Topics for Today:

- Announcements
  - Software: online students - apply for ATP/ATPDraw license, verify licensing when you receive it by e-mail, and we will mail you the install CD.
  - Office hrs: 4-5pm M,W; 10-11 Friday
  - Office: EERC 614. Phone: 906.487.2857
  - Book exercises from Ch.6,7 solutions posted

Chapter 6 - Transmission Lines

- Using the T-Line models
  - Short Transmission Lines - up to 50 miles (80 km)
  - Voltage Regulation, phasor diagrams
  - Per-phase impedance diagrams (positive seq only)
  - Medium-Length Lines (50 - 150 miles)
  - ABCD parameters for Medium-lines, power flow
  - Long Lines - more than 150 miles (240 km)
  - Derivation of long-line equations, meaning of equations
  - Characteristic Impedance $Z_C$
  - Propagation Constant $\gamma = \alpha + j\beta$
  - Surge-Impedance Loading (SIL)
  - Wavelength, velocity, Traveling waves, reflections
\[ Z_c = \sqrt{\frac{Z}{Y}} \quad \text{Imp per unit length} \]

\[ X = \sqrt{Z \cdot Y} = \alpha + j\beta \quad \text{Phase angle rotation} \]

Has a wave travels down line.

Attenuation

\[ V_s - \frac{Y'}{2} - \frac{Y'}{2} - R \]

Open Receiving End

\[ R_{load} = Z_c \quad \text{(SIL)} \]

Full Load

Short Circuit
Another Point:
- SIL = Surge Impedance Loading
- $R_{load} = |Z_c|$
- Total Reactive Power Consumed in Line = 0.
- "Flat" Line or flat voltage profile.
- $SIL = \frac{V^2}{Z_c} = \frac{V_s^2}{Z_c} = \frac{V^2}{Z_c}$
High $x/R$:
\[ z_c = \sqrt{\frac{z}{y}} \]

Low $x/R$:
\[ Z_e = \sqrt{\frac{Z}{\text{unit length}}} \]

\[ Z = R + jX \quad \text{per unit length} \]

\[ y = j \omega C \]

\[ 1 = \frac{\text{Real}}{100} \quad \text{for high } \frac{x}{lR} \text{ ratio} \]

\[ Z_e \Rightarrow \text{Real} \Rightarrow 10^2 \text{EV} \quad \frac{x}{lR} \leq 1 \]

Observations:
Propagation Wavelength $\lambda$

$\lambda = \text{distance req'd to change } \Psi \text{ by } 360^\circ$

$\lambda = \sqrt{\frac{2}{\mu \epsilon}} \alpha + j \beta$  (Assume Lossless)

$e^{j\beta x}$: term provides phase rotation in each term of $I(x)$, $V(x)$.

$\lambda = \frac{2\pi}{\beta} \Rightarrow \lambda = \frac{2\pi}{\omega \sqrt{\mu \epsilon}} = \frac{2\pi}{2\pi f \sqrt{LC}}$

$\nu = \frac{1}{\sqrt{LC}} = 3 \times 10^8 \text{ m/s} = \frac{1}{\sqrt{\frac{e_0}{M_0}}}$
@ 60 Hz, \( \lambda = \frac{v}{f} = \frac{3 \times 10^8 \text{ m/s}}{60} \)

BPL: 2-40 MHz \( \approx \) 5000 Km \( \approx \) 3100 miles

@ 2 MHz, \( \lambda = \frac{3 \times 10^8}{2 \times 10^5} = 150 \text{ m} \)

- Side Comments (later) on T-line loading limits
  1) - Thermal
  2) - Voltage Limits, \( V_S \) & \( V_R \) \( \Rightarrow \) \( VR \)
  \( 0.95 < V < 1.05 \)
  3) - Stability Limits
(From Lecture 15)

\[ V(x) = \frac{(VR + Z_c I_R) e^{jx}}{2} + \frac{(VR - Z_c I_R) e^{-jx}}{2} \]

\[ I(x) = \frac{(VR + Z_c I_R) e^{jx}}{2} - \frac{(VR - Z_c I_R) e^{-jx}}{2} \]

\[ Z_c = \frac{1}{\sqrt{1 + \beta^2}} \]

\[ x = \text{characteristic impedance} \]

\[ \alpha = \text{propagation constant} \]

\[ \beta = \text{attenuation constant} \]

\[ \gamma = \sqrt{\beta^2} \]

\[ Z_c = \frac{1}{\sqrt{1 + \beta^2}} \]
Travelling Waves

Impedance at receiving end:

\[ Z_R = \frac{V_R}{i_R} = \frac{V_R^+ + V_R^-}{i_R^+ + i_R^-} = \frac{V_R^+}{Z_c} - \frac{V_R^-}{Z_c} \]

\[ V_R^- = \frac{Z_R - Z_c}{Z_R + Z_c} \]

Reflection Coefficient
If receiving end is...
- Open-ckt (i.e. $Z_R = \infty$)
  \[ P_R = \frac{R - Z_c}{R + Z_c} = +1 \]
  \[ \therefore V_R^- = V_R^+ P_R = V_R^+ \]
- Short-ckt (i.e. $Z_R = 0$)
  \[ P_R = \frac{0 - Z_c}{0 + Z_c} = -1 \]