EC8651 - Transmission Lines and RF Systems

Anna University
2 Mark Questions with Answers

UNIT I - TRANSMISSION LINE THEORY

1. Define characteristic impedance

(Or)

What is characteristic impedance [AU:May'15][AU:DEC'06]

In a uniform transmission line, it is the ratio of the voltage amplitude to the current amplitude of a single wave traveling down it. This is also called as "Surge impedance".

The impedance measured at any point in a transmission line is called as characteristic impedance. It is denoted as Z_o.

It is given by, $Z_o = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$ ohms/Km.

2. Define propagation constant.

(Or)

What is propagation constant? What are its 2 components? [AU:JUN'09][AU:DEC'07][AU:MAY'13]

Propagation constant is defined as the natural logarithm of the ratio of the sending end current or voltage to the receiving end current or voltage of the line.

Propagation constant is a complex quantity and is expressed as $P = \alpha + j\beta$ Where, The real part is called the attenuation constant and the imaginary part is called as the phase constant.

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

3. State the important properties of infinite line. [AU:MAY'04, DEC'11]

An infinite line is a line in which the length of the transmission line is infinite.

A finite line, which is terminated in its characteristic impedance, is termed as infinite line. So for an infinite line, the input impedance is equivalent to the characteristic impedance.

No waves will ever reach receiving end hence there is no reflection.

4. What is the relationship between characteristic impedance and propagation constant. [AU:JUN'09][AU:May'10]

$P.Z_o = R + j\omega L$

$$\frac{P}{Z_O} = G + j\omega C$$

5. What is the significance of Reflection coefficient? [AU:Jan'16]

It is a measure of the mismatch between the load impedance Z_R and the characteristic impedance Z_o of the line.

when $Z_R=Z_O$; $K=0$; No reflection

$Z_R=0$; $K=1\angle 180°$; Reflection is maximum

$Z_R=\infty$; $K=1\angle 0°$; Reflection is maximum

6. Define wavelength of the line. [AU:Jan'16][AU:DEC'04]

The distance the wave travels along the line while the phase angle is changing through 2π radians is called a wavelength.

$$\lambda = \frac{2\pi}{\beta}$$

7. Write the condition for a distortionless line.[AU:JUN'09]

The condition for a distortionless line is, $\frac{R}{L} = \frac{G}{C}$

8. How frequency distortion occurs in a line?

(Or)

What is frequency distortion?[AU:MAY'07][AU:DEC'08]

When a signal having many frequency components are transmitted along the line, all the frequencies will not have equal attenuation and hence the received end waveform will not be identical with the input waveform at the sending end because each frequency is having different attenuation. This type of distortion is called frequency distortion.

9. How to avoid the frequency distortion that occurs in the line?

(Or)

How distortion can be reduced in a transmission line?[AU:MAY'11]

(Or)

If a line is to have neither frequency nor delay distortion, how do you relate attenuation constant and velocity of propagation to frequency? [AU:DEC'11]

In order to reduce frequency distortion occurring in the line,

a) The attenuation constant should be made independent of frequency.

b) By using equalizers at the line terminals which minimize the frequency distortion.

10. What is delay distortion?

(Or)

What is phase distortion?
[AU:MAY'06][AU:DEC'08][AU:DEC'09][AU:DEC'10]

When a signal having many frequency components are transmitted along the line, all the frequencies will not have same time of transmission, some frequencies being delayed more than others. So the received end waveform will not be identical with the input waveform at the sending end because some frequency components will be delayed more than those of other frequencies. This type of distortion is called phase or delay distortion.

11. What is a distortion less line? What is the condition for a distortion less line? [AU:MAY'09][AU:MAY'10]

A line, which has neither frequency distortion nor phase distortion is called a distortion less line.

The condition for a distortion less line is RC=LG. Also,

a) The attenuation constant should be made independent of frequency.
b) The phase constant β should be a product of 'ω' with some constant (made dependent of frequency).
c) The velocity of propagation is independent of frequency.

