Engineering ElectroMagnetism
Experiment - 6

Design a quarter-wave transformer using HFSS simulator

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Aim:

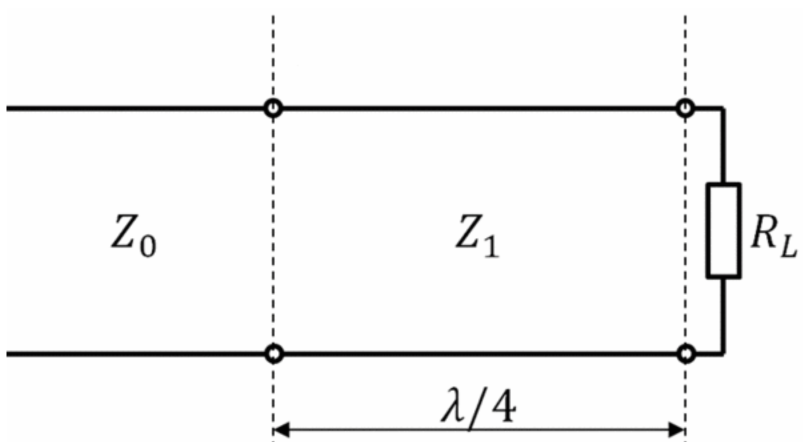
To design a quarter wave transformer using HFSS simulator to match a 50 ohm transmission line with 100 ohm transmission line as shown in Fig. 1 at 1 GHz using micro strip technology on an FR-4 substrate (thickness (t)=1.6mm, and dielectric constant=4.4).

Components or Software required:

Ansoft HFSS software

Theory

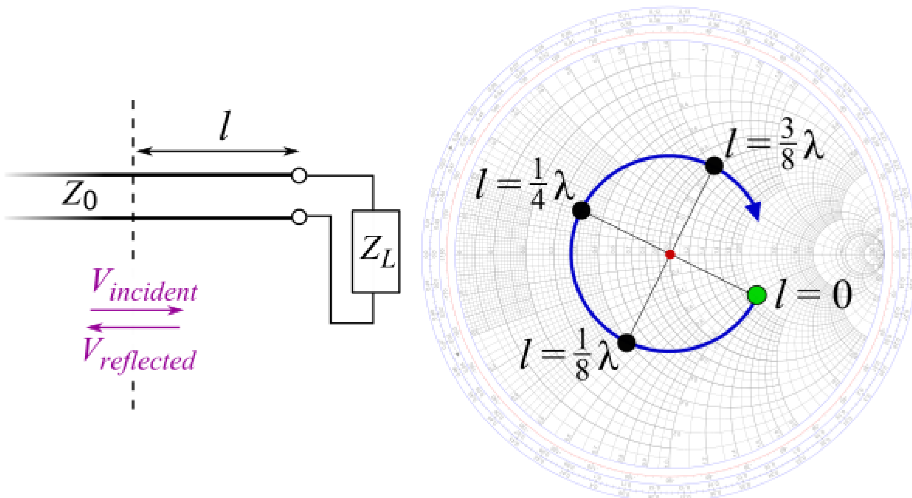
A quarter-wave transformer is a basic impedance transformer which is regularly utilized in impedance coordinating to limit the energy which is reflected when a transmission line is associated with a heap. The quarter-wave transformer utilizes a transmission line with various trademark impedance and with a length of one-fourth of the guided-frequency to coordinate with a line to a heap.



Circuit schematics of quarter-wave transformer

The relationship between the characteristic impedance, Z_0, input impedance, Z_{in} and load impedance, Z_L is: Zin/Zo=Zo/ZL

A transmission line that is ended in some impedance, ZL, that is not quite the same as the trademark impedance, Z0, will bring about a wave being reflected from the end back to the source.



OUR MODEL

The quarter-wave transformer in this model associates a 50 Ω line to a 100 Ω load at 1 GHz, and is acknowledged utilizing a microstrip innovation on a FR-4 substrate and are simulated using ANSYS HFSS software.

Substrate Material: FR4 (εr = 4.4)

Substrate Dimensions : 84.248mil x 100mil x 1.6mil

This model has a microstrip of 50 Ω that needs to be matched to a load of 100 Ω.

