# Practical Session 1

# RF Simulation using Microwave Office

## *Aim*

The aim of this practical is to provide some experience in simulating RF circuits using the RF simulation package Microwave Office.

It is desirable to do this session individually, to maximise the learning experience, however, depending on resources available, some students may need to work in groups of two students per computer.

## *Requirements*

This laboratory session may be marked on the preparation done before the laboratory session, the progress in the Laboratory session, your understanding of the operation of the circuits you are simulating, the performance of your completed hybrid and coupler and the quality of the notes taken during the session.

## *Procedure*

### Task 1: Simulation of a Wilkinson Transformer Hybrid

Wilkinson Hybrids are described in Chapter 3 "RF Transformers" of the RF Electronics Lecture notes by C. J. Kikkert, distributed by AWR Corp.

A transformer for use with a Wilkinson Transformer Hybrid was measured at a frequency of 1 MHz as having a leakage inductance of 250nH and a magnetising inductance of 250μH for a 25 ohm winding.

### Simulation

Run the computer simulation package Microwave Office.

Select Options $\Rightarrow$ Project Options and then select Global Units to ensure that the Frequency units are MHz, Length = mm, Inductance in nH, Capacitance in pF, Conductance in S and Resistance in $\Omega$. Set any other units to convenient similar values as required.

 Click on Circuit Schematics and then on the Project $\Rightarrow$ Add Schematic $\Rightarrow$ New Schematic to add a new schematic page. Call this schematic "Transformer Hybrid".

Select the Element tab at the bottom left hand of the screen and select lumped elements and inductor. Select the inductor element and hold the left mouse button and drag that onto the circuit schematic. Release the left mouse and click the right mouse button to rotate the component as required. When the component is at the correct location and orientation click the left mouse button to place the component. Place all the other components required for the basic Wilkinson transformer hybrid shown in figure 1. Add the required input and output port and change the output port impedance to 25 ohm.
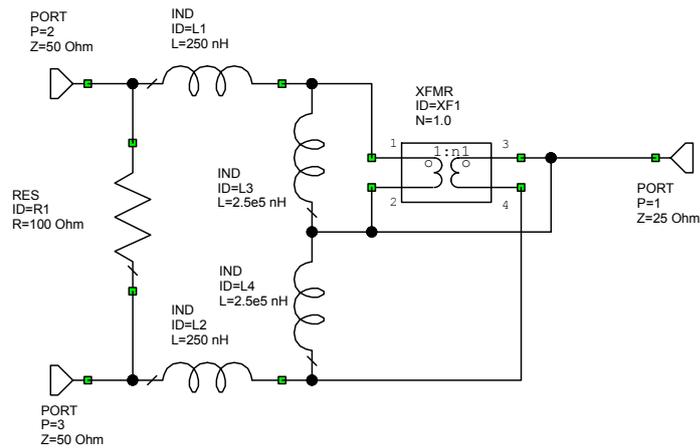
Figure 1. Wilkinson Transformer Hybrid.

Set the frequencies at which the calculations are to take place by selecting the Options ⇒ "Project Options" to set the Start Frequency as 0.01 MHz, the Stop Frequency as 100 MHz and the Frequency Increment as 0.0002 MHz. Select "exponential" and then "apply" to enter the values. This will then perform the calculations on the transmission line over the frequency range of 10 kHz - 100 MHz.

In Microwave Office, select Project ⇒ Graphs ⇒ Add Graph ⇒ Rectangular. Call this graph "Wilkinson Transformer Hybrid". Select this graph and add a measurement. The measurement type is "Port Parameters" and the measurement is S parameters. Check the dB output values check box and set the port numbers for the measurement required (see next paragraph). S12 will give the coupling from port 1 to port 2. S11 gives the return loss on port 1. Repeat this for all the measurements required. Select Simulate ⇒ Analyse to perform the simulation.

