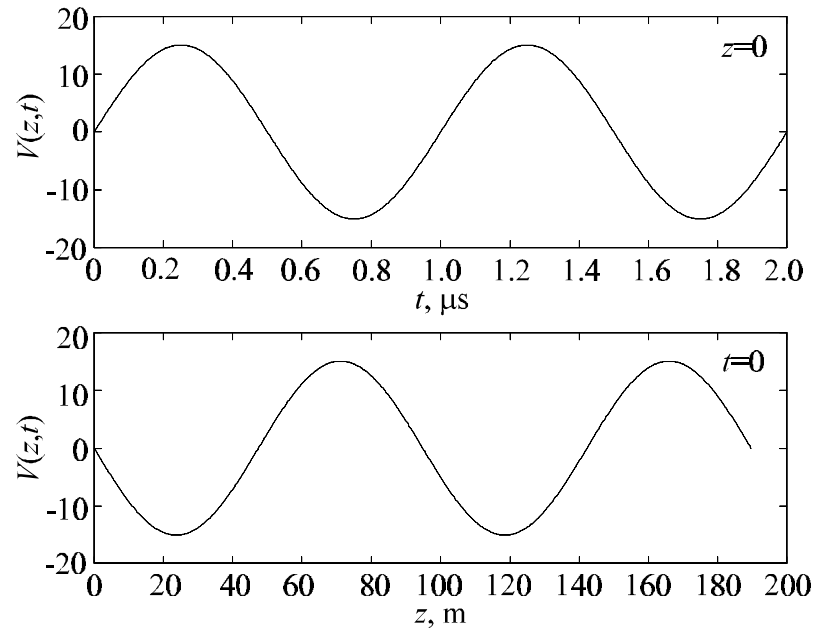
- Phase velocity

$$v_p = \lambda f = \frac{1}{\sqrt{\epsilon\mu}} = \frac{c}{\sqrt{\epsilon_r}}$$

- Traveling voltage wave

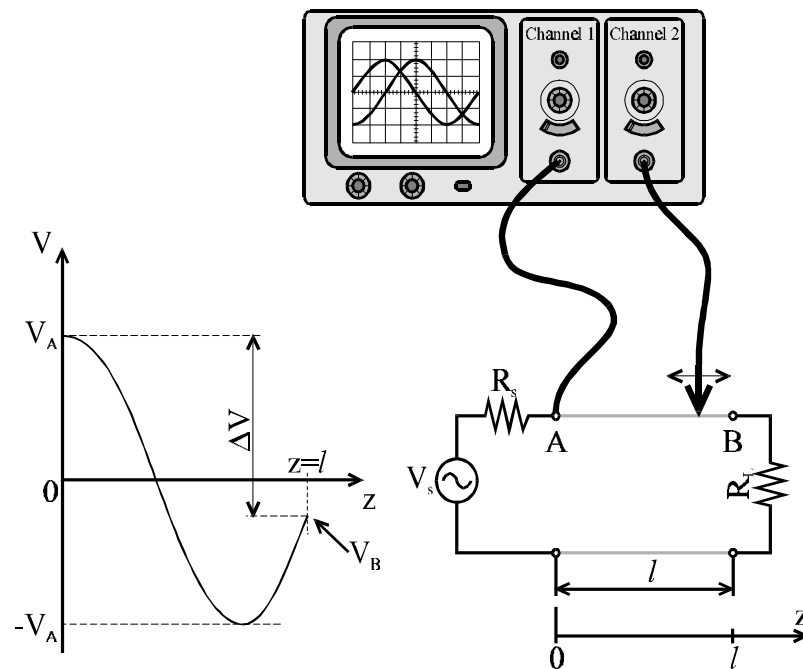
$$V(z, t) = E_{0x} \frac{\sin(\omega t - kz)}{k}$$

