

Recitation Questions for

Chapter 10 – Transmission Lines

in W. H. Hayt, Jr. and J. A. Buck, *Engineering Electromagnetics*, McGraw-Hill, 2019, pp. 303-368.

The purpose of these recitation questions is to assist the reader in assessing their mastery of the key concepts introduced in this chapter. The answers can be found in the textbook but are given here for convenience. ELEC 311 students should be prepared to provide answers to these questions in class or on an exam.

Introduction

1. What are transmission lines used for?

Ans. – Transmission lines are used to transmit electric energy and signals from one point to another, specifically from a *source* (or generator) to a *load*.

Examples include the connection between a transmitter and an antenna, connections between computers in a network, or connections between a hydroelectric generating plant and a substation hundreds of miles distant.

Other familiar examples include the interconnects between components of a stereo system and the connection between a cable service provider and your television set.

Examples that are less familiar include the printed circuit board connections between radio frequency, microwave, or digital devices that are designed to operate at high frequencies.

2. Why are basic circuit analysis methods insufficient when dealing with transmission lines?

Ans. – Voltage and current propagate at a finite speed as a wave phenomenon. When distances between the source and load are short, the speed of propagation and time delay can be ignored. When distances are sufficiently large:

- 1) time delay effects become appreciable (and increase with distance) and
- 2) the phase difference between the voltage or current observed at one point and the voltage or current observed at another point becomes a function of both time *and distance* (and become more pronounced as frequency increases (and wavelength decreases) because the phase difference depends on the ratio of distance to wavelength.)

Basic circuit analysis techniques do not account for such distance effects.

On a uniform lossless transmission line, both the speed and the ratio of voltage to current along the line are determined by the inductance and capacitance per unit length of the line. Specifically, the velocity of propagation is given by $1/\sqrt{LC}$ and the ratio between V and I at any z and t is given by $Z_0 = \sqrt{L/C}$.

3. When must one consider elements as distributed rather than lumped?

Ans. – One must consider elements as distributed if the propagation delay across the element dimension is on the order of the shortest time interval of interest. In the time-harmonic case, this condition would lead to a measurable phase difference between each end of the device in question.

4. What are the four objectives of this chapter?

Ans. – In this chapter, we investigate wave phenomena in transmission lines. Our objectives include:

- (1) to understand how to treat transmission lines as circuit elements possessing complex impedances that are functions of line length and frequency,
- (2) to understand wave propagation on lines, including cases in which losses may occur,
- (3) to learn methods of combining different transmission lines to accomplish a desired objective, and
- (4) to understand transient phenomena on lines.

10.1 Physical Description of Transmission Line Propagation

1. How does the LC ladder network of Fig. 10.2 model the propagation of a voltage wavefront along a transmission line?

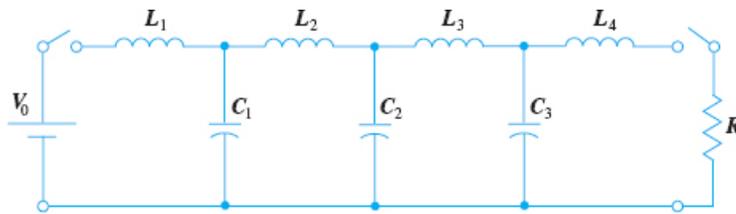


Figure 10.2 Lumped-element model of a transmission line. All inductance values are equal, as are all capacitance values.

Ans. – The series inductance captures the manner in which energy is stored the magnetic field due the current travelling along the line while the shunt capacitance captures the manner in which energy is stored the electric field due the voltage between the lines. Series inductance acts to oppose any changes in current while the shunt capacitance acts to oppose any changes in voltage.

If a step voltage is applied to the input, *e.g.*, by closing the switch, the finite time that it takes for the inductors and capacitors to reach steady state will cause the voltage wavefront to propagate along the ladder network at a finite speed.

2. Why is this ladder configuration referred to as a pulse-forming network?

Ans. – Assume that the load is disconnected and the voltage source is connected to the LC network until the capacitors are charged and the circuit has reached steady state.

If the voltage source is disconnected, and the resistor load is then connected, it will take a finite time for the circuit to discharge across the resistor. Rather than the instantaneous discharge that would occur for a single captor or inductor, we will observe a voltage pulse of finite duration across the resistor.