12. What is reflection co-efficient?

(Or)

Define reflection coefficient

Reflection Coefficient can be defined as the ratio of the reflected voltage or current to the incident voltage or current at the receiving end of the line.

It is denoted by 'K' or 'r' or 'ρ'

$$\text{Reflection Coefficient, } K = \frac{\text{Reflected Voltage or current at load}}{\text{Incident voltage or current at the load}}$$

$$K = Vr/Vi$$

$$K = \frac{Z_R - Z_O}{Z_R + Z_O}$$

13. Define reflection loss.[AU:May'15] [AU:May'08]

If the load impedance is equal to the Characteristics impedance ($Z_R \neq Z_O$), then the energy delivered to the load under mismatch condition is always less than the energy which would be delivered to the load under matched condition. This is called as reflection loss.

(Or)

Reflection loss is defined as the number of nepers or decibels by which the current in the load under image matched conditions would exceed the current actually flowing in the load.

14. Define reflection factor. [AU-MAY2015]

The ratio which indicates the change in current in the load due to reflection at the mismatched function is called as reflection factor.

Reflection loss is inversely proportional to the reflection factor.

$$\text{Reflection Factor} = \left[\frac{2\sqrt{Z_R Z_O}}{Z_R + Z_O}\right]$$

15. Define insertion loss. [AU-MAY2015]

The insertion loss of a line or network is defined as the number of nepers or decibels by which the current in the load is changed by the insertion.

Insertion loss = Current flowing in the load without insertion of the network to Current flowing in the load with insertion of the network

16. Write the expressions for the phase constant and velocity of propagation for telephone cable.[AU:DEC'10]

The phase constant of a telephone cable is given by,

$$\beta = \sqrt{\frac{\omega RC}{2}}\ rad/km$$

The velocity of propagation is given by,

$$v_p = \frac{\omega}{\beta} = \frac{\omega}{\sqrt{\frac{\omega RC}{2}}} = \sqrt{\frac{2\omega}{RC}}\ m/\sec$$

17. Find the reflection coefficient of a 50 ohm line when it is terminated by a load impedance of 60+j 40 ohm. [AU-NOV2015][AU:MAY'08]

Solution:

$Z_R = (60+j40)\Omega$

$Z_O = 50\Omega$

The reflection coefficient is given by,

$$K = \frac{Z_R - Z_O}{Z_R + Z_O} = \frac{(60+j40)-50}{(60+j40)+50} = \frac{10+j40}{110+j40} = \frac{41.231\angle 75.96°}{117.0469\angle 19.98°} = 0.3522\angle 55.98°$$

K=0.3522Ď55.98î

18. What is phase velocity and group velocity?[AU:DEC'05]

The velocity of the wave along the line decided by ω and phase constant β is called as phase velocity.

$$v_p = \frac{\omega}{\beta}$$

The velocity which is produced by a group of frequency traveling along the system is called group velocity. It is defined as,

$$v_p = \frac{d\omega}{d\beta}$$

19. What is meant by loading?[AU:DEC'03]

The process of achieving condition of distortionless line artificially by increasing L or decreasing C is called as loading of a line.

20. Find the attenuation and phase shift constant of a wave propagating along the line whose propagation constant is 1.048x10^{-4} Ď88.8î. (2) [AU-NOV2008]

$\gamma = \alpha + j\beta \quad = 1.048\text{x}10^{-4}\angle 88.8°$

$\quad = 2.1947\text{x}10^{-6} + j1.04777\text{x}10^{-4}$

$\alpha = 2.1947\text{x}10^{-6}$ Np/m

$\beta = 1.04777\text{x}10^{-4}$ rad/m

21. A transmission line has Z_o = 745Ď12î t and is terminated in Z_R=100 t . Calculate reflection loss in dB. [AU:MAY'11]

$$\text{Reflection Factor} = \text{k} = \frac{2\sqrt{Z_R Z_O}}{|Z_R + Z_O|} = \frac{2\sqrt{(100)(745)}}{|100 + j0 + 728.72 - j154.894|} = \frac{545.8937}{843.0711} = 0.6475$$

$$\text{Reflection loss} = 20\log\frac{1}{|\text{k}|} = 20\log\frac{1}{0.6475} = 3.7751dB$$