Parameter	Value	Description
h	1.6 mm	Substrate thickness
		Metallization thickness
eps_r	4.4	Substrate permittivity
Z01	50 Ω	Impedance of transmission line 1.
Z02	100 Ω	Impedance of transmission line 2.
W1	3.058 mm	50 Ω line width
W2	0.709 mm	70.71 Ω line width

L	42.09mm	Quarter wave transformer length.

Procedure:

1. Make the substrate and assign the material to it.
2. Assign the dimensions of the substrate.
3. Make the transmission lines, calculate the starting coordinates and assign dimensions to them.

4. Make lumped port excitation on both sides of the substrate.

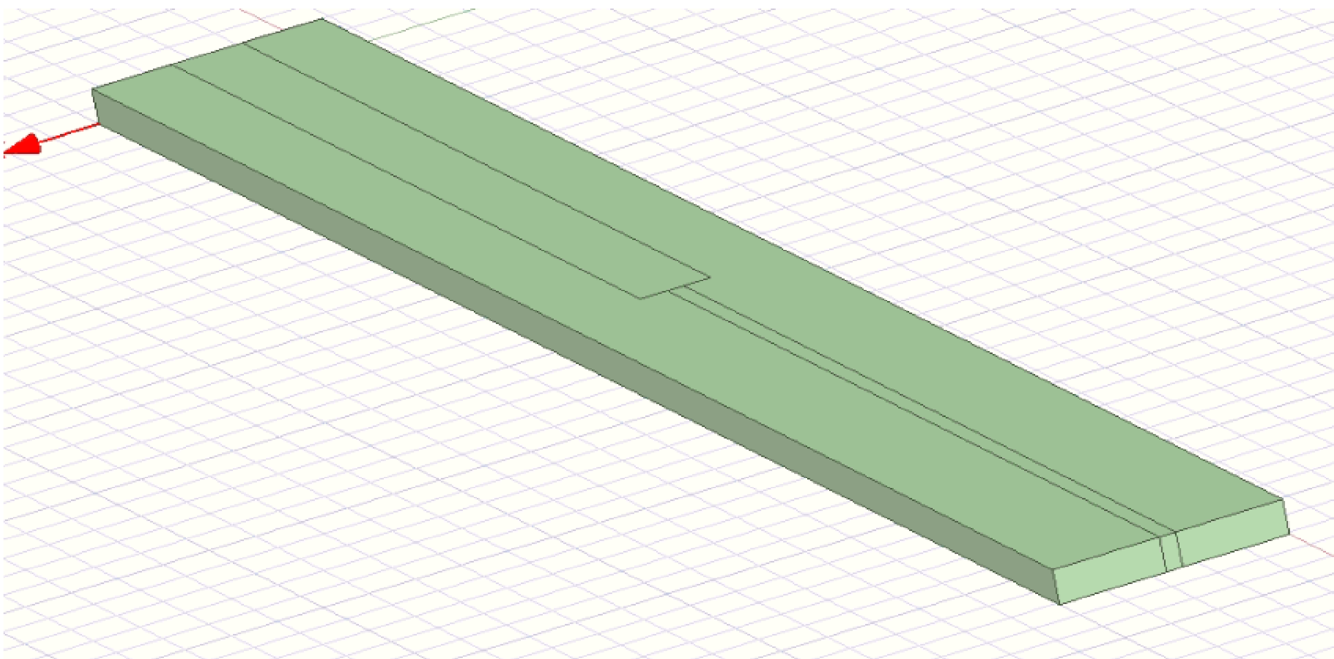


Fig 1. Substrate and transmission lines without quarter wave transformer.