3. What are the two approaches that we can use to analyze transmission lines?

Ans. – There are two possible approaches to the analysis of transmission lines:

- (1) one can obtain the fields by solving Maxwell’s equations subject to the physical configuration of the line, and with these find general expressions for the wave power, velocity, and other parameters of interest, or,
- (2) one can (for now) avoid the fields and solve for the voltage and current using an appropriate circuit model.

It is the latter approach that we use in this chapter; the contribution of field theory is solely in the prior (and assumed) evaluation of the inductance and capacitance parameters.

10.2 The Transmission Line Equations

1. What do each of the circuit elements in Fig. 10.3 model?

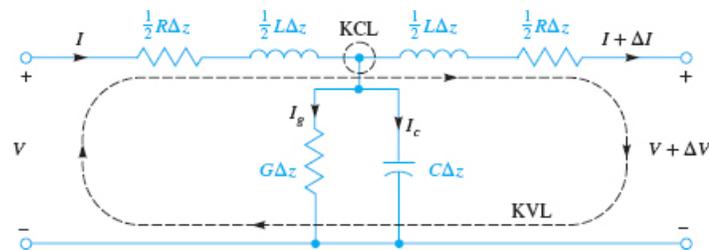


Figure 10.3 Lumped-element model of a short transmission line section with losses. The length of the section is Δz . Analysis involves applying Kirchhoff’s voltage and current laws (KVL and KCL) to the indicated loop and node, respectively.

Ans. – The series inductance captures the manner in which energy is stored the magnetic field due to the current travelling along the line while the shunt capacitance captures the manner in which energy is stored the electric field due to the voltage between the lines. Series inductance acts to oppose any changes in current while the shunt capacitance acts to oppose any changes in voltage.

The series resistance captures the manner in which energy is dissipated due to the current travelling along the line while the shunt conductance captures the manner in which energy is dissipated due to the voltage between the lines.

2. What are the telegraphist’s equations?

Ans. – The *telegraphist’s equations* relate the change in voltage with distance to the change in current with time, and vice versa, *i.e.*,

$$\frac{\partial V}{\partial z} = -\left(RI + L \frac{\partial I}{\partial t}\right)$$

$$\frac{\partial I}{\partial z} = -\left(GV + C \frac{\partial V}{\partial t}\right).$$

3. How are the telegraphist’s equations derived?

Ans. – The telegraphist’s equations are derived by applying Kirchhoff’s voltage and current laws, to the circuit in Figure 10.3.

4. How does one transform the telegraphist's equations into the general wave equations for the transmission line?

Ans. – First, apply $\frac{\partial}{\partial z}$ to the first telegraphist's equation and $\frac{\partial}{\partial t}$ to the second telegraphist's equation and equating them via the common term that contains $\frac{\partial^2 I}{\partial t \partial z}$. It is then a simple matter to use this result to obtain the *general wave equations* for the voltage and current carried by transmission lines, *i.e.*,

$$\frac{\partial^2 V}{\partial z^2} = LC \frac{\partial^2 V}{\partial t^2} + (LG + RC) \frac{\partial V}{\partial t} + RGV$$

and

$$\frac{\partial^2 I}{\partial z^2} = LC \frac{\partial^2 I}{\partial t^2} + (LG + RC) \frac{\partial I}{\partial t} + RGI .$$

10.3 Lossless Propagation

1. In our transmission line model, when does lossless propagation occur?

Ans. – In our model, lossless propagation occurs when $R = G = 0$.

2. In the lossless case, to what form do the general wave equations reduce?

Ans. – For the lossless case, the wave equations for voltage and current are given by

$$\frac{\partial^2 V}{\partial z^2} = LC \frac{\partial^2 V}{\partial t^2}$$

and

$$\frac{\partial^2 I}{\partial z^2} = LC \frac{\partial^2 I}{\partial t^2} .$$

3. What is the general form of the solution to the reduced or lossless wave equations?

Ans. – The general form of the solution to the reduced or lossless wave equations are the forward and backward travelling solutions, *i.e.*,

$$V(z, t) = f_1\left(t - \frac{z}{v}\right) + f_2\left(t + \frac{z}{v}\right) = V^+ + V^- .$$

4. What does the characteristic impedance of a transmission line represent?

Ans. – The characteristic impedance of a transmission line gives the ratio between V and I at any point z along the transmission line for a given travelling wave.

