Low Loss T-line

Standard RG58 cable
\( f = 1\text{MHz} \)
\( R' = 0.1 \Omega/m \)

\[ e^{-\alpha \cdot 1600} = 0.2 \]

\[ \alpha = \frac{\ln(1/0.2)}{1600} = 0.001 \text{ Np/m} \]

\[ \alpha = \frac{R'}{2Z_o} \]
## Types of Transmission Lines

### (a) Coaxial line

**$R' (\Omega/m)$**

\[
\frac{R_s}{2\pi} \left( \frac{1}{a} + \frac{1}{b} \right)
\]

**$R_s$**

\[
\frac{R_s}{\pi a}
\]

**$2R_s/w$**

### (b) Two-wire line

**$L' (H/m)$**

\[
\frac{\mu}{2\pi} \ln \left( \frac{b}{a} \right)
\]

**$\approx \frac{\mu}{\pi} \ln \left( \frac{d}{a} \right)$** for $d >> 2a$

### (c) Parallel-plate line

**$C' (F/m)$**

\[
\frac{2\pi\varepsilon}{\ln \left( \frac{b}{a} \right)}
\]

**$G' (S/m)$**

\[
G' = \frac{\sigma}{\varepsilon} C'
\]

$L'C' = \mu\varepsilon$

for TEM T-lines

$(\mu, \varepsilon, \sigma)$ pertain to insulator

$(\mu_c, \sigma_c)$ pertain to conductor

Skin depth $\delta = \frac{1}{\sqrt{\pi\mu_c\sigma_c}}$
Distortionless Lines

- Example: \( R' = 0.025 \, \Omega/m \) \( L' = 0.195 \, \mu H/m \)
  \( G' = 0 \, S/m \) \( C' = 78 \, pF/m \)

\( l = 10,000 \, m \)
Distortionless Lines

- Square and Gaussian pulses are distorted
Distortionless Lines

- Distorted at the input and due to propagation
Distortionless Lines

- Add a capacitor to the input to partially compensate for the input distortion.
Distortionless Lines

- There remains distortion due to propagation
Distortionless Lines

- Result: no distortion but smaller pulses

\[ G' = 10^{-5} \text{ S/m} \]

\[ \frac{G'}{C'} = \frac{R'}{L'} \]
Distortionless Lines

- Expanded view
Distortionless Lines

• In the early days of telephony, Heaviside proposed making lines distortionless.
• This was done by adding inductance rather than conductance since the losses were not increased significantly.

$$\frac{G'}{C'} = \frac{R'}{L'}$$

http://www.du.edu/~jcalvert/tech/cable.htm

Campbell-Shaw Loading
Oliver Heaviside

- He reduced Maxwell’s equations from 20 with 20 unknowns to 2 with 2 unknowns.
- From Cats -- Journey to the Heaviside Layer: Up up up past the Russell hotel, Up up up to the Heaviside layer

http://www-gap.dcs.st-and.ac.uk/~history/BigPictures/
Distortionless Lines

• To add resistance and make the signal better is hard to accept without some serious theoretical basis.
• Adding these components made it possible for phone calls to go from NY to Chicago.
• This is maybe the very best example of why a solid, math-based education can produce some non-intuitive results in engineering.
Distortionless Lines

• References

• http://www.hep.princeton.edu/~mcdonald/examples/distortionless.pdf
• http://www.du.edu/~jcalvert/tech/cable.htm