22. If the reflection coefficient of a line is 0.3Ď-66î. Calculate the standing wave ratio.[AU:MAY'09]

K=0.3∠-66°

|k|=0.3, ∠φ =-66°

SWR is given by,

$$S = SWR = \frac{1+|K|}{1-|K|} = \frac{1+0.3}{1-0.3} = \frac{1.3}{0.7} = 1.8571$$

UNIT II HIGH FREQUENCY TRANSMISSION LINES

1. State the standard assumptions made for radio frequency line.

(Or)

What are the assumptions to simplify the analysis of line performance at high frequencies?[AU:May'15]

The standard assumptions made for radio frequency line are,

1. Due to the skin effect, the currents are assumed to flow on the surface of the conductor and the internal inductance is zero.
2. Due to skin effect, the resistance R increases with $\sqrt{f}$ while the line reactance ωL increases directly with frequency f.
   Hence the second assumption is ωL>>R.
3. The third assumption is that the line at RF is constructed such that the leakage conductance G is zero.

2. Define the term SWR.

(Or)

What is Standing Wave Ratio? [AU:MAY'06] [AU:DEC'06] [AU: DEC '03] [AU: DEC '11] [AU:MAY'13]

The ratio of the maximum to minimum magnitudes of voltage or current on a line having standing waves called standing waves ratio.

$$S = \frac{|E_{max}|}{|E_{min}|} = \frac{|V_{max}|}{|V_{min}|} = \frac{|I_{max}|}{|I_{min}|}$$

3. What are standing waves? [AU:MAY'05]

If the transmission is not terminated in its characteristic impedance, then there will be two waves traveling along the line which gives rise to standing waves having fixed maxima and fixed minima.

4. Define node and antinode.

(Or)

What are nodes and antinodes on a line? [AU:DEC'05]

The points along the line where magnitude of voltage or current is zero are called **nodes** while the points along the lines where magnitude of voltage or current first maximum are called **antinodes or loops**.

5. State the relation between standing wave ratio S and reflection co-efficient, K.

(Or)

Write the expression for SWR interms of i) Reflection co-efficient ii) Z_L and Z_o. [AU:Jan'16]

(Or)

Write the expression for standing wave ration in terms of reflection co-efficient. [AU:May'15]

The relation between standing wave ratio S and reflection co-efficient k is, $S = \frac{1+|K|}{1-|K|}$

$$S = \frac{|Z_R|}{|Z_O|} = \frac{R_R}{R_O} \text{(for } R_R > R_O\text{)}$$

6. **What is the value of SWR for open circuit, short circuit and matched line?[AU:MAY'04]**

When the load is either open circuit or short circuit, the value of $|K|$ is '1'. Hence the value of SWR is '∞'.

When the load is matched with characteristic impedance, the value of $|K|$ is '0'. Hence the value of SWR is '1'.

7. **What is zero dissipation line/dissipationless line? [AU:MAY'05]**

A line for which the effect of resistance R is completely neglected is called dissipationless line or Zero dissipation Line.