5. What do the reduced wave equations predict as expressions for the velocity of propagation and characteristic impedance of a transmission line?

Ans. - The velocity of propagation is given by $1/\sqrt{LC}$ and the ratio between V and I at any z and t is given by $Z_0 = \sqrt{L/C}$.

10.4 Lossless Propagation of Sinusoidal Voltages

1. Why is understanding of sinusoidal wave propagation on transmission lines important?

Ans. – An understanding of sinusoidal waves on transmission lines is important because any signal that is transmitted in practice can be decomposed into a discrete or continuous summation of sinusoids. This is the basis of frequency domain analysis of signals on transmission lines.

2. What is the sinusoidal form of the solution to the reduced wave equations?

Ans. – The sinusoidal form of the solution to the reduced wave equations is

$$V(z, t) = |V_0| \cos[\omega(t \pm z/v_p) + \phi] = |V_0| \cos[\omega t \pm \beta z + \phi]$$

3. What is the significance of ω , β and λ when analyzing lossless transmission lines?

Ans. – The parameters ω , β and λ are the angular frequency, phase constant, and effective wavelength of the wave. The ratio of ω to β gives the phase velocity while $2\pi/\beta$ yields λ .

4. What cosine arguments correspond to forward and backward wave propagation, respectively?

Ans. – If the cosine argument is $\omega t - \beta z$ then the wave is travelling in the forward direction. If the cosine argument is $\omega t + \beta z$ then the wave is travelling in the backward direction.

10.5 Complex Analysis of Sinusoidal Waves

1. Why is it useful to express sinusoidal waves in terms of complex exponential functions?

Ans. – Manipulation of complex exponential functions is much simpler and compact than manipulation of sinusoidal functions.

2. What is the complex instantaneous voltage?

Ans. – The complex instantaneous voltage is given by $V_c(z) = V_0 e^{\pm j\beta z} e^{j\omega t}$.

3. What is the phasor voltage?

Ans. – The phasor voltage is given by $V_s(z) = V_0 e^{\pm j\beta z}$.

4. How does one convert between complex instantaneous and phasor form?

Ans. – The *phasor* voltage is formed by dropping the $e^{j\omega t}$ factor from the complex instantaneous voltage.

The complex instantaneous voltage is formed by multiplying the phasor form by $e^{j\omega t}$.

10.6 Transmission Line Equations and Their Solutions in Phasor Form

1. How does one manipulate the general wave equation to obtain an expression for the propagation constant and characteristic impedance of a transmission line?

Ans. – The general wave equation is given by

$$\frac{\partial^2 V_s}{\partial z^2} = LC \frac{\partial^2 V_s}{\partial t^2} + (LG + RC) \frac{\partial V_s}{\partial t} + RGV_s$$

If we substitute $j\omega$ for $\frac{\partial}{\partial t}$ and re-arrange, we can obtain an expression of the form

$$\frac{\partial^2 V_s}{\partial z^2} = \gamma^2 \frac{\partial^2 V_s}{\partial t^2}$$

where $\gamma^2 = (R + j\omega L)(G + j\omega C)$.

The telegraphist's equations are given by

$$\frac{\partial V}{\partial z} = -(RI + L \frac{\partial I}{\partial t})$$

$$\frac{\partial I}{\partial z} = -(GV + C \frac{\partial V}{\partial t}).$$

If we substitute $j\omega$ for $\frac{\partial}{\partial t}$ and re-arrange, we can obtain an expression of the form

$$\frac{\partial V_s}{\partial z} = -ZI_s$$

$$\frac{\partial I_s}{\partial z} = -YV_s.$$

Substituting $V_s(z) = V_0^+ e^{-\gamma z} + V_0^- e^{\gamma z}$ and $I_s(z) = I_0^+ e^{-\gamma z} + I_0^- e^{\gamma z}$ into these expressions allows us to determine that

$$-\gamma V_0^+ e^{-\gamma z} + \gamma V_0^- e^{\gamma z} = -Z(I_0^+ e^{-\gamma z} + I_0^- e^{\gamma z})$$

Equating the terms that correspond to forward and backward travelling waves reveals that

$$Z_0 = \frac{V_0^+}{I_0^+} = -\frac{V_0^-}{I_0^-} = \frac{Z}{\gamma} = \frac{Z}{\sqrt{ZY}} = \sqrt{\frac{Z}{Y}}$$

2. What is the propagation constant of a transmission line in terms of its series inductance and shunt admittance?

Ans. – In terms of series inductance and shunt admittance, the propagation constant of a transmission line is given by $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \sqrt{ZY}$.

