Microwave theory, March 22, 2016

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Electrical and information technology

Outline

MONDAY:

- Reflection coefficient Γ
- Input impedance
- Standing wave ratio

Tuesday and Wdnesday:

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

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

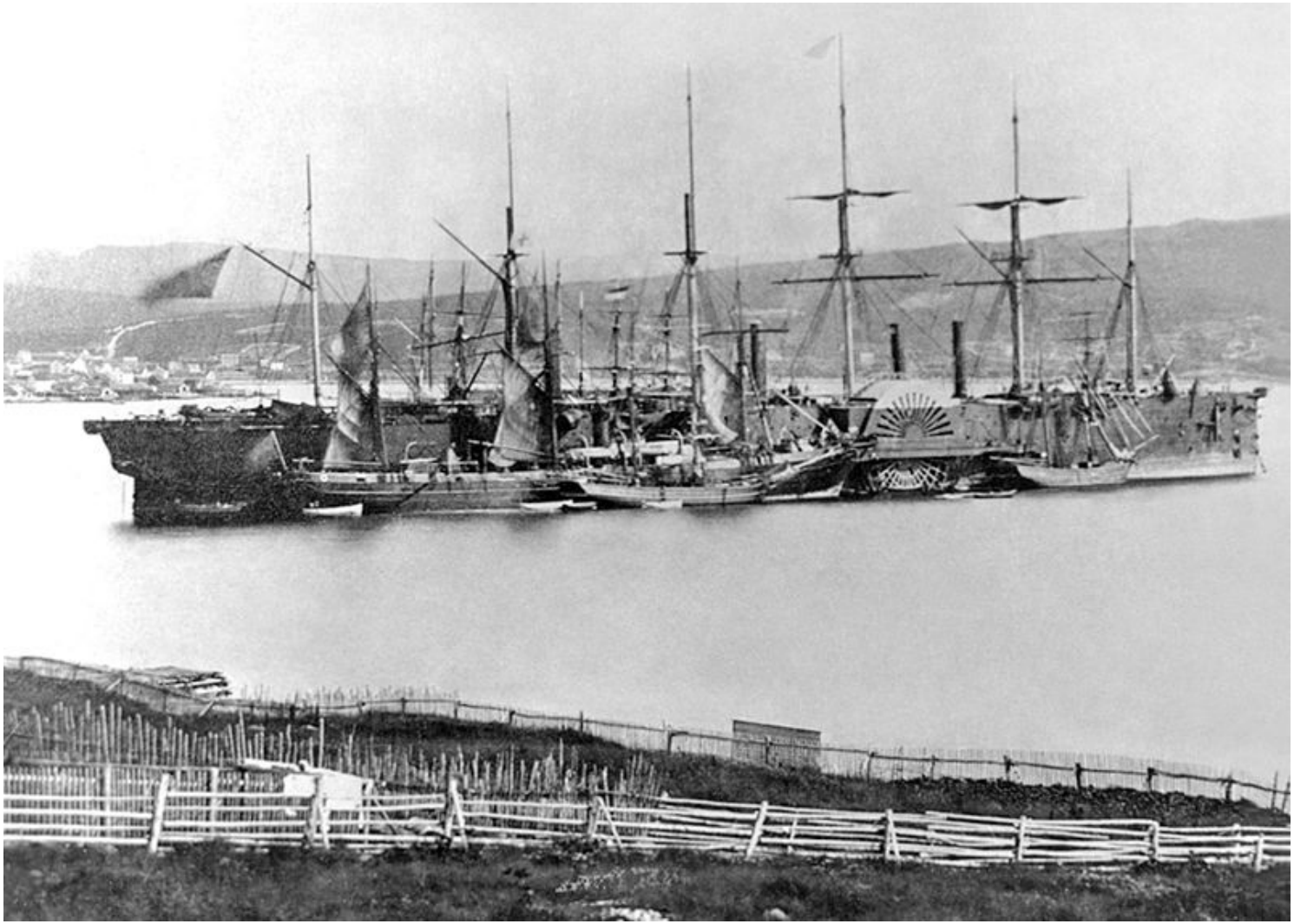
$R \neq 0$ and/or $G \neq 0 \Rightarrow$

- Losses.
- $V(z) = V_p e^{-\gamma z} + V_n e^{\gamma z}$
- $\gamma = \sqrt{(R + \mathrm{j}\omega L)(G + \mathrm{j}\omega C)} = \alpha + \mathrm{j}\beta$=propagation constant
- $\alpha =$ attenuation constant.
- $\beta =$phase constant. $\beta = \dfrac{\omega}{v_\mathrm{p}}$ where $v_\mathrm{p} =$phase speed.
- Distortion since v_p, 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!

Then $Z = \sqrt{\dfrac{L}{C}}$, $v_{\mathrm{p}} = \dfrac{1}{\sqrt{LC}}$, and $\alpha = R\sqrt{C/L}$ frequency independent!

Oliver Heaviside

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 based on Heaviside's idea..