5. Now we define radiation boundary around our model for given frequency

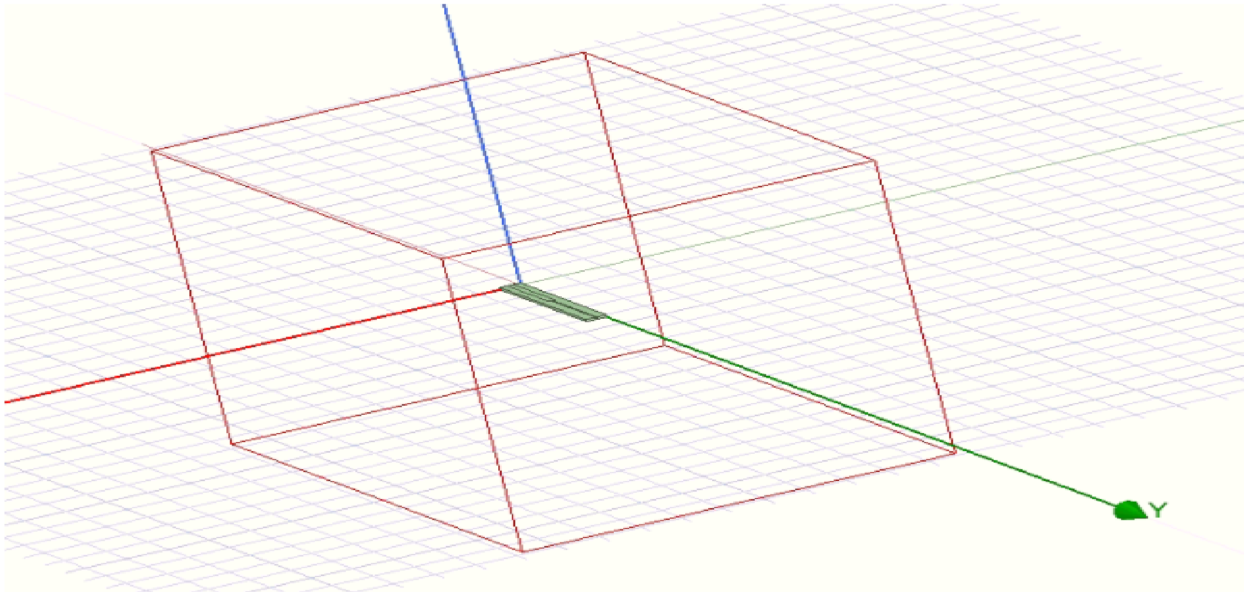


Fig 2.radiation boundary around the model

6. Find length and other dimensions of the quarter wave transformer from an online microstrip calculator using dimensions of substrate and known resistance of quarter wave transformer to be 70.7 ohms.

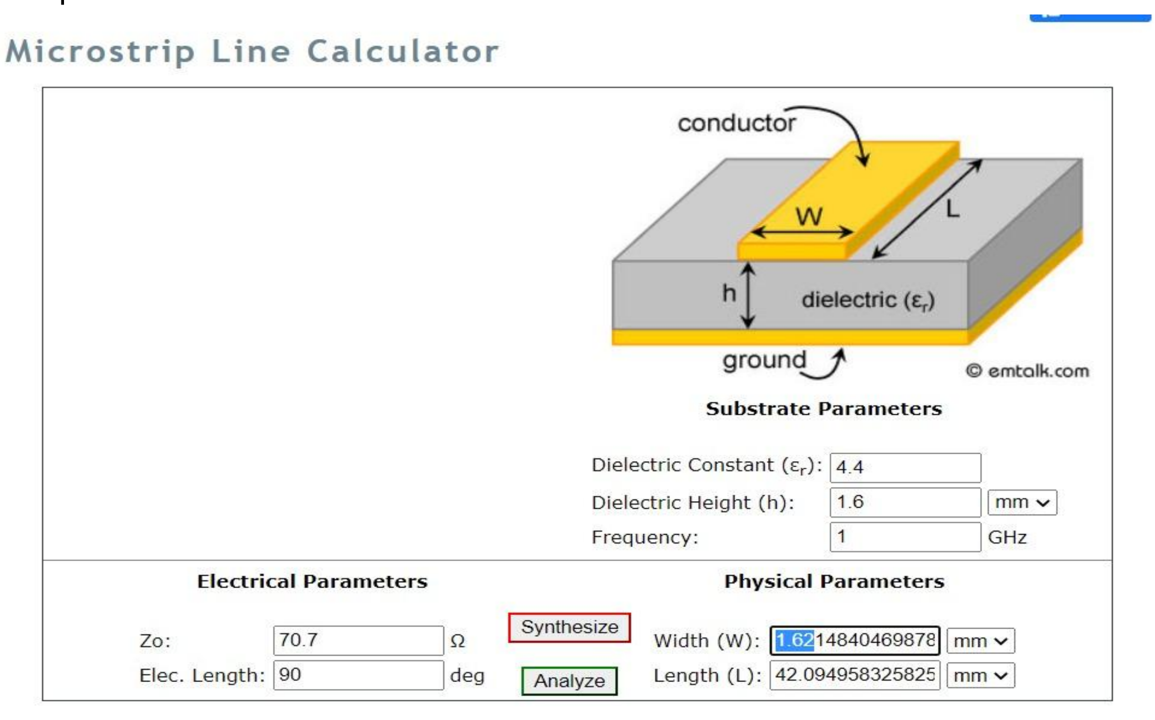


Fig 3. Online microstrip line calculator being used.