If the line is lossless, $\gamma = j\beta = j\omega\sqrt{LC}$ or $\beta = \omega\sqrt{LC}$.

3. What is the solution to the general wave equation when expressed in phasor form?

Ans. – The solution to the general wave equation when expressed in phasor form is

$$V_s(z) = V_0^+ e^{-\gamma z} + V_0^- e^{\gamma z}.$$

4. What is the characteristic impedance of a transmission line in terms of its series inductance and shunt admittance?

Ans. – In terms of series inductance and shunt admittance, the characteristic impedance of a transmission line is given by $Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \sqrt{\frac{Z}{Y}}$.

If the line is lossless, $Z_0 = \sqrt{\frac{L}{C}}$.

10.7 Low-Loss Propagation

1. What is the low-loss approximation?

Ans. – In the low-loss approximation, we require $R \ll \omega L$ and $G \ll \omega C$. This condition is often true in practice.

2. How can we use a binomial series to study the behaviour of a transmission line when losses are low?

Ans. – We use the first three terms in a binomial series to simplify the general expression

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

for the low-loss case. The terms involving RG^2 , R^2G , and R^2G^2 can be neglected as these will be negligible compared to all others. The result is

$$\gamma = \alpha + j\beta \doteq j\omega\sqrt{LC} \left[1 + \frac{1}{j2\omega} \left(\frac{R}{L} + \frac{G}{C} \right) + \frac{1}{8\omega^2} \left(\frac{R^2}{L^2} - \frac{2RG}{LC} + \frac{G^2}{C^2} \right) \right]$$

We can apply the same approach to simplify the general expression

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

for the low-loss case. The result is:

$$Z_0 \doteq \sqrt{\frac{L}{C}} \left\{ 1 + \frac{1}{2\omega^2} \left[\frac{1}{4} \left(\frac{R}{L} + \frac{G}{C} \right)^2 - \frac{G^2}{C^2} \right] + \frac{j}{2\omega} \left(\frac{G}{C} - \frac{R}{L} \right) \right\}$$

3. What are the conditions under which a wideband signal will not be distorted as it propagates along a transmission line?

Ans. – A wideband signal will not be distorted if the phase and group velocities that are constant with frequency. On a TEM transmission line, *e.g.*, two-wire lines of the sort considered in this chapter, the phase and group velocities are identical.

4. What is the Heaviside condition and what is its significance?

Ans. – The condition that $R/L = G/C$ yields phase and group velocities that are constant with frequency and eliminates distortion of wideband signals. This is referred to as Heaviside's condition.

10.8 Power Transmission and the Use of Decibels in Loss Characterization

1. For sinusoidal voltage and current on a transmission line, what is the instantaneous power?

Ans. – For sinusoidal voltage and current on a transmission line, the instantaneous power is

$$P(z, t) = V(z, t)I(z, t) = |V_0||I_0| e^{-2\alpha z} \cos(\omega t - \beta z) \cos(\omega t + \beta z + \theta).$$

2. For sinusoidal voltage and current on a transmission line, what is time-averaged power?

Ans. – For sinusoidal voltage and current on a transmission line, the time-averaged power is

$$\langle P \rangle = \frac{1}{T} \int_0^T P(z, t) dt = \frac{1}{2} \frac{|V_0|^2}{|Z_0|} e^{-2\alpha z} \cos \theta .$$

3. How does power attenuate with distance along a transmission line?

Ans. – Time-averaged power as a function of distance is given by $P(z) = P_0 e^{-2\alpha z}$.

4. How is power loss in decibels (dB) defined?

Ans. – Power loss in dB is defined as $P(\text{dB}) = 10 \log P_o/P_i$.

