TRANSMISSION LINE THEORY

1. What is transmission line?

Transmission line is a system of conductors that transfers electrical signals from one place to another.

2. What are the primary and secondary constants of a transmission line?

Primary (line) constants:

Resistance, Inductance, capacitance and conductance.

Secondary constants:

characteristic impedance (Z_0) and Propagation constant (γ).

3. Name the types of distortion.

1. Frequency distortion
2. Delay (Phase) distortion

4. Define wavelength.

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

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

5. How can distortion be reduced in a transmission line?

* Frequency distortion is reduced by the use of equalisers.
* Delay distortion is reduced by the use of coaxial cable.

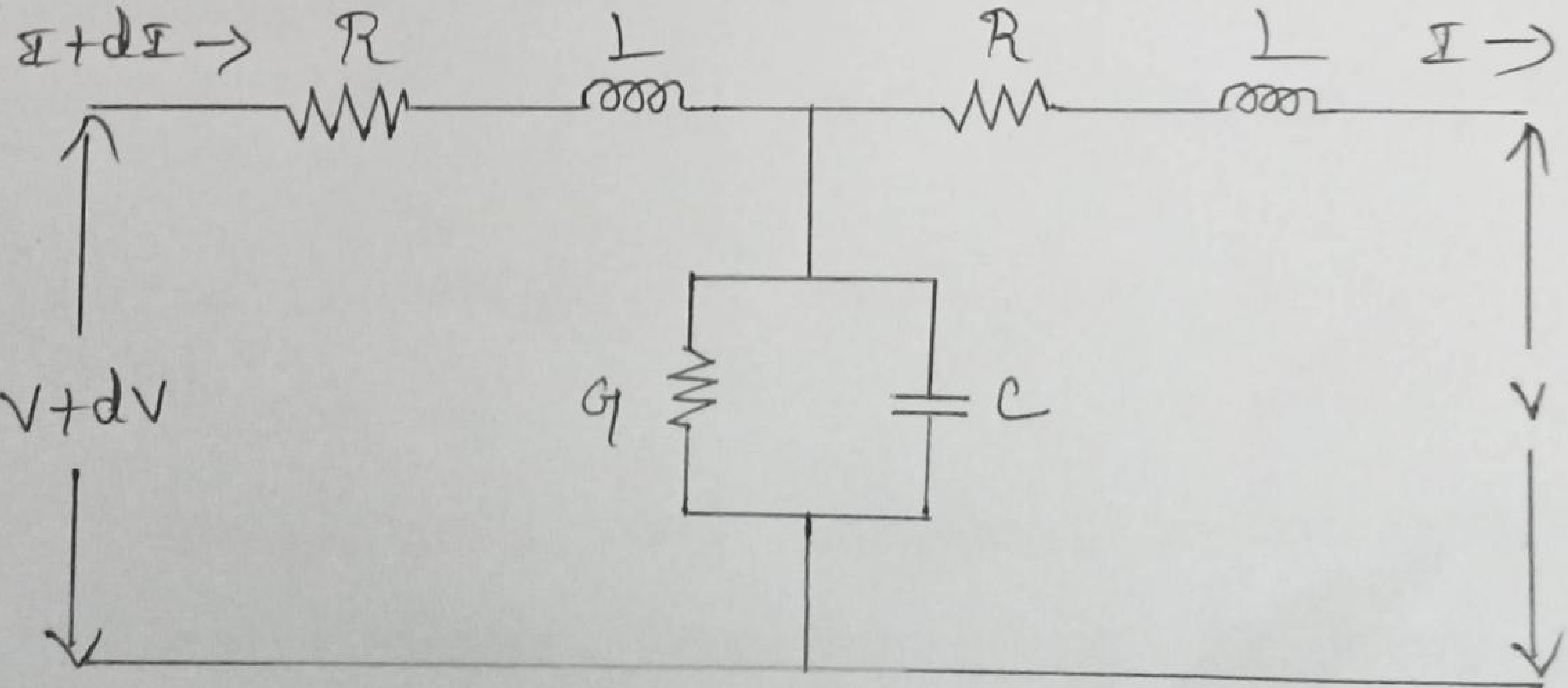
6. What is meant by distortionless line? Write the condition for distortionless line.

A line with no frequency and delay distortion is termed as distortionless line.

Condition for distortionless line is,

$$R/L = G/C$$

7. Draw the equivalent circuit of a transmission line.



8. What is called an infinite line?

If the length of the transmission line is infinite is named as infinite line.

It is a hypothetical line which has input impedance equal to the characteristic impedance.