7. 1st note readings of s parameter without quarter wave transformer, then with quarter wave transformer.

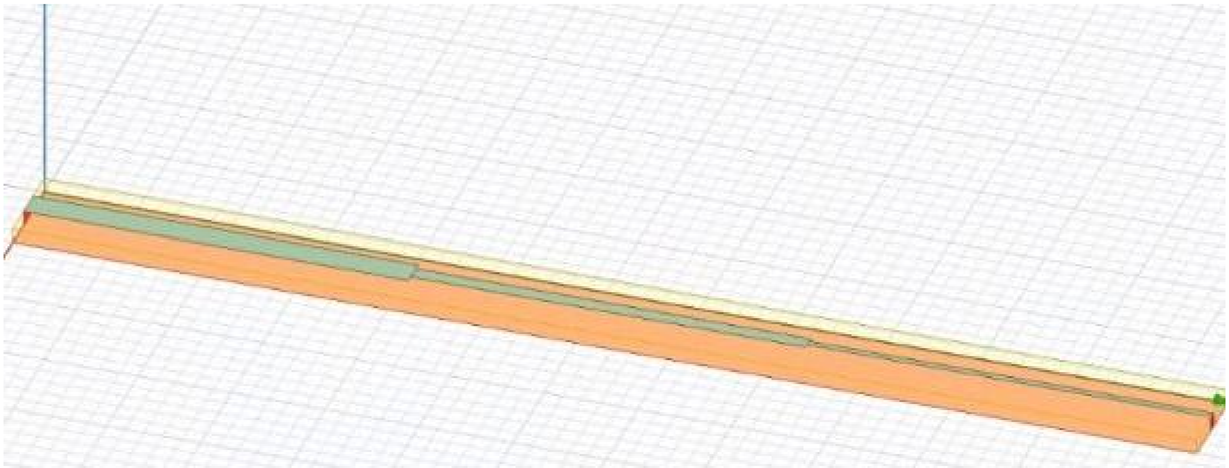


Fig 4. We now use a quarter wave transformer for impedance matching.

8. Save projects, validate the model and analyze.
9. Check Solution Data to create Differential pair S-Parameter Plot. Plot Field Overlay.

Observations and Results

Importance of S parameter:-The S parameters are important performance metrics when we deal with the case of high frequencies and help us analyse whether our design is meeting the requirements.

- S11 parameter gives us the reflection coefficient occurring at port 1 when port 2 is terminated with matched load and excitation is provided at that port. We desire it to be as low as possible for maximum signal transmission (preferably, less than -15dB for a good design).
- Similarly, S22 parameter gives us the reflection coefficient occurring at port 2 when port 1 is terminated with matched load and excitation is given at port 2. We also desire it to be as low as possible.

