Microwave theory, March 19, 2014

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Electrical and information technology

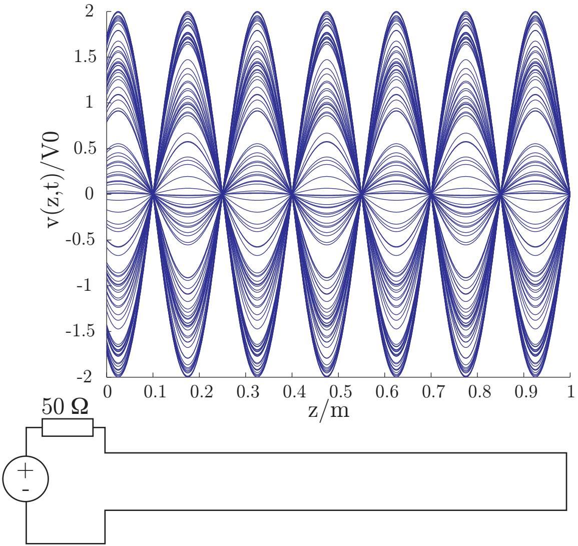
Outline

- Reflection coefficient Γ
- Input impedance

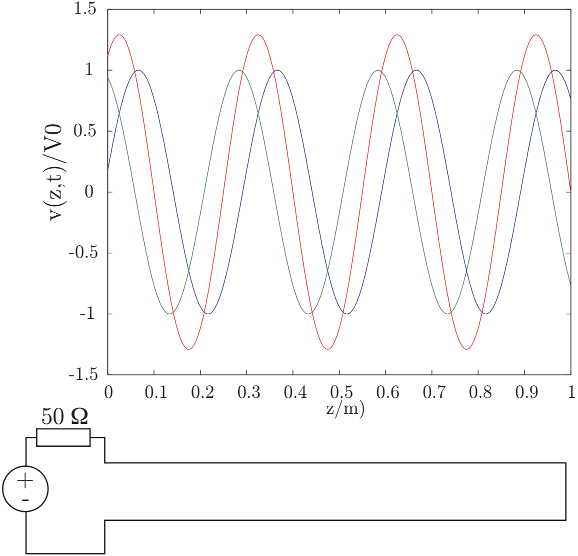
Today:

- Standing wave ratio
- Lossy transmission line. Attenuation. Distortion.
- R, L, G, C

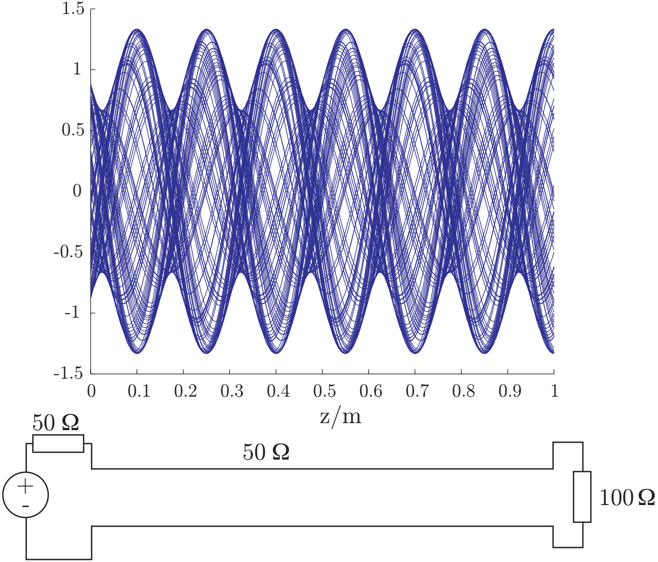
Standing wave



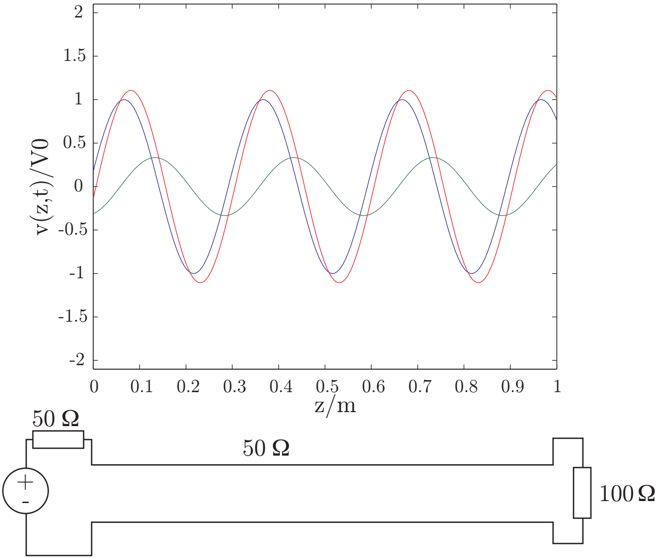
Standing wave



Standing wave



Standing wave



Reflection coefficient Γ

- $V(z) = V_p e^{-j\beta z} + \Gamma V_p e^{\mathrm{j}\beta(z-2\ell)}$
- $\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$ =reflection coefficient at $z = \ell$.
- $v(z,t) = \mathrm{Re}\{V(z)e^{\mathrm{j}\omega t}\}$
- $v(z,t) = V_p \cos(\omega t - \beta z) + \Gamma V_p \cos(\omega t + \beta z - 2\beta\ell)$

