Fields and Waves

Lesson 4.5

LOSSY TRANSMISSION LINES

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Lossless/Lossy Models of TL

Lossless Model of TL:

\[ L \quad L \quad L \quad C \quad C \quad C \]

Lossy Model of TL:

\[ R \quad G \quad R \quad I/G \quad R \quad I/G \]

Loss effects due to Resistances:

- R - resistance of conductors
- G - conductivity of insulators

- both are ideally small
Estimation of $R$

, if constant cross-section

On a per meter basis,

because inner and outer conductors are in series

- At high frequencies, not all the copper is used for conducting (see Lesson 3.1)
- Current only flows in outer portion due to skin depth effects
The $1/G$ component represents radial current flow, due to small $\sigma$ of insulator.

- the cross-sectional area is not constant

**Estimation of G:**

From Electrostatics,

$$\vec{j} = \sigma \cdot \vec{E} = \frac{\sigma}{\varepsilon} \cdot \vec{D}$$

Also,

$$g = \frac{G}{l} = \frac{\sigma}{\varepsilon} \cdot c$$

Do Problem 1a & 1b
Effects on $Z_c$ - Characteristic Impedance

For Lossless system, $R_c$ represents

$$R_c = \sqrt{\frac{l}{c}}$$

Replace $j \cdot \omega \cdot l$ with $r + j \cdot \omega \cdot l$

Replace $j \cdot \omega \cdot c$ with $g + j \cdot \omega \cdot c$

$$Z_c = \frac{r + j \cdot \omega \cdot l}{\sqrt{g + j \cdot \omega \cdot c}}$$
For lossless systems:
\[ \beta = \omega \cdot \sqrt{l \cdot c} \]

For lossy systems:
\[ \gamma = \alpha + j \cdot \beta = \sqrt{(r + j \cdot \omega \cdot l)(g + j \cdot \omega \cdot c)} \]

The phasors have the factor:
\[ e^{-\gamma \cdot z} = e^{-\alpha \cdot z} \cdot e^{-j \cdot \beta \cdot z} \]

Attenuation/loss factor due to resistance