Lab Manual

Experiment No. RF1a

Aim of Experiment:

Observe the transient phenomenon of terminated coaxial transmission lines in order to study their time domain behavior.

Requirement:

You have to install a LabVIEW Run time Engine on your computer to run the exe file in order to perform the experiment. The Run Time Engine can be downloaded free of cost from the following link: http://joule.ni.com/nidu/cds/view/p/id/1101/lang/en

Knowledge Required for the Experiment:

- Transverse Electromagnetic wave.
- Transmission-Line.
- General Transmission-Line equations.
- Transmission-Line parameters.
- Reflection Coefficient.

Objective of Experiment:

The main objective of the experiment is to observe the transient phenomenon of terminated coaxial transmission lines. The transmission line is considered as lossless and for such lines ($R = 0, G = 0$), characteristic impedance becomes characteristic resistance $R_0 = {}^{1}/_{\sqrt{LC}}$, and voltage and current waves propagate along the line with a velocity $u = {}^{1}/_{\sqrt{LC}}$. In this experiment a d-c voltage source V_0 is applied through a series (internal) resistance R_g at $t = 0$ to the input terminals of a lossless line terminated in a load resistance R_l. This experiment shows the voltage and current wave travelling on the transmission line and total voltage and total current can also be seen at any specified point on transmission line w.r.t. time.

Theory:

Transmission line: It is a device designed to guide the electrical energy from one point to another. It is used, for example, to transfer the RF energy from source to antenna. For efficient point-to-point transmission of power and information the source energy must be directed or guided. Transmission line that consists of two or more conductors may support transverse electromagnetic (TEM) waves, characterized by the lack of longitudinal field components. The TEM mode of guided waves is one in which **E** and **H** are perpendicular to each other and both are transverse to the direction of propagation along the guiding line. TEM waves have uniquely defined voltage, current, and characteristic impedance.

The three most common types of guiding structures that support TEM waves are:

1. *Parallel-plate transmission line*
2. *Two-wire transmission line.*
3. *Coaxial transmission line.*

Coaxial transmission line: This type of transmission line consists of an inner conductor and outer conductor separated by a dielectric medium. This structure has the important advantage of confining the electric and magnetic fields entirely within the dielectric region. No stray fields are usually generated inside a coaxial transmission line, and little external interference is coupled into the line.

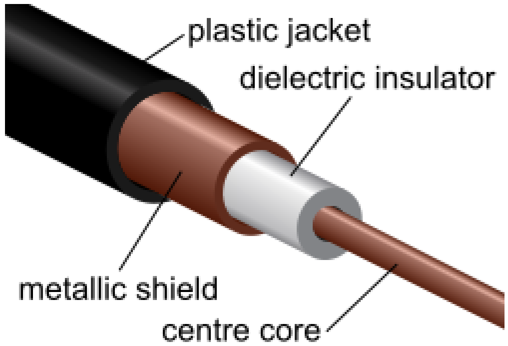

***Fig 1**: Coaxial cable*

http://www.websters-online-dictionary.org/definitions/Coaxial%20Cable?cx=partner-pub-0939450753529744%3Av0qd01-tdlq&cof=FORID%3A9&ie=UTF-8&q=Coaxial%20Cable&sa=Search#922

General Transmission-Line Equation: A transmission line is a distributed-parameter network and must be described by circuit parameters that are distributed throughout its length. Under matched conditions, standing waves exit in a transmission line while, no standing wave exist in lumped-circuit elements in an ordinary electric network.

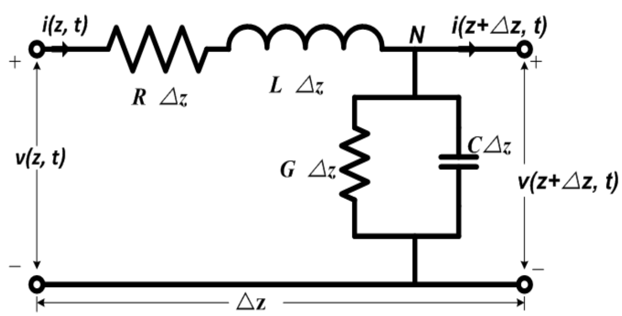

***Fig 2:** Equivalent circuit of a differential length of a two-conductor transmission line.*

Consider a differential length Δz of a transmission line that is described by the following four parameters:

R, resistance per unit length, in Ω/m.
L, inductance per unit length, in H/m.
G, conductance per unit length, in S/m.
C, capacitance per unit length, in F/m.