8. **What is the nature and value of Z_0 for the dissipationless line?**

(Or)

What is the value of Z_0 for the dissipationless line?[AU:JUN'09]

For dissipationless line, the value of Z_O is purely resistive and given by, $Z_O = R_O = \sqrt{\frac{L}{C}}$

9. **State the values of ~ and for the dissipation less line [AU:DEC'03]**

$\alpha = 0$

$\beta = \omega \sqrt{LC}$ rad /Km

10. **For the zero dissipation line, what will be the values of attenuation constant and characteristic impedance?[AU-NOV2015]**

(Or)

Write down primary constants and secondary constants for the line of zero dissipation. [AU:DEC'03]

$Z_O = R_O = \sqrt{\frac{L}{C}}$

$P = \gamma = \alpha + j\beta = j\omega\sqrt{LC}$

$\alpha = 0$

$\beta = \omega\sqrt{LC}$

11. Give the input impedance of a dissipationless line. [AU:MAY'06]

The input impedance of a dissipationless line is given by

$$Z_S = Z_{in} = R_O \left[\frac{1 + |K|\angle\phi - 2\beta s}{1 - |K|\angle\phi - 2\beta s} \right]$$

12. Give the input impedance of open and short circuited lines.[AU:DEC'10]

The input impedance of open and short circuited lines is given by,

$$Z_{OC} = -jR_O \cot\beta s = -jR_O \cot\left(\frac{2\pi}{\lambda}.s\right)$$

$$Z_{SC} = jR_O \tan\beta s = jR_O \tan\left(\frac{2\pi}{\lambda}.s\right)$$

13. At a frequency of 80 MHz, a lossless transmission line has a characteristic impedance of 300 t and a wavelength of 2.5m. Find L and C. [AU-MAY2012]

Solution:

$$Z_o = R_o = \sqrt{\frac{L}{C}} = 300\Omega$$

$$\frac{L}{C} = 90000 \qquad -(1)$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\omega\sqrt{LC}} = \frac{2\pi}{2\pi f\sqrt{LC}} \frac{1}{f\sqrt{LC}} = 2.5$$

$$\sqrt{LC} = 5\times10^{-9}$$

$$LC = 2.5\text{x}10^{-17} \qquad (2)$$

Solving (1) and (2) we get

L=1.5μH and C=16.6667pF

14. A lossless transmission line has a shunt capacitance of 100pF/m and a series inductance of 4«H /m. Determine the characteristic impedance. [AU-NOV2015]

The characteristic impedance of a lossless line is given by,

$$Z_o = R_o = \sqrt{\frac{L}{C}} = \sqrt{\frac{4\times10^{-6}}{100\times10^{-12}}} = 200\Omega$$

UNIT III-IMPEDANCE MATCHING IN HIGH FREQUENCY LINES

1. **Why is a quarter wave lines called as impendence inverter?**

   (Or)

   Why a quarterwave line is considered as a impedance inverter? Justify [AU:May'15]

   A quarter wave lines may be considered as an impendence inverter because it can transform a low impendence in to a high impendence and vice versa.

2. **Mention the significance of Quarter wave line. [AU:Jan'16]**

   Quarter wave line can be used as impedance matching device between transmission line and resistive load such as an antenna.

   Short circuited Quarter wave line can be used an insulator to support open wire or inner conductor of a coaxial line.

3. **What is a Stub? Why it is used in between transmission line? [AU:May'15]**

   A Stub is a small transmission line connected in parallel with main line at a certain distance from the load.

   A Stub is used to match impedance between transmission line and load. It is used to cancel the reactive component in the main transmission line.

4. **What is the application of the quarter wave matching section?**

   (Or)

   What is the application of Quarter wave line? [AU:DEC'07][AU:MAY'11]

   An important application of the quarter wave matching section is to a couple a transmission line to a resistive load such as an antenna.

   If the antenna resistance is RA and the characteristic impendence of the line is Ro, then a quarter wave impedance matching section is designed such that its characteristic impendence is $R_o' = \sqrt{R_A . R_O}$

5. **Write the expression for input impedance of open and short circuited dissipationless line.[AU:DEC'10](Or)**

   The input impedance of a short circuited line is given by,

   $Z_{SC} = jR_o \tan\beta S$

   The input impedance of a open circuited line is given by,

   $Z_{OC} = -jR_o \cot\beta S$

6. What is meant by electrical length of the line?

The length of the transmission line expressed interms of wavelength is called as electrical length of the line.