5. How can one convert power loss in dB to Nepers (Np)?

Ans. – The conversion factor between attenuation (or gain) in decibels and Nepers is $1 \text{ Np} = 8.686 \text{ dB}$ or $1 \text{ dB} = 0.1151 \text{ Np}$.

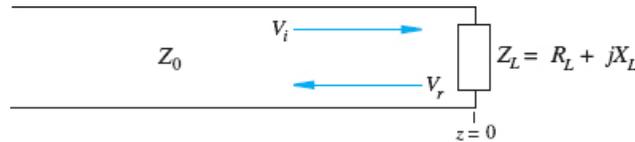
10.9 Wave Reflection at Discontinuities

1. Why is a reflected wave generated when the load impedance doesn't match the characteristic impedance of the transmission line?

Ans. – Along the transmission line, the ratio of voltage to current in the incident wave, $V_i/I_i = Z_0$ but $V_L/I_L = Z_L$ at the load. Both cannot be true at $z = 0$.

By introducing a reflected wave where $V_r/I_r = Z_0$ and $\Gamma_0 = \frac{V_r}{V_i} = \frac{Z_L - Z_0}{Z_L + Z_0}$, we can cause

$\frac{V_i + V_r}{I_i + I_r} = \frac{V_L}{I_L}$ and thereby match the boundary conditions.



2. What is the voltage reflection coefficient in terms of the load impedance and the characteristic impedance of a transmission line?

Ans. – The voltage reflection coefficient is given by $\Gamma_0 = \frac{V_r}{V_i} = \frac{Z_L - Z_0}{Z_L + Z_0}$.

3. What is the voltage transmission coefficient in terms of the load impedance and the characteristic impedance of a transmission line?

Ans. – The voltage transmission coefficient is given by $\tau_0 = \frac{V_t}{V_i} = \frac{2Z_L}{Z_L + Z_0}$.

4. Give expressions for the power reflection and power transmission coefficient?

Ans. – The power reflection and transmission coefficients are given by $|\Gamma|^2$ and $1 - |\Gamma|^2$, respectively.

The power reflection coefficient $|\Gamma|^2 = P_r/P_i$ can be expressed in dB as $20 \log |\Gamma|$. This is often expressed in terms of its reciprocal, P_i/P_r . Commonly referred to as the *return loss*, it is expressed in dB as $-20 \log |\Gamma|$.

5. How can the above be modified to account for the case where a semi-infinite transmission line with a given characteristic impedance is connected to a second transmission line with a different characteristic impedance?

Ans. – In situations involving the connection of two semi-infinite transmission lines having different characteristic impedances, reflections will occur at the junction, with the second line being treated as the load. For a wave incident from line 1 (Z_{01}) to line 2 (Z_{02}), we find

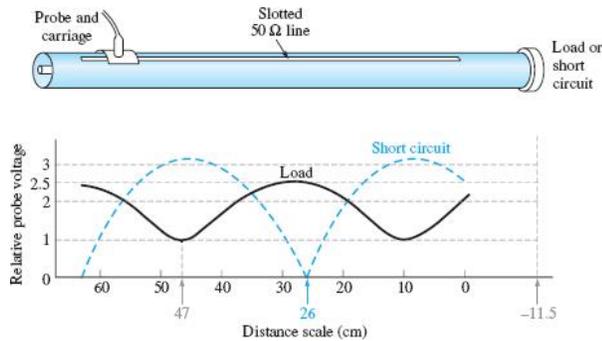
$$\Gamma_0 = \frac{V_r}{V_i} = \frac{Z_{02} - Z_{01}}{Z_{02} + Z_{01}}$$

The fraction of the power that propagates into the second line is then $1 - |\Gamma|^2$.

10.10 Voltage Standing Wave Ratio

1. What is a slotted line?

Ans. – A slotted line is a coaxial transmission line with a solid outer conductor into which a longitudinal (or lengthwise) slot has been cut. By inserting a probe into the slot and moving it along the length of the line, the electric field (and voltage) can be sampled as a function of distance and the voltage standing wave visualized.



2. What is a voltage standing wave?

Ans. – A voltage standing wave is the interference pattern between the incident and reflected waves that forms along the length of the transmission line. The pattern repeats every half wavelength.

