Lab Manual

Experiment No. 6

Aim of Experiment:

Study the behavior of impedance matching for passive networks using Smith chart.

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:

- ➢ Transmission line calculations
- ➢ Smith chart
- ➢ Resistance and Reactance Circle on Smith Chart.
- ➢ $|\Gamma| -$ Circle on Smith chart.
- ➢ Transmission line Impedance matching

Objective of Experiment:

In this experiment we discuss methods for impedance-matching on lossless transmission lines. The impedance-matching can be performed as:

- ➢ Impedance matching by single-stub
- ➢ Impedance matching by double-stub

Objective of the experiment is to make student familiar to the application of Smith chart for impedance-matching on lossless transmission line. The two important method used for impedance matching, single-stub and double-stub, so that, when performed on the real equipment they should be able to judge the position of stub on transmission line hence, probability of mistake will be decreased upto some extent.

Theory:

In discussing the use of the Smith chart for transmission-line calculations in the previous experiment (Experiment 5), we have assumed the line to be lossless. The lossless assumption enables us to say that the magnitude of the $\Gamma e^{-j2\beta z'}$ term does not change with line length z' and that we can find z_i from z_L, and vice versa, by moving along the $|\Gamma|$-circle by an angle equal to $2\beta z'$.

Matching the source and load to the transmission line or waveguide in a general microwave network is necessary to deliver maximum power from the source to the load. Here we have used two types of impedance matching, single-stub and double-stub. In single-stub method for impedance matching we place a short-circuited stub in parallel with the transmission line having characteristic impedance R_0. In some instances, the distance determined for the single stub tuner may not be convenient for implementation. In those cases, a double stub tuner may be required as shown in figure,
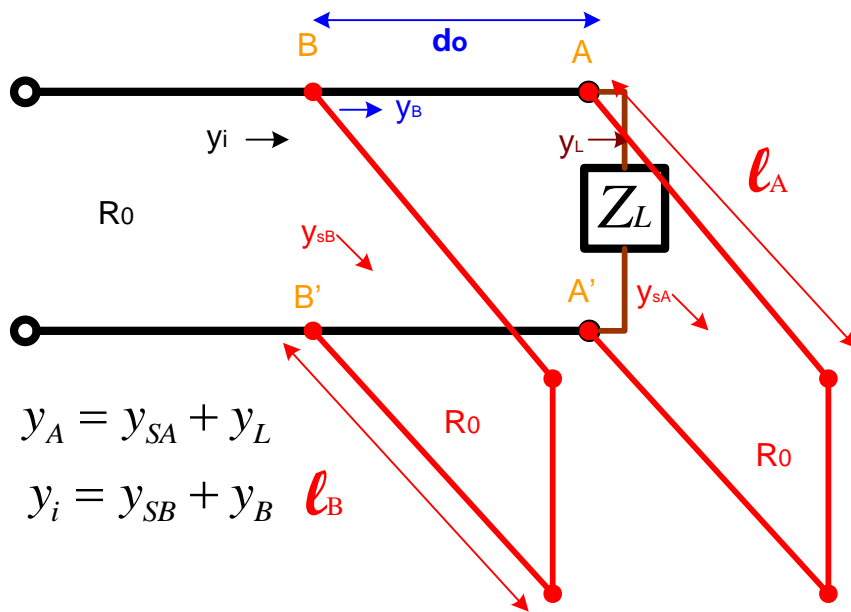
Fig 1: Impedance matching with double stub.

$$y_A = y_{SA} + y_L$$

$$y_i = y_{SB} + y_B$$

A double-stub transmission line impedance matching network is composed of two short ciruited sections of transmission line, separated by a length of transmission line, placed along the main signal line. The short cicuited sections provide an equivalent shunt susceptance. The short circuited sections are attached perpendicular to the main line as shown in the figure 1. The construction of the short circuited section is similar to the main line.

The load impedance is typically dependent on the frequency of operation. The distance, d_2 can be moved back and forth to get a wide range of susceptance values. The distance d_1 and d_2 can be found in terms of fractions of wavelength of the signal being transmitted using a Smith Chart.

Transmission line impedance matching:

Transmission lines are used for the transmission of power and information. For radio frequency power transmission it is highly desirable that as much power as possible is transmitted from the generator to the load and as little power as possible is lost on the line itself. This will require that the load be matched to the characteristic impedance of the line so that the standing-wave ratio on the line is as close to unity as possible. For information transmission it is essential that the lines be matched because reflections from mismatched loads and junctions will result in echoes and will distort the information-carrying signal. In this section we discuss several methods for impedance-matching on lossless transmission lines. We note parenthetically that the methods we develop will be of little consequence to power transmission by 60(Hz) lines inasmuch as these lines are generally very short in comparison to the 5(Mm) wavelength and the line losses are appreciable. Sixty-hertz power-line circuits are usually analyzed.