7. Why is the quarter wave line called as copper insulator?

As quarter wave line is shorted at ground, its input impedance is very high. So, the signal on line passes to the receiving end without ant loss due to this mechanical support. Thus the line acts as an insulator at this point. Hence such a line is referred as copper insulator.

8. why are short circuited stubs preferred over open circuited stubs? [AU:MAY'04]

At high frequencies, open circuited stubs radiate some energy which is not in the case of short circuited stub. Hence short circuited stubs are preferred.

9. Write the procedure to find the impedance from the given admittance using smith chart. [AU:MAY'08]

First find normalized admittance for the given admittance. Then locate that point on the smith chart say at point 'A'. Now to find impedance of the given admittance at point A, rotate point A along constant S circle by a distance $\lambda/4$ or 0.25λ and locate point B which is located diametrically opposite to point A. Then check point B for intersection of R-circle and X-circle and obtain the normalized impedance value. Then multiply the obtained normalized impedance value by characteristic impedance Z_O and get the actual impedance for given admittance using the smith chart.

10. Distinguish between single and double stub matching[AU-MAY'08] [AU-NOV'15][AU:MAY'08][AU:MAY'12]

S.No	Single stub matching	Double stub matching
1	It has one stub to match the transmission line impedance	It requires two stub for impedance matching
2	Stub has to be placed at a definite place on a line	The location of the stub is arbitrary
3	Length and Location of the stub has to be altered for impedance matching	Only Length of the stub has to be altered for impedance matching

UNIT IV GUIDED WAVES BETWEEN PARALLEL PLANES

1. Mention the characteristics of TEM waves. [AU:Jan'16]

i. It is a special type of TM wave.

b) It does not have either E_z or H_z component.

c) Its velocity is independent of frequency.

d) Its cut-off frequency is zero.

2. What are degenerate modes in a rectangular waveguide?[AU:Jan'16]

Some of the higher order modes having the same cutoff frequency are called as degenerate modes.

3. Define dominant mode. What is the dominant mode of rectangular waveguide? [AU:May'15]

The modes that have the lowest cut off frequency is called the dominant mode

The lowest mode for TE wave is TE_{10} (m=1, n=0) whereas the lowest mode for TM wave is TM_{11} (m=1, n=1). The TE_{10} wave has the lowest cut off frequency compared to the TM_{11} mode. Hence the TE_{10} (m=1, n=0) is the dominant mode of a rectangular waveguide.

4. What is the wave impedance for TE waves in a rectangular WG?

$$Z_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \text{ or } \frac{\omega\mu}{\beta}$$

5. What is the wave impedance for TM waves in a rectangular WG?

$$Z_{TM} = \eta\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

6. What is the wave impedance for TEM waves in a waveguide?

$$Z_{TEM} = \eta = \sqrt{\frac{\mu}{\varepsilon}}$$

7. Write the expression for phase velocity in a waveguide

$$\nu = \frac{\omega}{\sqrt{\omega^2\mu\varepsilon - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2}}$$

8. Why TEM mode is not possible in rectangular waveguide?

Transverse electromagnetic (TEM) wave do not have axial component of either E or H so, it cannot propagate within a single conductor waveguide.

9. Why TM_{01} and TM_{10} modes in a rectangular waveguide do not exist.

For TM modes in rectangular waveguides, neither m or n can be zero because all the field equations vanish (i.e., $E_z = E_y = H_x = H_y = 0$). If m=0, n=1 or m=1, n=0 no fields are present. Hence TM_{01} and TM_{10} modes in a rectangular waveguides do not exist.

CIRCULAR WAVE GUIDES AND RESONATORS

1. What is Bessel equation? What is Bessel function?

The analysis of field components within the hollow, perfectly conducting cylinder with uniform circular cross-section is carried out using the cylindrical co-ordinate system. The resulting differential equation is called as **Bessel's equation**. The solution of such equation is called as **Bessel's function**.