Input impedance

The input impedance is the equivalent impedance at $z = 0$

$$Z(0) = Z_0 \frac{Z_L \cos \beta\ell + \mathrm{j} Z_0 \sin \beta\ell}{Z_0 \cos \beta\ell + \mathrm{j} Z_L \sin \beta\ell}$$

Quarter wave transformer

Quarter wave transformer. $\ell = \lambda/4 \Rightarrow \beta\ell = \pi/2 \Rightarrow$

$$Z(0) = \frac{Z_0^2}{Z_L}$$

We can get any $Z(0)$ we like by choosing Z_0!

Standing wave ratio (SWR)

$$S = \frac{|V(z)|_{\text{max}}}{|V(z)|_{\text{min}}}$$

$$S = \frac{|V_p| + |V_n|}{|V_p| - |V_n|} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

The SWR is very good for measuring Γ and Z_L at high frequencies.

Lossy transmission lines

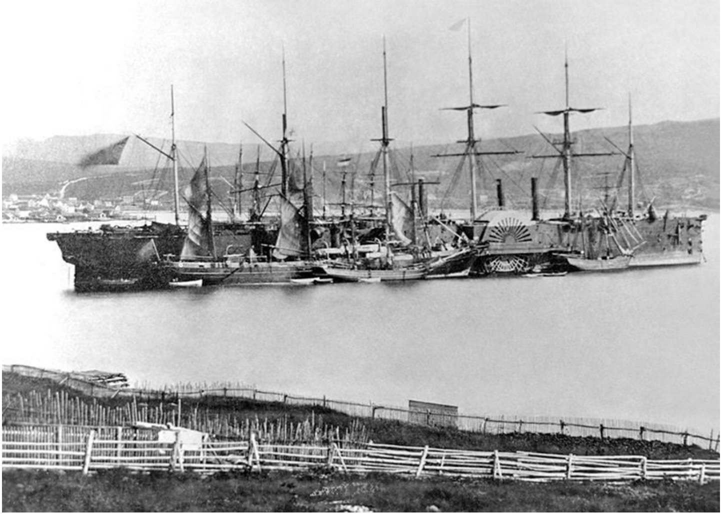
$R \neq 0$ and/or $G \neq 0 \Rightarrow$

- Losses.
- Attenuation ($V^+(z) = V_p e^{-\alpha z} e^{-\mathrm{j}\beta z}$).
- Distortion since β, α, Z_0 are frequency dependent.

Atlantic cable

- August 16, 1858 "Glory to God in the highest; on earth, peace and good will toward men." 16 h to send (0.5 signs/minut). Morse signals were sent as $+V$ for $\cdot$ and -V for $-$.
- 1865 The Great Eastern laid a new cable. Eight words per minute. No repeaters.
- Around 1900: 120 words per minute
- 1956 Transatlantic telephone cable. 36 channels with bw 4 kHz.
- 1988 Fiber optical cables

The Great Eastern



Oliver Heaviside

Lossy transmission lines

$$\gamma = \sqrt{(R + \mathrm{j}\omega L)(G + \mathrm{j}\omega C)} = \alpha + \mathrm{j}\beta$$

$$Z = \sqrt{\frac{R + \mathrm{j}\omega L}{G + \mathrm{j}\omega C}}$$

$v_p = \omega/\beta$

Heaviside's idea

$$\gamma = \mathrm{j}\omega\sqrt{LC}\sqrt{(1-\mathrm{j}R/(\omega L))(1-\mathrm{j}G/(\omega C))} = \alpha + \mathrm{j}\beta$$

$$Z = \sqrt{\frac{L}{C}}\sqrt{\frac{R/L+\mathrm{j}\omega}{G/C+\mathrm{j}\omega}}$$

1887 Heaviside said: Let $R/L = G/C$ by adding L!
Operational calculus (Laplace transform)
Vector analysis for Maxwell equations
Lorentz force
Transmission line theory
Cerenkov radiation
Admittance, conductance, impedance, inductance, permeability, permittivity

Michael Pupin

1899 Pupin took a patent on Pupin coils.
1883 went to study for Maxwell. Found that Maxwell had died 1879.
Moved to Berlin and started to study for Hermann von Helmholtz.
Heinrich Hertz was also a student of Helmholtz.