Impedance matching by single-stub :

We will now look into the problem of matching a load impedance Z_L to a lossless line that has a characteristic impedance R_0 by placing a single short-circuited stub in parallel with the line, as shown in fig 2.
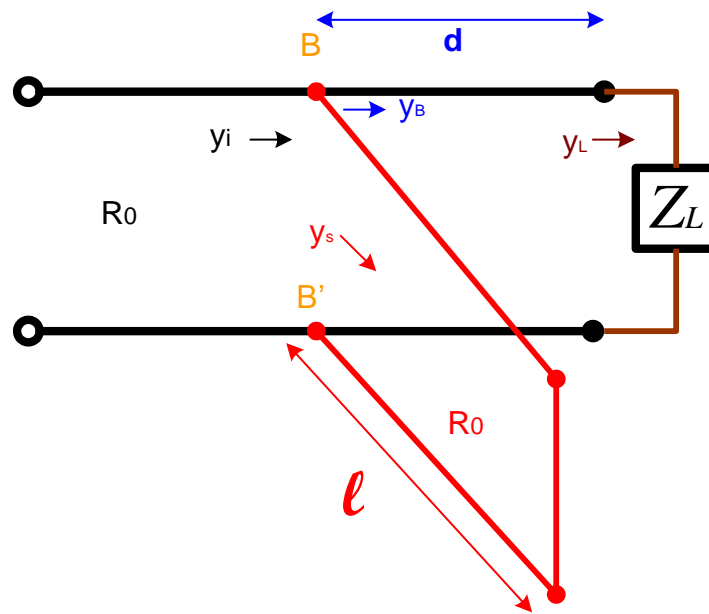

Fig 2: Impedance matching with single stub

This is the single-stub method for impedance matching. We need to determine the length of the stub, l, and the distance from the load, d, such that the impedance of the parallel combination to the right of points $B\text{-}B'$ equals R_0. Short-circuited stubs are usually used in preference to open-circuited stubs because an infinite terminating impedance is more difficult to realize than a zero terminating impedance for reasons of radiation from an open end and coupling effects with neighboring objects. Moreover, a short-circuited stub of an adjustable length and a constant characteristic resistance is much easier to construct than an open-circuited one. Of course, the difference in the required length for an open-circuited stub and that for a short-circuited stub is an odd multiple of a quarter-wavelength.

The parallel combination of a line terminated in Z_L and a stub at points $B\text{-}B'$ in the above figure suggest that it is advantageous to analyze the matching requirements in terms of admittances. The basic requirement is

$$Y_i \;=\; Y_B \;+\; Y_S$$

$$= \; Y_0 \;=\; 1/R_0.$$

In terms of normalized admittances, the above equation becomes, $1 \;=\; y_B \;+\; y_S$,
where $y_B \;=\; R_0\, y_B$ is for the load section and $y_S \;=\; R_0\, y_S$ is for the short-circuited stub. However, since the input admittance of a short-circuited stub is purely susceptive, y_S is purely imaginary.

Using the Smith chart as an admittance chart, we proceed as follows for single-stub matching:

➤ Enter the point representing the normalized load admittance y_L.
➤ Draw the $|\Gamma|\,-$circle for y_L, which will intersect the $g = 1$ circle at two points. At these points, $y_{B1} \;=\; 1 + jb_{B1}$ and $y_{B2} \;=\; 1 + jb_{B2}$. Both are possible solutions.
➤ Determine load-section lengths d_1 and d_2 from the angles between the point representing y_L and the points representing y_{B1} and y_{B2}

> ➢ Determine stub lengths l_{B1} and l_{B2} from the angles between the short-circuit point on the extreme right of the chart to the points representing $-jb_{B1}$ and $-b_{B2}$, respectively.

