Experiment No. 1 Computation & Verification of Reflection Coefficient, VSWR and Input Impedance of a transmission line

Aim:

To compute and verify reflection coefficient, VSWR and input impedance of a given transmission line.

Software requirements:

Software- SmithV4.1

Theory:

Smith Chart is the invention of two researcher's Philip Smith and Tosaku who hold individual credits in this chart discovery. This chart was developed in the period 1930s at Bell Telephone's Research laboratory. Smith chart is considered as a graphical measuring tool which is constructed mainly to solve problems related to RF transmission lines and matching devices. Smith chart is plotted on the complex reflection coefficient plane in two dimensions and is scaled in normalised impedance (the most common), normalised admittance or both, using different colours to distinguish between them and serving as a means to categorize them into different types. Smith chart can be used to display several parameters including; impedances, admittances, reflection coefficients, VSWR, scattering parameters, noise figure circles, constant gain contours and regions for unconditional stability.

Smith chart is constructed by superimposing the locus of constant resistance normalized values (which are circles centered on real axis) and locus of constant reactance normalized values (which are circles centered on imaginary axis). The intersection of r-circles and x-circles which are orthogonal to each other will specify different normalized impedances on Smith chart.

Reflection Coefficient (Γ):

The reflection coefficient is a parameter that describes how much of a wave is reflected by an impedance discontinuity in the transmission medium. It is equal to the ratio of the amplitude of the reflected wave (V^-) to the incident wave (V^+), with each expressed as phasors. Mathematically,

$$\Gamma = \frac{V^-}{V^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Voltage Standing Wave Ratio (VSWR):

It is defined as a ratio of maximum voltage to minimum voltage. Voltage Standing Wave Ratio (VSWR) or standing wave ratio is a measure of how well matched a transmission line is to a load. Mathematically, it is defined as:

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

Input Impedance:

The input impedance of a transmission line is the impedance offered by it at the input terminals. As the source is connected at the input terminals, this quantity has some special significance while selecting the source. During computations, input impedance is quite useful parameter to find the power flowing into the line when a generator is connected to it. To push maximum power over to the line, the source impedance and input impedance of line must have a complex conjugate relationship.

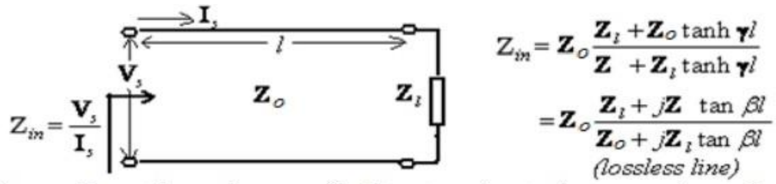

Figure Input impedance of a line terminated over an impedance.

Formally, the input impedance of a line can be defined as the ratio of complex phasor voltage to complex phasor current at its input terminals. Mathematically,

$$\mathbf{Z}_{in} = \frac{\mathbf{V}_{in}}{\mathbf{I}_{in}} = \frac{\text{Input voltage}}{\text{Input current}}$$

It is complex quantity, value being dependent upon the configuration, length and termination of the line.

For a general (lossy) line:

$$\mathbf{Z}_{in} = \mathbf{Z}_o \frac{\mathbf{Z}_l + \mathbf{Z}_o \tanh \gamma l}{\mathbf{Z}_o + \mathbf{Z}_l \tanh \gamma l}$$

For an ideal (lossless) line:

$$\mathbf{Z}_{in} = \mathbf{Z}_o \frac{\mathbf{Z}_l + j\mathbf{Z}_o \tan \beta l}{\mathbf{Z}_o + j\mathbf{Z}_l \tan \beta l}$$

Numerical Example:

A lossless transmission line with Z_0 = 50 Ω is 30 m long and operates at 2 MHz. The line is terminated with a load Z_L = (60+j40) Ω. If v = 0.6*c on the line, calculate:

(a) Reflection coefficient
(b) Standing wave ratio
(c) Input impedance

[Students are expected to solve above example using:
Method-I: Analytical Approach (using formulae)
Method-II: Graphical Approach (using Smith chart)
and compare the results with experimental observed values].

Observation Table:

Sr. No.	Parameter	Theoretical Value		Experimental Value
		Analytical	Graphical	
1.	Reflection coefficient (Γ)			
2.	VSWR (s OR ρ)			
3.	Input impedance (Zin)			

Conclusion:

After performing this experiment, we can conclude that the experimentally observed values of reflection coefficient, VSWR and input impedance are matching (within tolerable limits of experimental errors) with the values computed using analytical as well as graphical approach.