2. Mention the applications of circular waveguide.

Circular waveguides are used as attenuators and phase-shifters.

3. Mention the dominant modes in rectangular and circular waveguides.

For a rectangular waveguide, the dominant mode is TE_{01}.

For a Circular waveguide, the dominant mode is TE_{11}.

4. Write the expression for cut-off frequency in a circular waveguide.

$$f_c = \frac{h_{mn}}{2\pi\sqrt{\mu\varepsilon}}, \text{ where } h_{mn} = \frac{(ha)_{mn}}{a}$$

5. Why is TM_{01} mode preferred to the TE_{01} mode in a circular waveguide?

TM_{01} mode is preferred to the TE_{01} mode, since it requires a smaller diameter for the same cut-off wavelength.

6. Write the expression for resonant frequency for a rectangular resonator.

$$\text{The resonant frequency, } f_o = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

7. What is the dominant mode for a rectangular resonator?

The dominant mode of a rectangular resonator depends on the dimension of the cavity. For b< a< d, the dominant mode is TE_{101} mode.

8. Write the resonant frequency of a circular resonator.

The resonant frequency is,

For TE, $$f_o = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{x'_{nm}}{a}\right)^2 + \left(\frac{p\pi}{d}\right)^2}$$

For TM, $$f_o = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{x_{nm}}{a}\right)^2 + \left(\frac{p\pi}{d}\right)^2}$$

9. What is the dominant mode for a circular resonator?

The dominant mode of a circular resonator will depend on the dimensions of the resonator.

For d< 2a, the dominant mode is TM_{010}.

For d≥ 2a, the dominant mode is TE_{111}.

10. What is the wave impedance for TE waves in a Circular WG?

$$Z_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \text{ or } \frac{\omega\mu}{\beta}$$

11. What is the wave impedance for TM waves in a Circular WG?

$$Z_{TM} = \eta\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

PROBLEMS:

1. A rectangular waveguide has the following dimensions l=2.54cm, b=1.27 cm waveguide thickness=0.127 cm. Calculate the cut-off frequency for TE_{11} mode. (2) **[AU-NOV2006]**
2. A rectangular waveguide with dimensions a = 8.5 cm and b = 4.3cm is fed by 5 GHz carrier. Will a TE_{11} mode be propagated? (2) **[AU-NOV2007]**
3. Calculate the cut-off wavelength of a rectangular wave guide whose inner dimensions are ‘a’ 2.3cm and ‘b’ = 1.03 cm operating at TE_{10} mode. (2) **[AU-MAY2008]**
4. Calculate the cut-off frequency of a rectangular wave guide whose inner dimensions are 'a'=2.5cm and 'b' =1.5cm operating at TE_{10} mode. (2) **[AU-NOV2008]**
5. A rectangular waveguide with dimension a=8.5 cm and b=4.3 cm. Determine the cut-off frequency for TM_{10} mode of propagation. (2) **[AU-MAY2009]**
6. A circular waveguide operated at 11 GHz has the internal diameter of 4.5cm for a TE01 mode propagation, calculate λ and λc ($(ha)_{01}$ = 2.405) (2) **[AU-NOV2006]**
7. A wave is propagated in a parallel plane waveguide. The frequency is 6 GHz and the plane separation is 3cm. Determine the group and phase velocities for the dominant mode. (2) **[AU-NOV2013]**
8. A rectangular waveguide with a=7cm and b=3.5cm is used to propagate TM10 at 3.5 GHz. Determine the guided wavelength. (2) **[AU-NOV2013]**
9. A rectangular waveguide with a 5 cm x 2 cm cross is used to propagate TM_{11} mode at 10GHz. Determine the cut off wavelength. (2) **[AU-NOV2014] [AU-NOV2015]**
10. A rectangular waveguides has the following dimensions l = 2.54 cm, b=1.27 cm and thickness= 0.127 cm. calculate the cutoff frequency for TE11 mode. (2) **[AU-MAY2015]**