ECEN452: ULTRA HIGH FREQUENCY TECHNIQUE
LAB01
SAMBONG JANG
DR. HUFF

GitHub email: aya00383@tamu.edu

Calculating the two-port S and ABCD matrices for a series impedance $Z = 10 + j25\,\Omega$ using a system impedance $Z_o = 50\Omega$ and the frequency sweep parameters from the simulations.

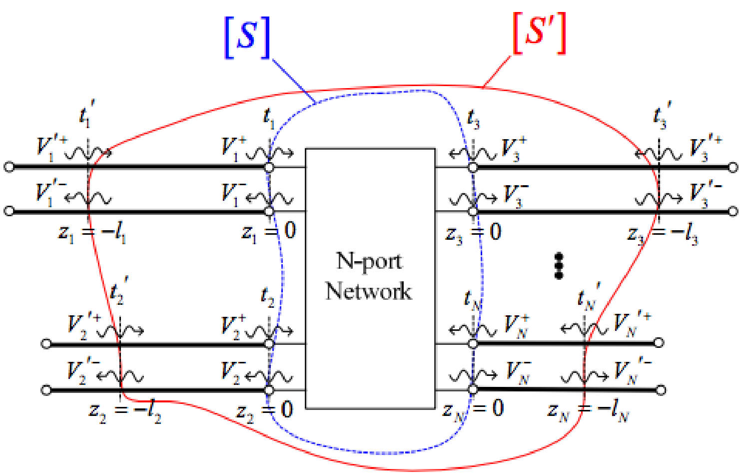
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 10 + j25 \\ 0 & 1 \end{bmatrix}$$

$$S = \begin{bmatrix} \dfrac{A + BY_0 - CZ_0 - D}{\Delta} & \dfrac{2(AD - BC)}{\Delta} \\ \dfrac{2}{\Delta} & \dfrac{-A + BY_0 - CZ_0 + D}{\Delta} \end{bmatrix}$$

$$\Delta = A + BY_0 + CZ_0 + D = 2.2 + j0.5$$

$$S = \begin{bmatrix} 0.13556 + j0.19646 & 0.86444 - j0.19646 \\ 0.86444 - j0.19646 & 0.13556 + j0.19646 \end{bmatrix} = \begin{bmatrix} 0.2387e^{j55.4} & 0.8865e^{-j12.804} \\ 0.8865e^{-j12.804} & 0.2387e^{j55.4} \end{bmatrix}$$

Now, for calculating shifted reference plane, it looks like the following:



Figure

$$[S'] = \begin{bmatrix} e^{-j\theta_1} & & 0 \\ & \ddots & \\ 0 & & e^{-j\theta_N} \end{bmatrix} \cdot [S] \cdot \begin{bmatrix} e^{-j\theta_1} & & 0 \\ & \ddots & \\ 0 & & e^{-j\theta_N} \end{bmatrix}$$

Figure

Now, we have all the ingredients to calculate the new S-parameter.

$$\theta = \beta l$$

Port 1 shifted by $0.8\lambda \therefore \theta_1 = 288°$

Port 2 shifted by $0.25\lambda \therefore \theta_2 = 90°$

$$S' = \begin{bmatrix} e^{-j288} & 0 \\ 0 & e^{-j90} \end{bmatrix} S \begin{bmatrix} e^{-j288} & 0 \\ 0 & e^{-j90} \end{bmatrix}$$

```
>> shift*S*shift

ans =

  -0.2383 + 0.0143i  -0.5845 - 0.6665i
  -0.5845 - 0.6665i  -0.2383 + 0.0143i
```

Figure. MATLAB Calculation

$$S' = \begin{bmatrix} 0.2387e^{j176.56} & 0.8845e^{j228.75} \\ 0.8845e^{j228.75} & 0.2387e^{j176.56} \end{bmatrix}$$

this network is reciprocal because the S-parameter is symmetric.