9. Define propagation constant.

It is defined as the natural logarithmic ratio of the sending end current or voltage to the receiving end voltage or current.

$$\gamma = \ln\left(\frac{I_s}{I_R}\right) = \ln\left(\frac{V_s}{V_R}\right)$$

* γ is a complex quantity

$$\gamma = \alpha + j\beta$$

where,

α – attenuation constant

β – phase constant (phase shift)

10. When does reflection take place on a transmission line?

When the load impedance is not equal to characteristic impedance of the transmission line (ie., $Z_R \neq Z_0$) reflection takes place.

HIGH FREQUENCY TRANSMISSION LINES

1. What are the assumptions to simplify the analysis of line performance at high frequencies?

* Current is considered as flowing on the surface of the conductor
* $\omega L >>> R$
* 'G' may be considered as zero

2. Define SWR.

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

$$SWR = \frac{|V_{max}|}{|V_{min}|} = \frac{|I_{max}|}{|I_{min}|}$$

3. Determine the values of SWR in the case of $Z_R = 0$ and $Z_R = Z_0$.

* $Z_R = 0$, $|K| = 1$, $SWR = \infty$
* $Z_R = Z_0$, $K = 0$, $SWR = 1$

4. Give the relation between SWR and reflection co-efficient.

* $SWR = \frac{1+|K|}{1-|K|}$
* $K = \frac{S-1}{S+1}$

5. A lossless line has a characteristic impedance of 400 Ω. Determine the standing wave ratio if the receiving end impedance is $(800 + j0.0)\ \Omega$.

Solution

$Z_0 = R_0 = 400\ \Omega$, $Z_R = 800 + j0.0 = 800\ \Omega$

Reflection co-efficient, $K = \frac{Z_R - Z_0}{Z_R + Z_0}$

$= \frac{800 - 400}{800 + 400} = \frac{400}{1200}$

$= 0.33$

Standing wave ratio, $SWR = \frac{1 + |K|}{1 - |K|}$

$= \frac{1 + 0.33}{1 - 0.33}$

$= 1.99$

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

When the quarter wave line is shorted to ground, the input impedance becomes very high. Thus it acts as an insulator. It provides mechanical support to open wire transmission line.

7. Give the properties of an infinite line.

* It is a hypothetical line which has input impedance equal to the characteristic impedance.

* A finite line terminated in a load equivalent to the characteristic impedance appears to the sending end as an infinite line.

8. A lossless transmission line has a shunt capacitance of 100 μF/m and a series inductance of 4 μH/m. Determine the characteristic impedance.

Solution

$C = 100\,\mu F/m, \quad L = 4\,\mu H/m$

Characteristic Impedance $Z_0 = \sqrt{\frac{L}{C}}$

$= \sqrt{\frac{4 \times 10^{-6}}{100 \times 10^{-6}}}$

$= 0.2\,\Omega$

9. Write the expression for the open and short circuited input impedance of dissipationless line.

Short circuit impedance, $Z_{sc} = jR_0 \tan \beta x$

Open circuit impedance, $Z_{oc} = -jR_0 \cot \beta x$

10. For the line of zero dissipation, what will be the values of attenuation constant and characteristic impedance.

Attenuation constant, $\alpha = 0$

Characteristic Impedance, $Z_0 = \sqrt{\frac{L}{C}}$

IMPEDANCE MATCHING IN HIGH FREQUENCY LINES

1. What is meant by impedance matching?

Impedance matching is designing source and load impedances to minimize signal reflection or maximize power transfer.

Impedance matching is the process of equating the value of load impedance to the value of source impedance for maximum power transfer from source to load.

In DC circuits,

* Source and load should be equal

In AC circuits,

* Source should either equal the load or the complex conjugate of the load

2. Give some of the impedance matching devices.

* Quarter wave line [or Transformer]
* Tapered line

3. Why quarter wave line is called as impedance inverter?

Quarterwave line is called as an impedance inverter because it can transform a low impedance into a high impedance and vice versa.

4. What is an impedance inverter?

An impedance inverter is a type of circuit which has input impedance inversely proportional to the impedance connected at the other end.

5. Distinguish between single stub and double stub matching.

Sr.No.	Single stub Matching	Double stub Matching
1.	It has one stub to match the impedance	It requires two stub for impedance matching
2.	It requires both length and location of stub to be altered for matching.	It requires only alter the length of stubs for matching.
3.	It requires stub should be placed on a definite place on a line.	The location of stub is arbitrary.

6. What is a stub? Why it is used in between transmission lines?

Stub is a short circuited or open circuited line designated at a distance from the load.

Stub is used in between transmission lines for impedance matching.