The phase difference between the incident and reflected waves changes with distance because the phasors that describe them rotate in opposite directions with distance.

3. How is voltage standing wave ratio defined in terms of the voltage along the line?

Ans. – The voltage standing wave ratio s is defined as the ratio of the amplitude of the maximum voltage observed to the amplitude of the minimum voltage observed, *i.e.*,

$$s = \frac{V_{max}}{V_{min}}$$

4. In general terms, where do the minimum and maximum voltages occur?

Ans. – V_{min} occurs where V_i and V_r add out of phase so $V_{min} = |V_i| - |V_r|$.

V_{max} occurs where V_i and V_r add in phase so that $V_{max} = |V_i| + |V_r|$.

5. How is voltage standing wave ratio defined in terms of the voltage reflection coefficient at the interface that gave rise to the reflected wave?

Ans. – In terms of the voltage reflection coefficient at the interface that gave rise to the reflected wave,

$$S = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

10.11 Transmission Lines of Finite Length

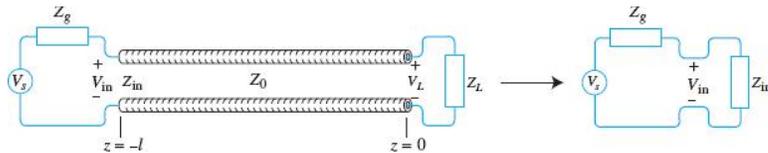
1. What complicates analysis of transmission lines of finite length?

Ans. – Consider the propagation of sinusoidal voltages on finite-length lines that have loads that are not impedance matched. In such cases, numerous reflections occur at the load and at the generator, setting up a multiple-wave bidirectional voltage distribution in the line.

Our objective is to determine the net power transferred to the load in steady state, but we must now include the effect of the numerous forward- and backward-reflected waves.

At $z = 0$, we can apply $\Gamma_0 = \frac{V_r}{V_i} = \frac{Z_L - Z_0}{Z_L + Z_0}$ to determine the voltage reflection coefficient.

At $z = -\ell$, we can apply $\Gamma = \frac{V_r}{V_i} = \frac{Z_w - Z_0}{Z_w + Z_0}$ to determine the voltage reflection coefficient where Z_w is the wave impedance.



2. What is wave impedance?

Ans. – Wave impedance is the ratio of the total phasor voltage $V_{sT}(z)$ (sum of the voltages associated with the forward and backward travelling waves) to the total phasor current $I_{sT}(z)$ (sum of the currents associated with the forward and backward travelling waves), *i.e.*,

$$Z_w(z) \equiv \frac{V_{sT}(z)}{I_{sT}(z)} = \frac{V_0^+ e^{-j\beta z} + V_0^- e^{j\beta z}}{I_0^+ e^{-j\beta z} + I_0^- e^{j\beta z}}$$

3. Give three forms of an expression for wave impedance as a function of position, $Z_w(z)$.

Ans.

$$Z_w(z) \equiv \frac{e^{-j\beta z} + \Gamma e^{j\beta z}}{e^{-j\beta z} - \Gamma e^{j\beta z}}$$

and

$$Z_w(z) = Z_0 \frac{Z_L \cos(\beta z) - jZ_0 \sin(\beta z)}{Z_0 \cos(\beta z) - jZ_L \sin(\beta z)}$$

and

$$Z_w(\ell) = Z_0 \frac{Z_L \cos(\beta \ell) + jZ_0 \sin(\beta \ell)}{Z_0 \cos(\beta \ell) + jZ_L \sin(\beta \ell)}$$

where z is a given position along the transmission line
 $\ell = -z$ is a distance from $z = 0$ back towards the source
 Z_0 is the characteristic impedance of the line
 β is the phase constant of the line and
 Z_L is the load impedance

Wave impedance is, in general complex, even if Z_0 and Z_L are both real

- What is the special property of a transmission line that is a half-wavelength long?
Ans. – A transmission line of length $\lambda/2$ will transform a real load impedance into an identical wave impedance at the input, *i.e.*, an identical input impedance, regardless of the characteristic impedance of the line.
- What is the special property of a transmission line that is a quarter-wavelength long?
Ans. – A transmission line of length $\lambda/4$ will transform a real load impedance into an input impedance given by $Z_{in} = Z_0^2/Z_L$.