Plot the coupling (S12, S13 and S23) between all ports and the input reflection coefficients (S11, S22, S33), for the frequency range of 10kHz to 100 MHz. Measure the frequency range over which the isolation is better than −20dB. Measure the coupling between port 1 and 2. How does this compare with the expected values?

Modify the circuit to include the impedance transformation from 25 Ω to 50 Ω as shown in figure 2.
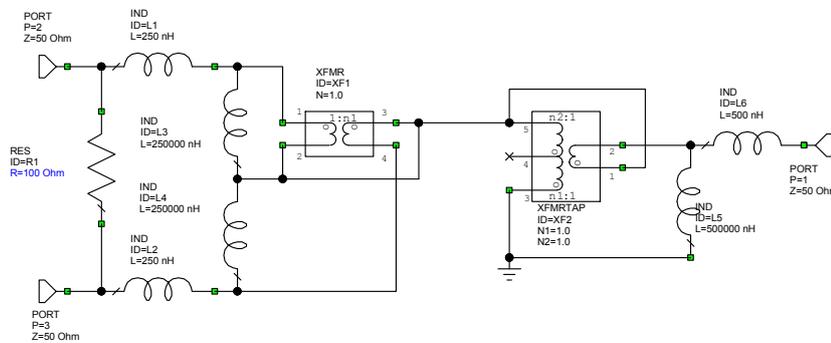


Figure 2. Wilkinson Transformer Hybrid with 50 Ω terminations.

Perform the same measurements as was done for the circuit of figure 1 and comment on the differences.

Double click on the resistor and check "Tune". Select Simulation $\Rightarrow$ Tune and observe the change in performance as the resistor is tuned. What resistance value gives the best isolation? How does this compare with the theoretical value?

## Task 2: Simulation and layout of a Branchline Coupler

Branchline Couplers are described in Chapter 4 "Transmission Line Hybrids" of the RF Electronics Lecture notes by C. J. Kikkert, distributed by AWR Corp.

The schematic for a Branchline coupler is shown in figure 3. Line TL1 and TL2 have an impedance of 50/√2 Ω for a 3 dB coupler, where the signal power at port 2 and port 3 are equal. Port 4 is the isolated port.

```
                              TLIN
                              ID=TL1
                              Z0=35.35 Ohm          PORT
      PORT                    EL=90 Deg             P=2
      P=1                     F0=1000 MHz           Z=50 Ohm
      Z=50 Ohm

  TLIN
  ID=TL3
  Z0=50 Ohm
  EL=90 Deg                TLIN              TLIN
  F0=1000 MHz              ID=TL2            ID=TL4
                           Z0=35.35 Ohm      Z0=50 Ohm
                           EL=90 Deg         EL=90 Deg
                           F0=1000 MHz       F0=1000 MHz


                                                  PORT
                                                  P=3
      PORT                                        Z=50 Ohm
      P=4
      Z=50 Ohm
```
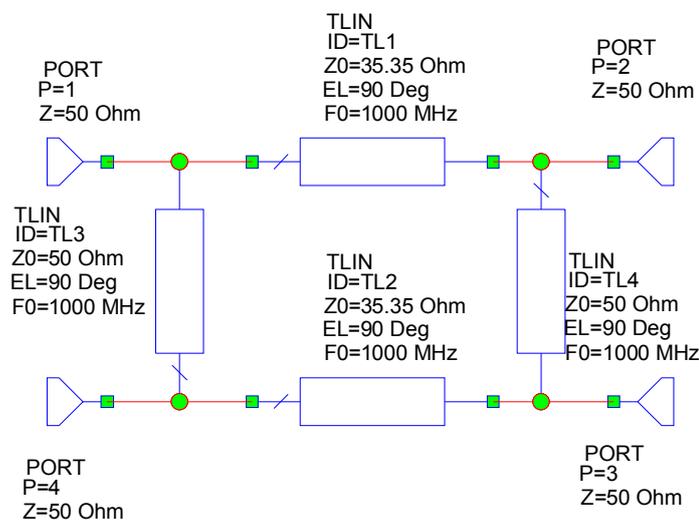
Figure 3. Branchline Coupler.