Note that *R* and *L* are series elements and *G* and *C* are shunt elements. Fig 2, shows the equivalent electric circuit of such a line segment. The quantities *v(z,t)* and *v(z+Δz, t)* denote the instantaneous voltages at *z* and *z+Δz*, respectively. Similarly, *i(z,t)* and *i(z+Δz, t)* denote the instantaneous currents at *z* and *z+Δz*, respectively.

Applying Kirchhoff's voltage law, we obtain

$$v(z,t) = R\,\Delta z\, i(z,t) - L\,\Delta z \frac{\partial i(z,t)}{\partial t} - v(z+\Delta z, t) = 0$$

$$Or, \qquad -\frac{v(z+\Delta z,t)-v(z,t)}{\Delta z} = Ri(z,t) + L\frac{\partial i(z,t)}{\partial t}$$

For $\Delta z \to 0$, above equation becomes,

$$-\frac{\partial v(z,t)}{\partial z} = Ri(z,t) + L\frac{\partial i(z,t)}{\partial t} \qquad (\mathbf{1})$$

Similarly, applying Kirchhoff's current law to the node N in Fig. 2, and in the limit as $\Delta z \to 0$ we have,

$$-\frac{\partial i(z,t)}{\partial z} = Gv(z,t) + C\frac{\partial v(z,t)}{\partial t} \qquad (\mathbf{2})$$

These equations are a pair of first-order partial differential equations in *v(z,t)* and *i(z,t)*. They are the ***general transmission-line equations.***

Simplifying the transmission-line equations to ordinary differential equations we have,

$$-\frac{dV(z)}{dz} = (R + j\omega L)I(z), \qquad (\mathbf{3})$$

$$-\frac{dI(z)}{dz} = (G + j\omega C)V(z). \qquad (\mathbf{4})$$

These equations are ***time-harmonic transmission-line equations,*** which reduces to the equation (5) and (6) if $\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$ (m^{-1}) where γ is the propagation constant whose real and imaginary parts, α and β, are the ***attenuation constant*** (Np/m) and ***phase constant*** (rad/m) of the line, respectively.

$$\frac{d^2V(z)}{dz^2} = \gamma^2 V(z) \qquad (\mathbf{5})$$

$$\frac{d^2I(z)}{dz^2} = \gamma^2 I(z) \qquad (\mathbf{6})$$

The solutions of equations (5) and (6) are

$$V(z) = V^+(z) + V^-(z) \qquad \mathbf{(7)}$$

$$= V_o^+ e^{-\gamma z} + V_o^- e^{\gamma z} \qquad \mathbf{(8)}$$

$$I(z) = I^+(z) + I^-(z) \qquad \mathbf{(9)}$$

$$= I_o^+ e^{-\gamma z} + I_o^- e^{\gamma z} \qquad \mathbf{(10)}$$

where the plus and minus subscripts denote waves travelling in the +z and –z direction.

In RF transmission, because of the impedance mismatch the power travelling on transmission line gets reflected at its termination. This mismatch happens when the characteristic impedance of transmission line are not same as source or load impedances. Normally the total voltage at any point of the transmission line is given by equation (8) and the total current at any point of the transmission line is given by equation (10)

Consider a transmission line of length l having characteristic impedance Z_o and connected to a voltage generator V_g with internal impedance Z_g, and terminated with a load impedance Z_L. Reflection coefficient at the generator end (Γ_g) and at the load end (Γ_L) are given by-

$$\Gamma_g = \frac{Z_g - Z_o}{Z_g + Z_o} \qquad (11)$$

and

$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o} \qquad (12)$$

When first wave, $V_1^+ = V_M e^{-\gamma z}$ reaches Z_L at Z=l , it is reflected because of impedance mismatch at load end, resulting in a wave V_1^- with a complex amplitude $\Gamma_L\,(V_M e^{-\gamma z})$ travelling the –z direction. As the wave V_1^-returns to the generator at z=0,