High frequency implies spatial voltage distribution



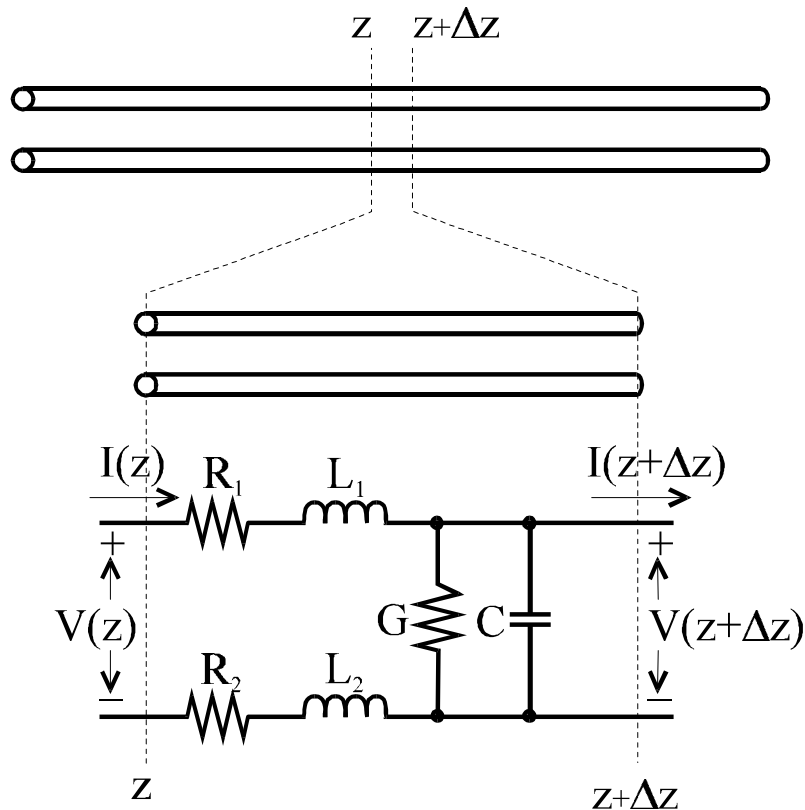
- Voltage has a time and space behavior
- Space is neglected for low frequency applications
- For RF there can be a large spatial variation

Generic way to measure spatial voltage variations



- For low frequency (1MHz)
Kirchhoff's laws apply
- For high frequency (1GHz)
Kirchhoff's laws do **not**
apply anymore