Substrates Table:

	FR4	Duroid 5880	Duroid 6006	Duroid 6010.2
ε_r	**4.4**	**2.2**	**6.15**	**10.2**
$Tan\delta$	**0.02**	**0.0009**	**0.0027**	**0.0023**

Figure

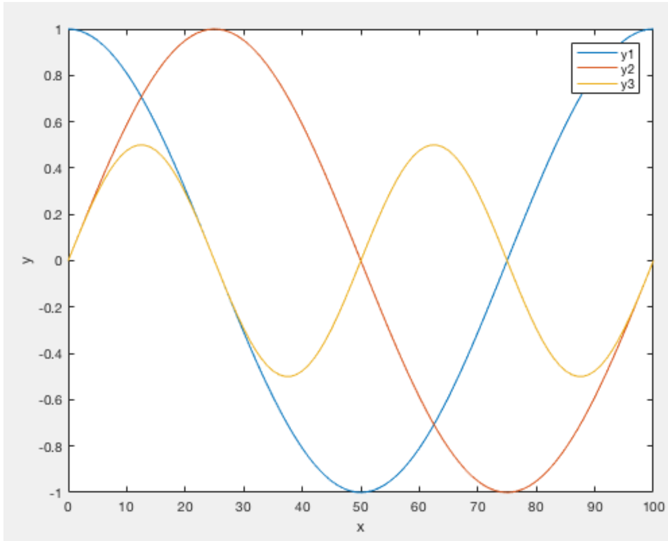
Connector Types:

	Type N	SMA	3.5mm	2.92mm	2.4mm	1.85mm
Type N	**Y**					
SMA		**Y**	**Y**	**Y**		
3.5mm		**Y**	**Y**	**Y**		
2.92mm		**Y**	**Y**	**Y**		
2.4mm					**Y**	
1.85mm					**Y**	**Y**

Figure

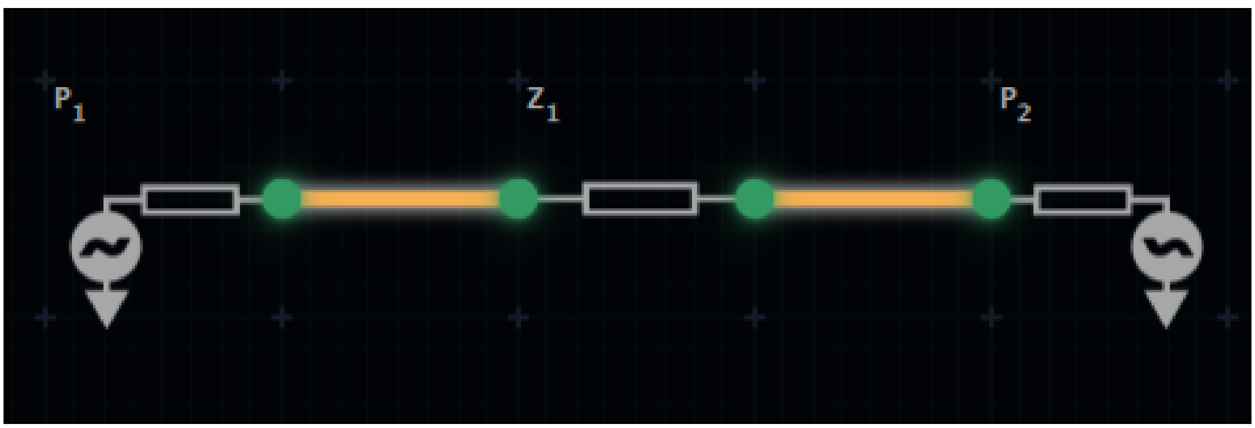
Matching Rule: Mechanical & Electrical Characteristics conditions such as the operating frequency.

PLOT:



Figure

FIRST CIRCUIT:



Figure

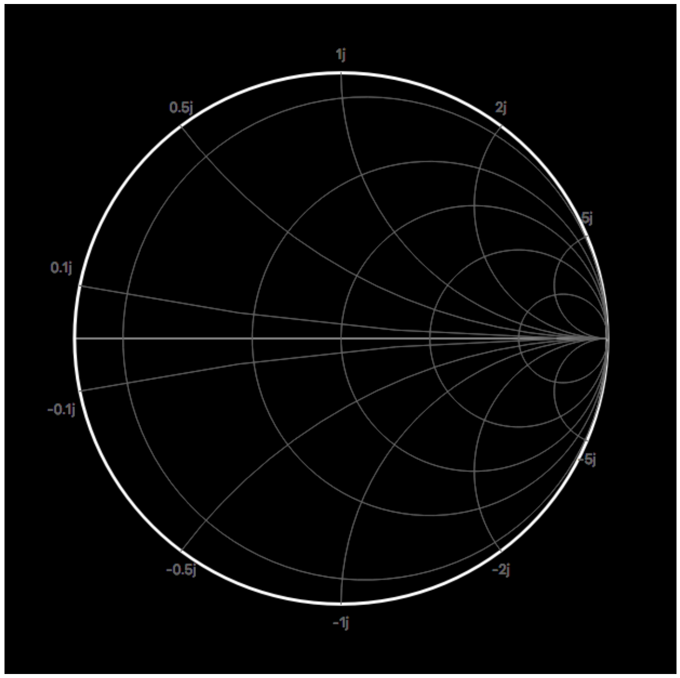


Figure. Smith Chart

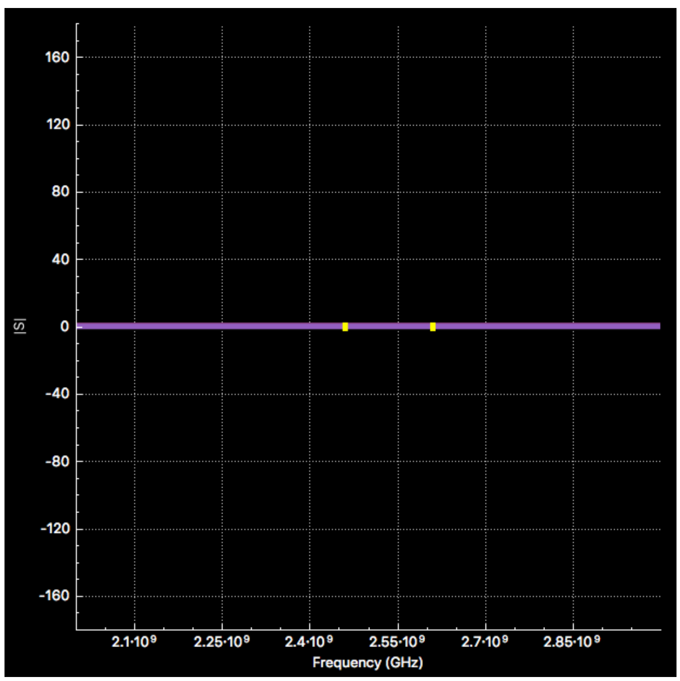


Figure. S-parameter Plot

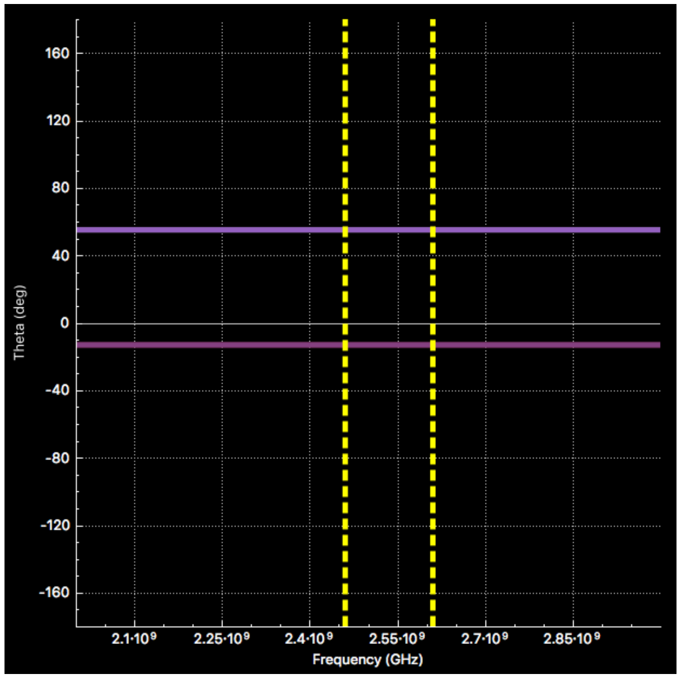