This coupler for a centre frequency of 1 GHz is to be made using microstripline on a RO3004 substrate (from Rogers). The following parameters apply: Er=3.38, H (thickness of substrate) = 0.8128 mm, T (Thickness of copper cladding) = 0.035 mm, Rho= (Conductivity with respect to Gold) = 0.7, Tand= (Loss factor) = 0.0027.

Open up a new Microwave Office project and select Tools $\Rightarrow$ TXLine to calculate the required width and length for the required microstrip lines. Insert a new schematic and call this BranchLine. Insert an MSUB substrate in the circuit and edit the values to match the RO4003 substrate. Draw the branchline coupler circuit, using microstrip transmission lines and including any microstrip T pieces required to ensure that the microstrip lines connect properly. Apply a 10mm 50 Ω transmission line at each of the input ports, as shown in figure 4, so that proper connections can be made to the circuit that is produced.

Make the schematic diagram active by clicking on it. Select View $\Rightarrow$ "New Layout View" to see the resulting PCB layout. If there are any red crosses shown in the layout, select Edit $\Rightarrow$ Snap Together to ensure that the lines and junctions are connected properly. Ensure that the PCB layout is correct and that all lines connect properly to each other. If not modify your circuit until all lines meet correctly.

Plot the coupling and reflection coefficients of all ports and the coupling between all ports from 500MHz to 1.5 GHz. Compare the simulated values with the expected values for an ideal coupler as shown in Figure 3. Why is there a difference? Tune the line lengths to provide the best isolation at 1 GHz.

Reduce the PCB area of the coupler by folding the vertical transmission lines as shown in the layout of figure 4. The bends are to be a radius of 3mm and the vertical line lengths should be equal and also larger than 4 mm, to minimise unwanted coupling between the folds. The line lengths of the vertical lines can be made equal by making that line length a variable L1 and then tuning that variable in order to give the correct isolation at 1 GHz. To allow the circuit diagram to know about the variable select the Schematic  and the pull down menu Draw $\Rightarrow$ Add Equation and then add the equation L1=10. Click on the equation and select properties and check "Tune", to allow the line length to be tuned. Similarly make the horizontal lines in the hairpins a variable (L2) and allow them to be tuned as well. When the layout is complete and the connections are all correct, Tune L1 and L2 to give the best isolation at 1 GHz.

Plot the coupling and reflection coefficients of all ports and the coupling between all ports from 500MHz to 1.5 GHz. Compare these results with those obtained before.
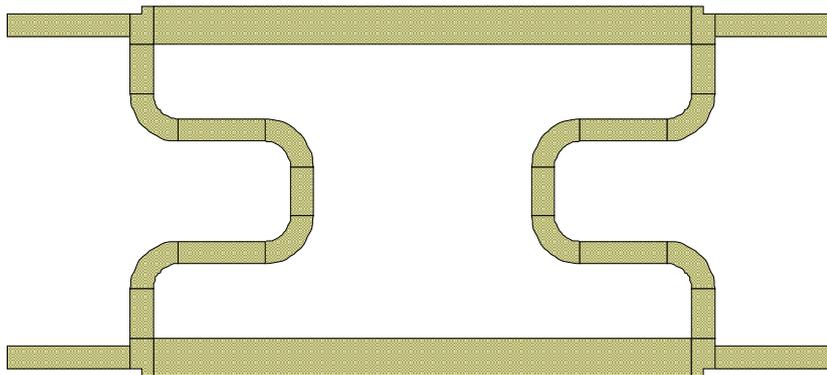


Figure 4. Branchline Coupler Layout.

The layout can now be exported as a .dxf file for import into a drawing program or into Protel or as a Gerber plot file .ger, for importing into photo plotters or PCB milling machines.

## *Equipment.*

Computer with Microwave Office. software