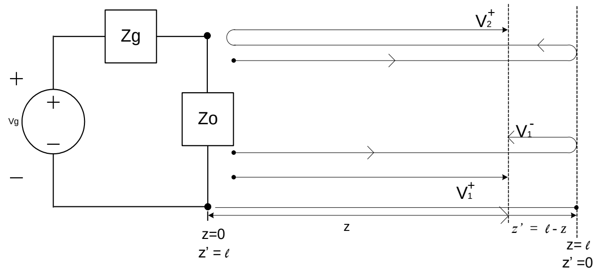

Fig 3: Voltage wave propagation on transmission line

It is again reflected for $Z_g \neq Z_o$, giving rise to second wave V_2^+ with a complex amplitude $\Gamma_L \Gamma_g\,(V_M e^{-\gamma z})$ travelling in the +z direction. This process continues indefinitely with reflections at both ends and the resulting standing waves $V(z')$ is the sum of all the waves travelling in both directions as shown in Fig. 2. When the line is terminated with a matched load Z_L=Z_o, only V_1^+ exists and it stops at the matched load with no reflections. If $Z_L \neq Z_o$ but Z_g=Z_o (if the internal impedance of the generator is matched to the line), then $\Gamma_L \neq 0$ and $\Gamma_g = 0$. As a consequence both $V_1^+$and V_1^- exist, and $V_2^+, V_2^-$and all higher order reflections vanish.

There are practical situations in which the sources and signals are not time-harmonic and the conditions are not steady state such as digital signals in computer networks and so on. In such cases the transient behavior of lossless transmission lines is considered.

LabVIEW PROGRAMMING:

As stated earlier, LabVIEW is a graphical programming environment used currently by millions of engineers to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. LabVIEW (VI file) can be useful in providing a better understanding of the transient behavior of a transmission line. Behavior of the waves on the transmission lines for different parameters like characteristic impedance Z_o, load impedance Z_L, generator resistance R_g, length of the line and so on can be visualized using LabVIEW.

Procedure:

Please download the files shown on the left to perform the actual experiment. It consists of three exe file one for the resistive load, second file for inductive load and the third file is for capacitive load.

Step 1: Set the source voltage (Vs) in volts and generator resistance (Rg).

Step 2: Set the number of cycles, number of points in distance scale and location of point (in meter) at which voltage has to be measured w.r.t. time.

Step 3: Enter the values of properties of transmission line i.e. length of transmission line(L) in meters, characteristic Impedance of transmission line (Ro) and dielectric constant (epsilon).

Step 4: In the output you will see four plots, one showing variation for the voltage vs distance in transmission line, second plot shows the variation for the current vs distance in transmission line, third plot shows the variation for the total voltage vs time at a point on transmission line and the fourth plot shows the variation for the total current vs time at a point on transmission line.

Step 5: Run the set up to see the results and if you wish to verify it for other parameters then click stop and repeat steps 1-4 and again run the set up.

Task:

1. Observe the voltage and current wave travelling along the transmission line by changing the values of source voltage, generator resistance and load resistance.
2. Observe the total voltage and total current at any point on the transmission line by varying the location of point at which voltage or current has to be measured.
3. Observe the total voltage and total current at a point on the transmission line by varying the length of transmission line and characteristic impedance.

Summary: This experiment shows the graphical construction of a reflection diagram. Both, the voltage reflection and current reflection diagram for the transmission-line circuit has been shown here. Step-by-step construction and calculation procedure of the voltage and current at a particular time and location on a transmission line with arbitrary resistive terminations tends to be tedious and difficult to visualize when it is necessary to consider many reflected waves. In such cases the graphical construction of a reflection diagram is very helpful.

References:

1. "Microwave Engineering", Third Edition, David M. Pozer
2. "Microwave Devices and Circuits", Third Edition, Edition, Samuel Y.Liao
3. "Field and Wave Electromagnetics", Second Edition, David K.Cheng
4. "Electromagnetic Waves and Radiating System", Edward C.Jordan, Keith G.Balmain