10.12 Some Transmission Line Examples

No review questions.

10.13 Graphical Methods: The Smith Chart

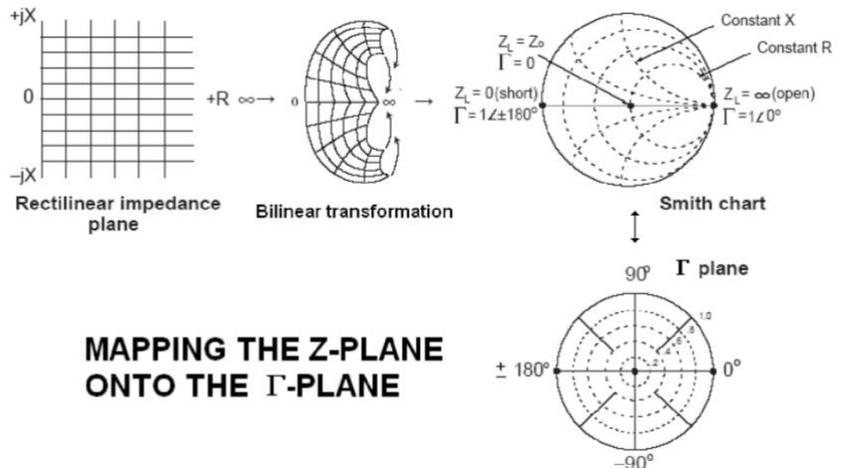
- What is a Smith Chart?
Ans. – The Smith Chart is a mapping of the complex or rectilinear impedance plane onto the complex reflection coefficient or Γ plane.
 The Smith Chart is useful because it allows one to visualize the manner in which Γ and the normalized wave impedance z_w evolve as one moves forward and backward along the transmission line without the need to conduct complex calculations.
- How do lines of constant resistance or constant reactance appear when mapped into the complex reflection coefficient plane?

Ans. – Lines of constant resistance appear as circles of different radii that are tangential at $\Gamma = 1$.

Lines of constant reactance appear as arcs of circles of different radii above and below $r = 0$ that are also tangential at $\Gamma = 1$.

- What is prime centre on a Smith Chart?

Ans. – Prime centre on a Smith chart corresponds to the centre of the Smith chart, *i.e.*, the point at which $\Gamma = 0$.



4. What direction of travel around a Smith Chart corresponds to moving towards the source?

Ans. – Travelling in the clockwise direction around a Smith Chart corresponds to moving towards the source or generator.

5. What direction of travel around a Smith Chart corresponds to moving towards the load?

Ans. – Travelling in the counter-clockwise direction around a Smith Chart corresponds to moving towards the load.

6. How can one transform impedance to admittance using a Smith Chart?

Ans. – The point on the Smith chart that is the same distance from prime centre but 180 degrees away from a given impedance z corresponds to the corresponding admittance $y = 1/z$.

7. How can one demonstrate the function and operation of a transmission line that is a half-or quarter-wavelength long using a Smith Chart?

Ans. – A full revolution around the Smith Chart corresponds to $\lambda/2$ of travel while one-half of a revolution around the Smith Chart corresponds to $\lambda/4$ of travel.

8. How can one eliminate the reflected wave using a single stub of appropriate design?

Ans. – Assume that the single stub is to be connected in parallel to the transmission line.

1. Move along the $|\Gamma|$ circle toward the generator until the real part of the wave admittance equals the characteristic admittance (reciprocal of the characteristic impedance) of the transmission line.
2. At this point, add a stub in parallel (a shunt stub) that has susceptance equal to the imaginary part of the wave admittance but opposite in sign. This will cancel the imaginary part of the wave admittance at this point.
3. Because the wave admittance equals the characteristic admittance of the transmission line at this point, there will be no reflected wave.

10.14 Transient Analysis

1. What is the main difference between steady-state and transient analysis?

Ans. – N/R

2. Explain how a voltage tracking diagram is used to keep track of the voltage at any point along a line.

Ans. – N/R

3. What is the main practical application of transient analysis?

Ans. – N/R