Shree Sathyam
College of Engineering and Technology
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai.
NH-544, Salem - Coimbatore Highways, Kuppanur, Sankari Taluk, Salem - 637301, TamilNadu, India.
Email : principal@shreesathyam.edu.in Web : www.shreesathyam.edu.in Phone : 04283 - 244080

Department of Electronics and Communication Engineering

EC3551 Transmission Lines and RF Systems

Unit 1 – Transmission Line Theory

Presented by

Dr. Kannan Pauliah Nadar, M.E., Ph.D.

Date: 01.08.2024 & Time: 1.45 PM (5th Hour)

Introduction to Transmission Line Theory

Transmission Line Overview:

Transmission lines are used to transport electrical signals with minimal loss over long distances.

Understanding their behavior is essential for designing efficient communication systems.

Key Concepts:

Voltage and current distribution along the line.

Reflection phenomena and impedance matching.

The Transmission Line

General Theory of Transmission Lines:

A transmission line is a specialized structure used for transferring electromagnetic energy.

It consists of conductors separated by a dielectric medium.

Transmission Line Equation:

The general transmission line equation describes the voltage and current along the line as a function of distance and time.

The equation takes into account resistance, inductance, capacitance, and conductance (R, L, C, G).

The Infinite Line and Wave Propagation

- **Infinite Transmission Line:**
  - In the ideal case, the transmission line extends infinitely, preventing reflections and losses.
- **Wavelength and Propagation Velocity:**
  - **Wavelength** (λ): The distance over which the signal's shape repeats.
  - **Propagation Velocity** (v): The speed at which the signal travels along the line, given by:

$$v = \frac{1}{\sqrt{LC}}$$

  where **L** is the inductance per unit length and **C** is the capacitance per unit length.

- **Relationship:**

$$\mathrm{Wavelength}(\lambda) = \frac{v}{f}$$

where f is the frequency of the signal.

Waveform Distortion and Distortion-less Line

- Waveform Distortion:
  - As signals propagate along a transmission line, they may suffer from distortion due to varying propagation speeds of different frequency components.
- Distortion-less Line:
  - A transmission line is called distortion-less if the signal does not suffer from changes in waveform shape during propagation.
  - Conditions for a distortion-less line:

$$R = \sqrt{L/C}, \quad G = 0$$

where **R** is resistance, **L** is inductance, **C** is capacitance, and **G** is conductance.

Line Termination and Reflection Coefficient

- **Line Not Terminated in Z_0:**
  - When the transmission line is not properly terminated (i.e., not matched to the characteristic impedance Z_0), reflections occur.
- **Reflection Coefficient (Γ):**
  - The reflection coefficient measures the ratio of the reflected voltage to the incident voltage:

$$\Gamma = \frac{V_{\text{reflected}}}{V_{\text{incident}}}$$

  - This coefficient depends on the impedance mismatch between the transmission line and its load.

Current, Voltage, Power, and Efficiency Calculations

- **Voltage and Current:**
  - The voltage and current along the transmission line can be described using the following general expressions:

$$V(x) = V_+ e^{-\gamma x} + V_- e^{\gamma x}$$

$$I(x) = \frac{1}{Z_0}(V_+ e^{-\gamma x} - V_- e^{\gamma x})$$

  where **V_-** and **V_+** are the backward and forward traveling wave voltages, and **γ** is the propagation constant.

- **Power Delivered and Efficiency:**
  - Power delivered to the load is calculated using:

$$P = \frac{V^2}{2Z_0}$$

  - The efficiency of transmission is defined as the ratio of the power delivered to the load to the total power sent along the line.

Open and Short Circuited Lines

- **Open-Circuited Line:**
  - For an open-circuited line, the load impedance is infinite, causing a reflection coefficient of +1.
- **Short-Circuited Line:**
  - For a short-circuited line, the load impedance is zero, leading to a reflection coefficient of -1.
- **Reflection Factor and Loss:**
  - Reflection factor is a measure of the power lost due to reflection, given by:

$$\text{Reflection Loss} = 10 \log_{10}(1 - |\Gamma|^2)$$

Input and Transfer Impedance

- Input Impedance:
  - The input impedance of a transmission line is the ratio of voltage to current at the input:

$$Z_{\text{in}} = Z_0 \frac{1 + \Gamma e^{-2\gamma l}}{1 - \Gamma e^{-2\gamma l}}$$

  - where l is the length of the line, and Γ is the reflection coefficient.
- Transfer Impedance:
  - Transfer impedance relates the voltage at the input to the current at the output, incorporating both the input and output impedance of the line.

Summary of Transmission Line Theory

- Transmission lines are fundamental components in RF and communication systems, enabling the transfer of electrical signals over distance.
- Understanding the key characteristics, such as reflection, impedance, and wave propagation, is crucial for designing efficient communication systems.
- Key equations include the transmission line equation, reflection coefficient, and impedance formulas.
- Proper termination and impedance matching are critical to minimizing losses and achieving efficient power transfer.

References

TEXTBOOKS

1. John D Ryder, “Networks lines and fields”,Prentice Hall of India, New Delhi,2005.

REFERENCES

1. Reinhold Ludwig and Powel Bretchko, “RF Circuit Design” – Theory and Applications”,Pearson Education Asia, First Edition, 2001.

2. D. K. Misra, “Radio Frequency and Microwave Communication Circuits”- Analysis andDesign, John Wiley & Sons, 2004.

3. Richard Chi-Hsi Li - , “RF Circuit Design” – A John Wiley & Sons, Inc, Publications.

4. W.Alan Davis, Krishna Agarwal, “Radio Frequency Circuit Design”, John Willy &Amp;Sons,2001.