Impedance matching by double-stub

The method of impedance matching by means of a single stub described in the previous section can be used to match any arbitrary, nonzero, finite load impedance to the characteristic resistance of a line. However, the single-stub method requires that the stub be attached to the main line at a specific point, which varies as the load impedance or the operating frequency is changed. This requirement often presents practical difficulties because the specified junction point may occur at an undesirable location from a mechanical viewpoint. Furthermore, it is very difficult to build a variable-length coaxial line with constant characteristic impedance. In such cases an alternative method for impedance-matching is to use two short-circuited stubs attached to the main line at fixed positions, as shown in the figure,
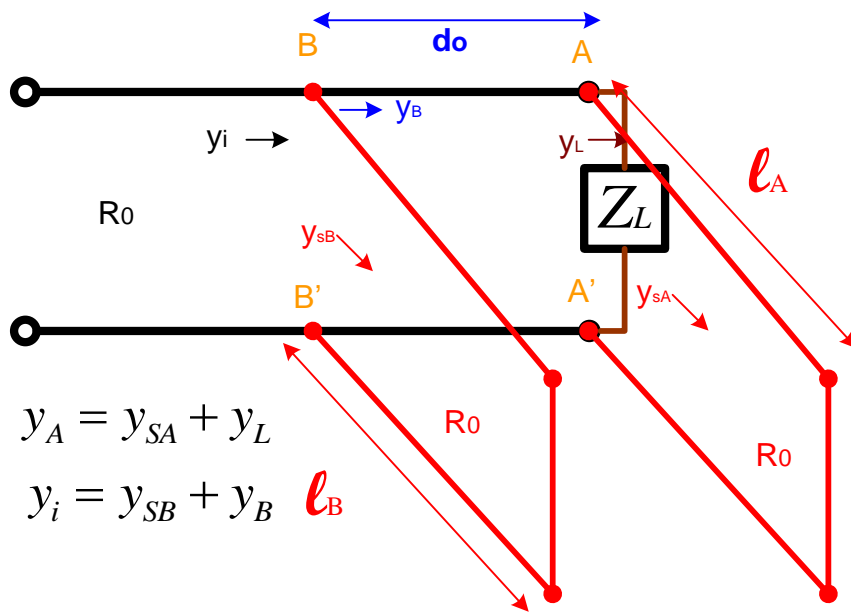

Fig 3: Impedance matching with double stub.

Here, distance d_0 is fixed and arbitrarily chosen and the lengths of the two stub tuners are adjusted to match a given load impedance Z_L to the main line. This scheme is the **double-stub method.**

In the above figure a stub of length l_A is connected directly in parallel with the load impedance Z_L at terminals A-A' , and a second stub of length l_B is attached at terminals B-B', at a fixed distance d_0 away. For impedance matching with a main line that has a characteristic resistance R_0 , we demand the total input admittance at terminals B-B', looking toward the load, to equal the characteristic conductance of the line; that is,

$$Y_i = Y_B + Y_{SB}$$
$$= Y_0 = 1/R_0.$$

In terms of normalized admittances, the above equation becomes, $1 = y_B + y_{SB}$

Now, since the input admittance y_{SB} of a short-circuited stub is purely imaginary, the above equation can be satisfied only if,

$$y_B = 1 + jb_B$$
$$y_B = -jb_B$$

Note that these requirements are exactly the same as those for single-stub matching.

On the smith admittance chart the point representing y_B must lie on the $g = 1$ circle. This requirement must be translated by a distance d_0 / λ "wavelength toward load". The procedure for solving a double stub matching problem on the Smith admittance chart is as follows.

➤ Draw the $g = 1$ circle. This is where the point representing y_B should be located.
➤ Rotate this circle in the counterclockwise direction by d_0 / λ "wavelengths toward load." This is where the point representing yA should be located.
➤ Enter the $y_L = g_L + jb_L$ point.
➤ Draw the $g = g_L$ circle, intersecting the rotated $g = 1$ circle at one or two points where $y_A = g_L + jb_L$
➤ Mark the corresponding y_B − points on the $g = 1$ circle: $y_B = 1 + jb_B$
➤ Determine stub length lA from the angle between the point representing y_A and the point representing y_L.
➤ Determine stub length lB from the angle between the point representing - jb_B and P_{SC} on the extreme right.

Procedure:

Please download the files shown on the left to perform the actual experiment.

Step 1: Enter the values of Resistive and Reactive part of load impedance.

Step 2: Enter the value of characteristic impedance.

Step 3: Length of stub (in terms of wavelength) and location of stub from the load end (in terms of wavelength) can be varied from the vertical bars provided.

Step 4: Run the VI to see the desired plot in Smith chart. The output can also be seen to the right of smith chart from numeric indicators.

In case, you wish to see the other plot then click stop and repeat steps 1-3 before running the program again.

Summary:
This experiment make student familiar to the application of Smith chart for impedance-matching on lossless transmission line. The two important method discussed in the experiment are single-stub and double-stub matching. This experiment will help in minimizing the probability of mistake when experiment performed on real equipment.

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