7. Design a quarter wave transformer to match a load of 200Ω to a source resistance 500Ω. The operating frequency is 200 MHz.

Solution

$$Z_L = 200\Omega, \quad Z_s = 500\Omega, \quad f = 200 MHz$$

$$\lambda = c/f = \frac{3\times10^8}{200\times10^6} = 1.5m$$

Length, $l = \lambda/4 = \frac{1.5}{4} = 0.375m$

Characteristic impedance, $Z_0 = \sqrt{Z_s . Z_L}$

$$= \sqrt{500\times200}$$

$$= 316.227\Omega$$

8. Give the names of circles on Smith chart.

* Constant 'R' circles
* Constant 'X' circles

9. Mention two applications of Smith chart.

* Determination of SWR, sending and impedance

and load admittance

* Solution of the stub matching problem may be easily carried out using smith chart

10. Write down the expression to determine the length and position of the stub.

$$\text{length}, l_t = \frac{\lambda}{2\pi} \tan^{-1}\left[\frac{\sqrt{1-|K|^2}}{2|K|}\right]$$

$$\text{location}, l_s = \frac{\lambda}{4\pi}\left[\phi + \pi - \cos^{-1}|K|\right]$$

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WAVEGUIDES

1. What are waveguides?

A hollow metallic tube of uniform cross-section for transmitting electromagnetic waves by successive reflections from the inner walls of the tube is called as waveguide.

[OR]

Wave guides are metal tubes or other device confining and conveying microwaves.

[OR]

Waveguide is an electromagnetic feed line used in microwave communications, broadcasting and radar installations.

2. List the characteristics of a waveguide.

* The (waveguide) tube wall provides distributed inductance.
* The empty space between the tube walls provide distributed capacitance.
* Waveguides are bulky, heavy and expensive.

3. What are guided waves? Give examples.

The electromagnetic waves that are guided along the conducting or dielectric surface are called guided waves.

Ex: * Parallel wires
* Transmission lines

4. Compare TE and TM waves.

Sl.No	TE WAVES	TM WAVES
1.	Transverse electric waves	Transverse magnetic waves
2.	No electric field component in the direction of wave propagation. ie., $E_z = 0$	No magnetic field component in the direction of wave propagation. ie., $H_z = 0$
3.	Only magnetic field component exists in the direction of wave propagation. ie., $H_z \neq 0$	Only electric field component exists in the direction of wave propagation. ie., $E_z \neq 0$
4.	TE waves are also known as H-waves.	TM waves are also known as E-waves.

5. A rectangular waveguide with dimensions a = 2.54 cm, b = 1.27 cm, waveguide thickness is 0.217 cm. TE_{10} mode at 6GHz. Calculate the cut-off frequency for TE_{11} mode.

Solution

Given, $a = 2.54\,cm = 2.54 \times 10^{-2}\,m$

$b = 1.27\,cm = 1.27 \times 10^{-2}\,m$

Cut-off frequency, $f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$

For TE_{11} mode $\Rightarrow$ $m=1, n=1$

$$\Rightarrow f_c = \frac{c}{2\pi}\sqrt{\pi^2\left(\frac{m}{a}\right)^2 + \pi^2\left(\frac{n}{b}\right)^2}$$

$$= \frac{c}{2\pi}\sqrt{\pi^2\left[\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2\right]}$$

$$= \frac{c\pi}{2\pi}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$= \frac{3 \times 10^8}{2}\sqrt{\left(\frac{10^2}{2.54}\right)^2 + \left(\frac{10^2}{1.27}\right)^2}$$

$$= 1.5 \times 10^8 \times \sqrt{1549.9969 + 6199.9876}$$

$$= 1.5 \times 10^8 \times \sqrt{7749.9845}$$

$$= 1.5 \times 10^8 \times 88.03$$

$$f_c = 132.045 \times 10^8\ Hz$$

(or) $f_c = 13.2045 \times 10^9 = 13.20\ GHz$

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6. A waveguide is generally operated at $f = 1.5 f_c$ where f_c is the cut-off frequency. Assuming that the broader dimension is twice the other dimension in a rectangular waveguide, calculate the dimension if it operates in TE_{10} mode at 6GHz.