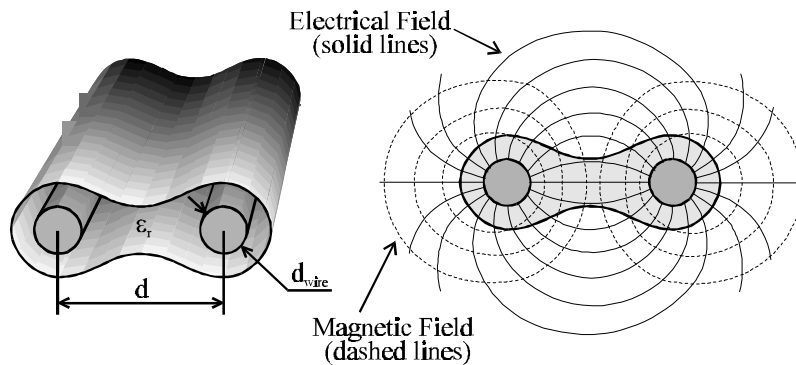
Kirchhoff's laws on a microscopic level



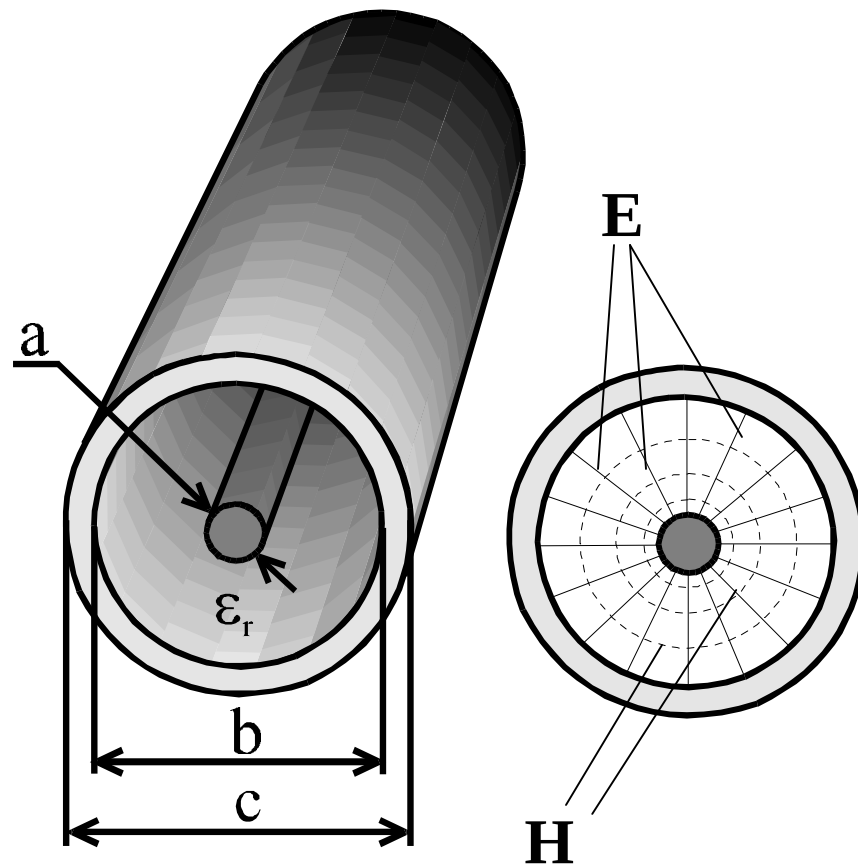
- Over a differential section we can again use basic circuit theory
- Model takes into account line losses and dielectric losses
- Ideal line involves only L and C

Example of transmission line: **Two-wire line**

- Alternating electric field between conductors
- alternating magnetic field surrounding conductors
- dielectric medium tends to confine field inside material

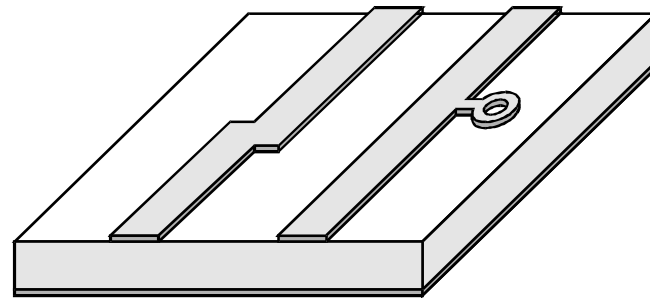


Example of transmission line: **Coaxial cable**

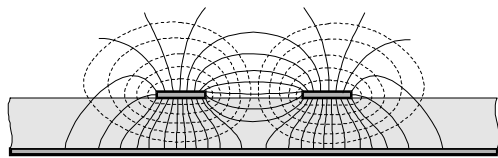


- Electric field is completely contained within both conductors
- Perfect shielding of magnetic field
- TEM modes up to a certain cut-off frequency

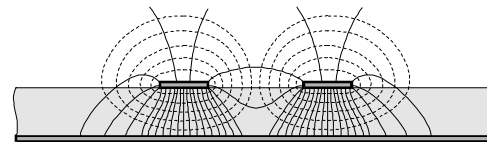
Example of transmission line: Microstrip line



Cross-sectional view



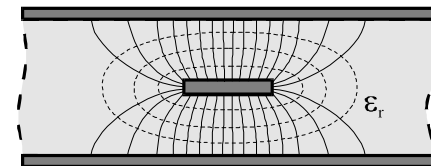
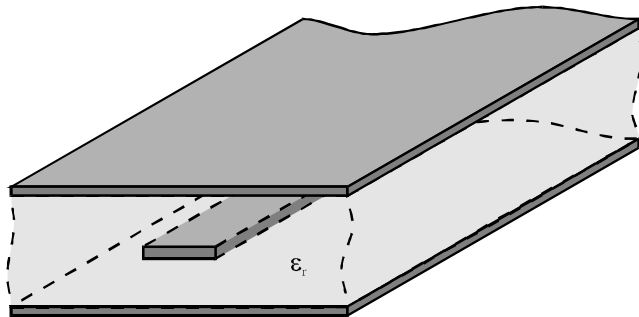
Low dielectric medium



High dielectric medium

Triple-layer transmission line

Conductor is completely shielded between two ground planes



Cross-sectional view