Figure. Phase Plot

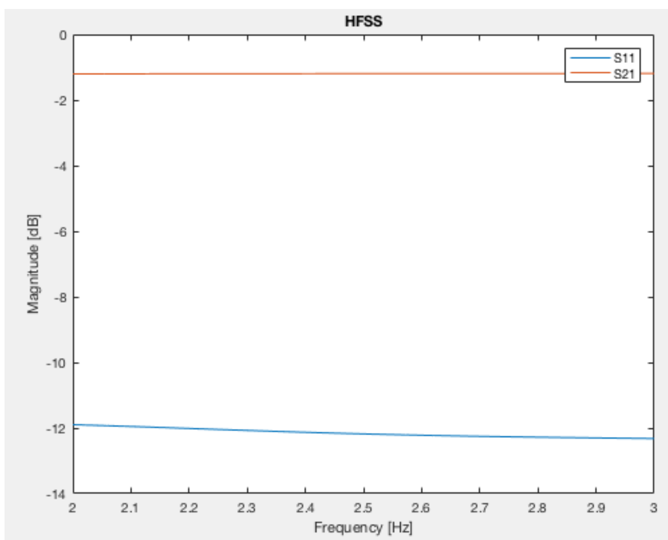
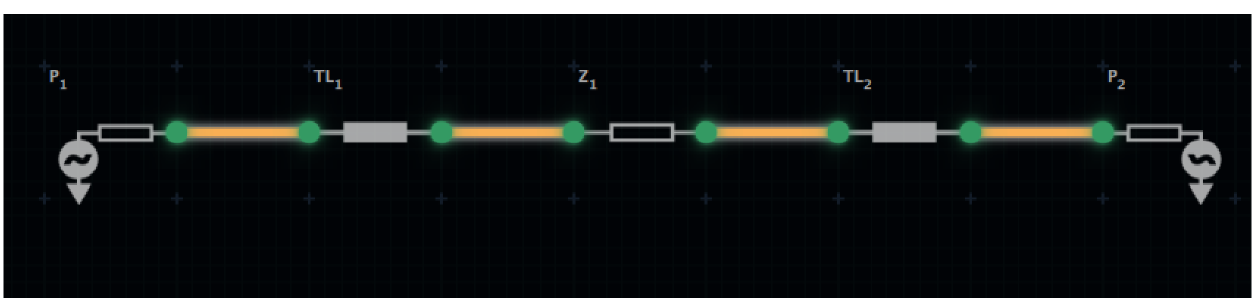


Figure. HFSS dB plot

SECOND CIRCUIT:



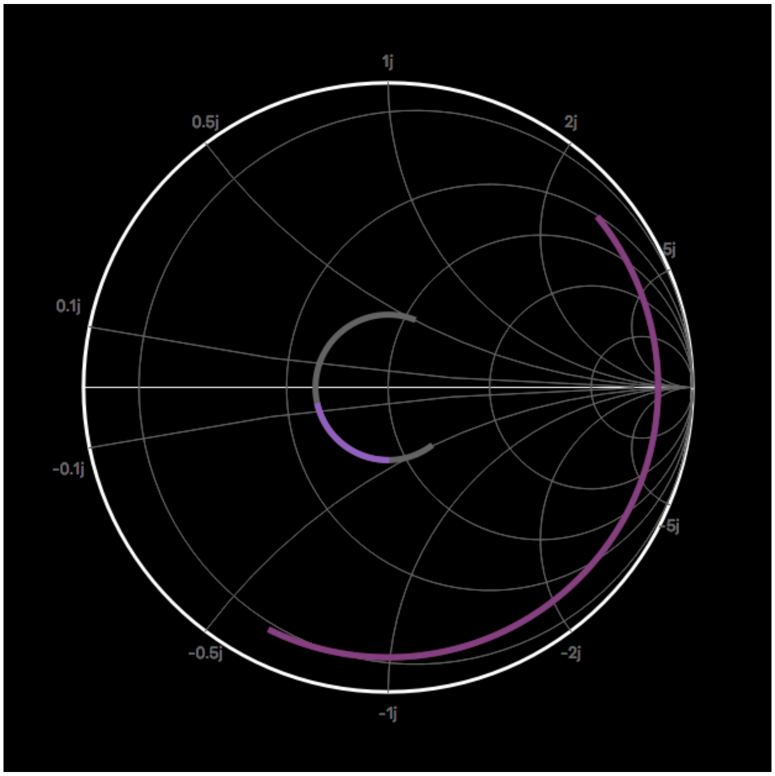


Figure. Smith Chart

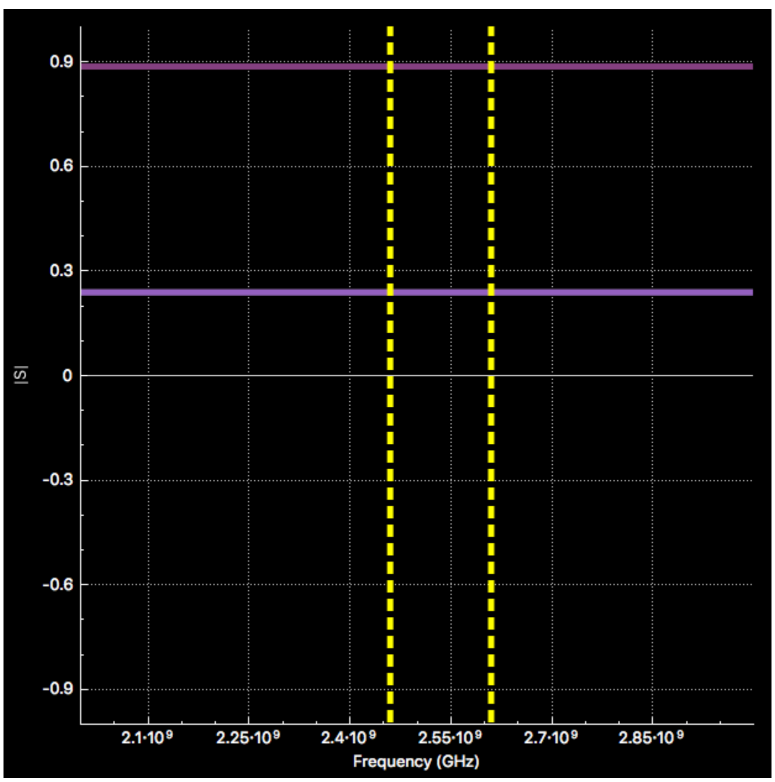


Figure.

Around the design frequency (f = 2.45GHz),

$$S_{11} = 0.238693$$

$$S_{12} = 0.886484$$
$$S_{21} = 0.886484$$
$$S_{22} = 0.238693$$

Thus, we can simply put them all together into a pretty matrix.

$$S = \begin{bmatrix} 0.238693 & 0.886484 \\ 0.886484 & 0.238693 \end{bmatrix}$$

Note that these are just the magnitude portion of S-parameter and the matrix is symmetric. The network could have been a reciprocal network if phase matrix is also symmetric; however, the phase matrix shows the following:

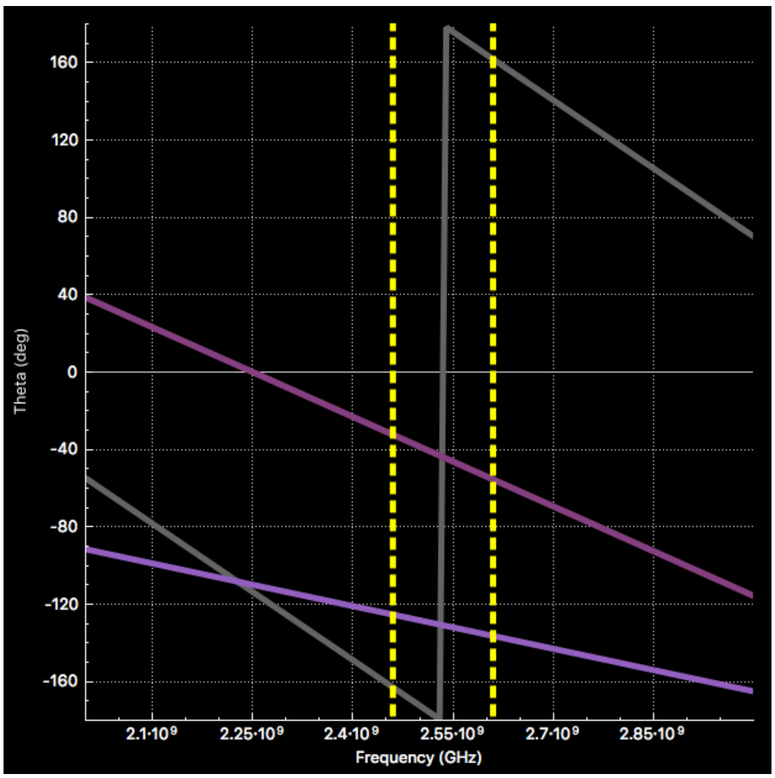


Figure. Phase vs. Frequency

$$S_{11} = -162.961$$
$$S_{12} = -32.3651$$
$$S_{21} = -32.3651$$
$$S_{22} = -125.372$$
$$S = \begin{bmatrix} -162.961 & -32.3651 \\ -32.3651 & -125.372 \end{bmatrix}$$

These values are just the phase portion of the S-parameter. Thus, the network is not reciprocal. Reciprocity of a circuit has a somewhat meaningful property because the circuit looks 'unchanged' no matter from which port is was seen in a two network case.