Solution

Given, $f = 1.5 f_c$, $f = 6GHz$ for TE_{10} mode

$$\Rightarrow f_c = f/1.5$$

$$= \frac{6 \times 10^9}{1.5} = 4 \times 10^9$$

$$f_c = 4\ GHz$$

For rectangular waveguide,

$$f_c = \frac{mc}{2a}$$

TE_{10} mode: $m=1, n=0$

$$\Rightarrow a = \frac{mc}{2f_c}$$

$$= \frac{1 \times 3 \times 10^8}{2 \times 4 \times 10^9}$$

$$a = 0.0375\ m$$

Broader Dimension = Twice the other dimension

$$= 2 \times 0.0375$$

$$= 0.075\ m$$

length $= 0.075\ m$, width $= 0.0375\ m$

7. What is dominant mode? Give examples.

The lowest order mode is called dominant mode.

Ex: TE_{10} and TM_{11}

8. What is cut-off frequency?

The frequency at which the wave motion causes is called the cut-off frequency of the wave.

9. What is principal wave?

Transverse electromagnetic waves (TEM) are waves in which both electric and magnetic fields are transverse entirely. It has no components of E_z and H_z. It is referred to as principal wave.

10. Define wave impedance.

Wave impedance is defined as the ratio of the electric field strength to the magnetic field strength.

$$Z_{TE} \text{ (or) } Z_{TM} = \frac{E}{H}$$

RF SYSTEM DESIGN CONCEPTS

1. What does radio frequency mean?

Radio Frequency (RF) is a measurement representing the oscillation rate of electromagnetic radiation spectrum or electromagnetic radio waves, from frequencies ranging from 1GHz to 300GHz.

2. What are active RF components?

Active components intended for RF systems may offer specialized functionality or they may offer standard functionality but with greater ability to maintain performance at high frequencies.

Ex: Amplifiers, Mixers, Energy sources ... etc ...

3. Give some examples of RF semiconductor materials.

RF semiconductor materials include Gallium Arsenide (GaAs), Gallium Nitride (GaN), Silicon (Si) and Silicon carbide (SiC).

These materials are significant in circuits such as RF filters, RF power amplifiers, RF low noise amplifiers and RF switches.

4. What are the components of RF?

Attenuators, DC blocks, couplers, filters, Phase shifters, Low Passive Intermodulation Components (terminations, adapters ....), Splitters, Dividers, Tappers.

5. What is meant by RF schottky diodes?

RF schottky diodes are silicon low barrier N-type devices, which can be used in sensitive power detectors, in sampling or in mixer circuits.

6. What is a Bipolar Junction Transistor?

A bipolar junction transistor is a three terminal semiconductor device that consists of two p-n junctions which are able to amplify a signal. It is a current controlled device.

7. Why BJT is called bipolar?

In BJT, the operation involves two kinds of charge carriers, holes and electrons. So it is named as (BJT) bipolar device.

8. What is field effect transistor (FET)?

Field Effect Transistor (FET) is a type of transistor that uses an electric field to control the flow of current in a semiconductor. It is a voltage controlled device.

9. What are the applications of field effect transistor?

* FETs are used in mixer circuits to control low inter modulations distortions
* FETs are used in low frequency amplifiers due to its small coupling capacitors
* FET is a voltage controlled device due to this it is used in operational amplifier as voltage variable resistors.

10. What is meant by high electron mobility transistor?

High electron mobility transistor (HEMT) is a field effect transistor incorporating a junction between two materials with different band gaps as the channel instead of a doped region.

11. List the applications of HEMT.

HEMTs are used in,

* Microwave communications
* Millimeter wave communications
* Radar Applications

* Radio Astronomy
* High gain and High frequency applications
* Voltage conversion Applications

12. What is transistor's carrier mobility?

The transistor's carrier mobility is an important parameter and determines the operation speed and high frequency response character of electronic devices made from solid materials.

13. What does a RF mixer do?

RF mixer is an active or passive device that converts a signal from one frequency to another. It can either modulate or demodulate a signal.

14. List the different types of mixers.

Main Types

1. Active Mixer (using BJTs or FETs)
2. Passive Mixer (using diode)

Based on configuration,

1. Unbalanced Mixer
2. Single balanced Mixer
3. Double balance Mixer ... and so on...

15. Define stability.

stability means that the transistor is stable when embedded between 50 Ω source and load, and it will not oscillate.

The amplifier is stable when the magnitude of reflection co-efficients are less than unity. Simply, the load and source reflection co-efficients are less than unity.

$$|\Gamma_L| < 1 \quad \text{and} \quad |\Gamma_S| < 1$$

16. What is meant by unconditional stability?

An amplifier remains stable for any passive source and load at the selected frequency and bias conditions. Such a situation is referred to as an unconditional stability.

17. Define transducer power gain.

Transducer power gain is nothing but the gain of the amplifier when placed between the source and load.

$$G_T = \frac{\text{Power delivered to the load}}{\text{Available power from the source}}$$