

Lab Manual

Experiment No. RF1b

Aim of Experiment:

Study the behavior of terminated coaxial transmission lines in frequency domain.

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:

This experiment gives the vision by which we can see the voltage wave travelling toward the load, voltage reflected wave from the load end and the voltage standing wave, by which we can understand the concept behind the transmission of analog signal in the lossless transmission line. In a transmission-line operating at high frequency, due to impedance mismatch between the source, transmission-line, and load there is a loss of energy transfer from source to load. The effects due to mismatch of the load and characteristic impedance can be studied here in frequency domain. This can be done by sending a wave on the line with its load mismatched and watching the reflected wave along with voltage standing wave over transmission line. By varying various parameters of transmission line their effects can be visualized accordingly.

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 \mathbf{E} and \mathbf{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.

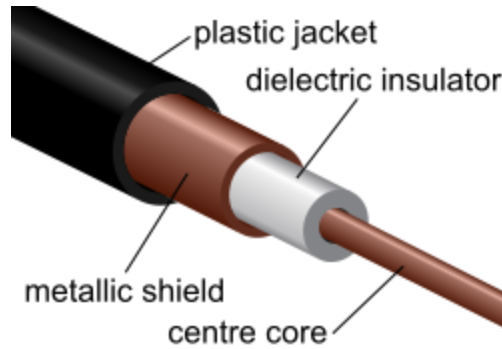


Fig 1: Coaxial cable

<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>

In this experiment at the generator terminal we have AC voltage source, and transmission line is considered as lossless i.e. $R = 0, G = 0$. Therefore the characteristic impedance becomes pure resistance ($R_0 = \sqrt{L/C}$). Since we know that the general solution for the transmission lines are:

$$V(z) = V_o^+ e^{-\gamma z} + V_o^- e^{\gamma z} \quad (1)$$

$$I(z) = I_o^+ e^{-\gamma z} + I_o^- e^{\gamma z} \quad (2)$$

Where,

$$\frac{V_o^+}{I_o^+} = -\frac{V_o^-}{I_o^-} = Z_0 \quad (3)$$

A transmission-line of finite length having characteristic impedance Z_0 terminated in arbitrary load impedance Z_L as shown in the Fig. 2, the length of the line is l . A sinusoidal voltage V_g with internal impedance Z_g is connected to the line at $z = 0$.

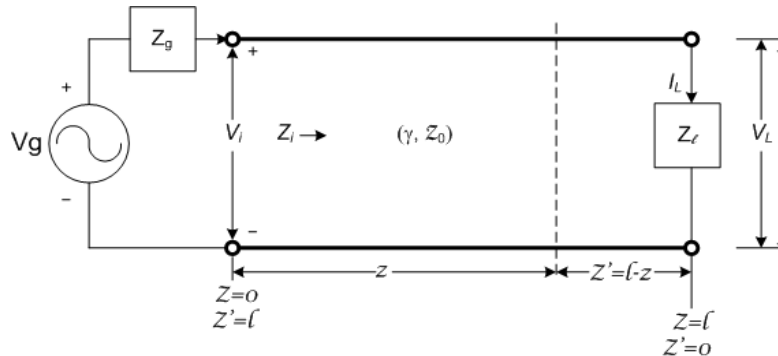


Fig 2: Finite transmission line terminated with load impedance Z_L .

The incident voltage V_i travels down the line $+z$ direction. When the finite transmission line is terminated with its own characteristic impedance (when a finite transmission line is matched), there is no reflected wave thus, we get 0 voltage reflection in the reflected voltage plot.

When the transmission line is terminated with impedance Z_l other than its characteristic impedance there is a reflected wave generated from the load end of the transmission line due to mismatch. This process continues indefinitely with reflection at the both ends, and the resulting standing wave $V(z')$ is the sum of all the waves travelling in both directions.

Standing wave ratio (SWR): Standing wave ratio (SWR) is defined as the ratio of the maximum to the minimum voltages along a finite, terminated transmission-line.

When the load is mismatched the presence of a reflected wave leads to standing waves where the magnitude of the voltage on the line is not constant. And, the voltage magnitude oscillates with position z along the line. The maximum value occurs when the phase term $e^{j(\theta-2\beta l)} = 1$, and is given by $V_{max} = |V_0^+|(1 + |\Gamma|)$. The minimum value occurs when the phase term $e^{j(\theta-2\beta l)} = -1$, and is given by $V_{min} = |V_0^+|(1 - |\Gamma|)$. As $|\Gamma|$ increases, the ratio of V_{max} to V_{min} increases, so a measure of the mismatch of a line, called the *standing wave ratio (SWR)*, can be defined as

$$SWR = \frac{V_{max}}{V_{min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \quad (4)$$

This quantity is also known as the voltage standing wave ratio, and is sometimes identified as VSWR. From equation (4) it is seen that SWR is a real number such that $1 \leq SWR \leq \infty$, where $SWR = 1$ implies a matched load.

LabVIEW Programming:

In the LabVIEW programming of the experiment incident voltage V_i is plotted. Incident voltage wave is given as $V_i = V_1^+ = \frac{Z_i}{Z_g + Z_i} V_g$. As, soon this incident voltage reaches at the load end, if the load is not matched to the characteristic impedance of the transmission-line, the voltage wave gets reflected. The reflected voltage wave is given by $V_1^- = \Gamma_L V_1^+$. Presence of reflected wave leads to standing waves where the magnitude of the voltage on the line is not constant. In the third plot of vi standing wave has been plotted, the value of it can be seen in the column of output parameter at the front panel.

Procedure:

Please download the files shown on the left to perform the actual experiment. The exe file is the LabVIEW file that will run on Lab VIEW Run time Engine

Step 1: Set the incident voltage (V_0) in volts and frequency (f) of incident wave in GHz.

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 meter, characteristic impedance of transmission line (R_0) in Ohm and relative dielectric constant (epsilon) of transmission line.

Step 4: Enter the value of load resistance (R_L) in Ohm.

Step 5: In the output you will see three plots first one showing the incident voltage travelling along transmission line, second plot shows the reflected voltage wave travelling along transmission line and the third plot shows the voltage standing wave along the transmission line.

Step 6: Run the VI to see the results. In case, you wish to see the result for different values then click STOP and repeat steps 1 – 5 before running the program again.

Task:

1. By specifying source and load values and giving the properties of transmission line, observe the travelling wave, reflected voltage wave and standing wave ratio.
2. Observe the waves in case of matched and mismatched impedance.
3. Observe the waves for short circuited and open circuited transmission line by specifying “0” value to load reactance and for load resistance specify the value “0” for short circuited and “inf” for open circuited transmission line.

Summary: This experiment gives a vision to see the high frequency voltage wave travelling in the transmission-line. This experiment helps in building concept of waves travelling in transmission line, reflected waves from the load end and the standing wave generated in case of impedance mismatch.

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