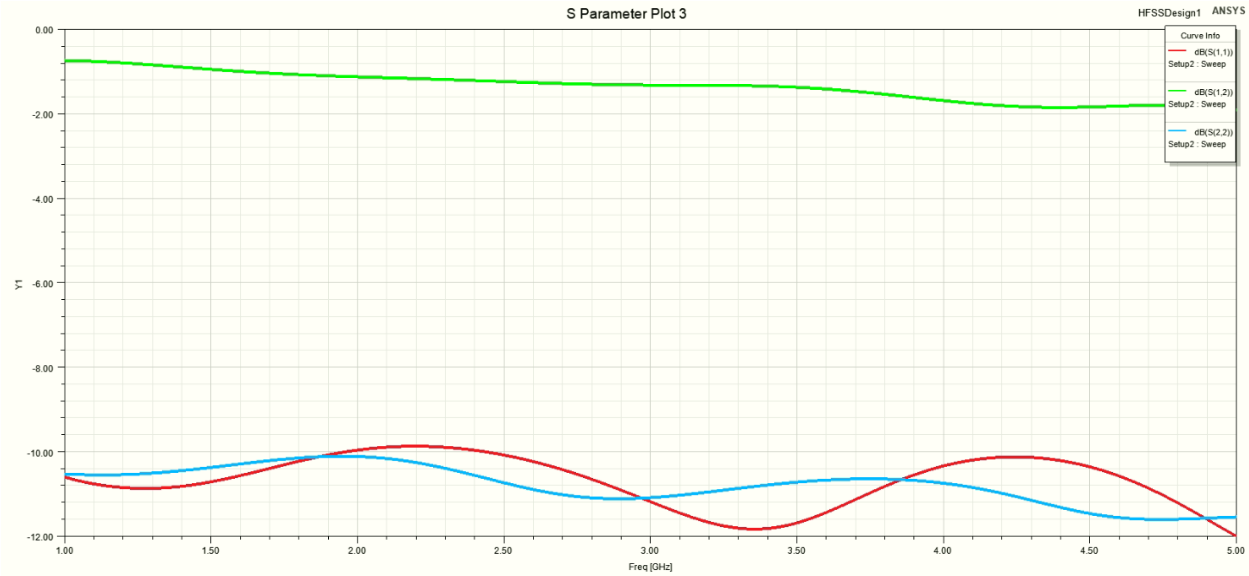


Fig 5. S parameters when we are not using quarter wave transformers.

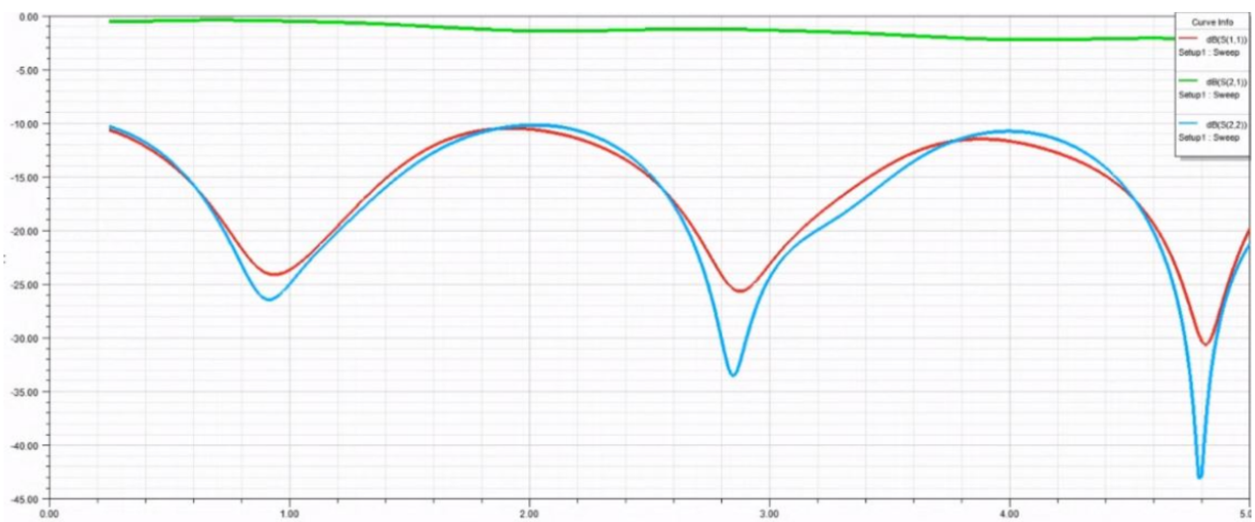


Fig 6. S parameters when we used a quarter wave transformer.

In the below table we calculate the value of these parameters at a given frequency of 1GHz.
All the values mentioned in the table are in dB.

	S11 Parameter	S21 Parameter	S22 Parameter
Without QWT	**-11.2**	**-0.7**	**-11.8**
With QWT	**-23.2**	**-0.5**	**-24.8**

Discussion

From the above table we can conclude the following:-

1. After using quarter wave transformer both S11,S22 parameters declined showing that quarter wave transformer's impedance matching reduced these reflection coefficients almost by 10dB.
2. We can see that using the Quarter wave also slightly increased the value of the S12 parameter. Now as opposed to the reflection coefficients(S11,S22) here increase in value makes our transmission line better as now there is greater strength of signal when it reaches load.

Conclusion:-

We can use a quarter wave transformer of about 70.7ohm resistance to match impedance of 50ohm line with 100 ohm line. This impedance matching can improve the value of our reflection coefficients considerably by almost 10dB. Also we do get slight improvement in S12 parameter as well.