Sharif University of Technology
Electrical Engineering Complex

Microwave Engineering

Project

Group 8

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February 2, 2024

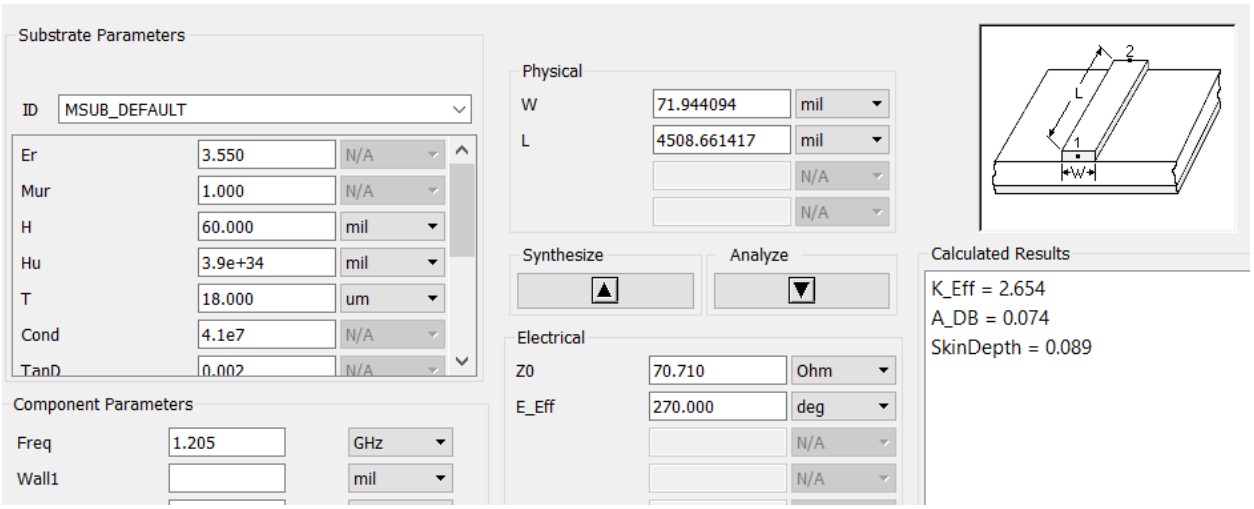
Question 1

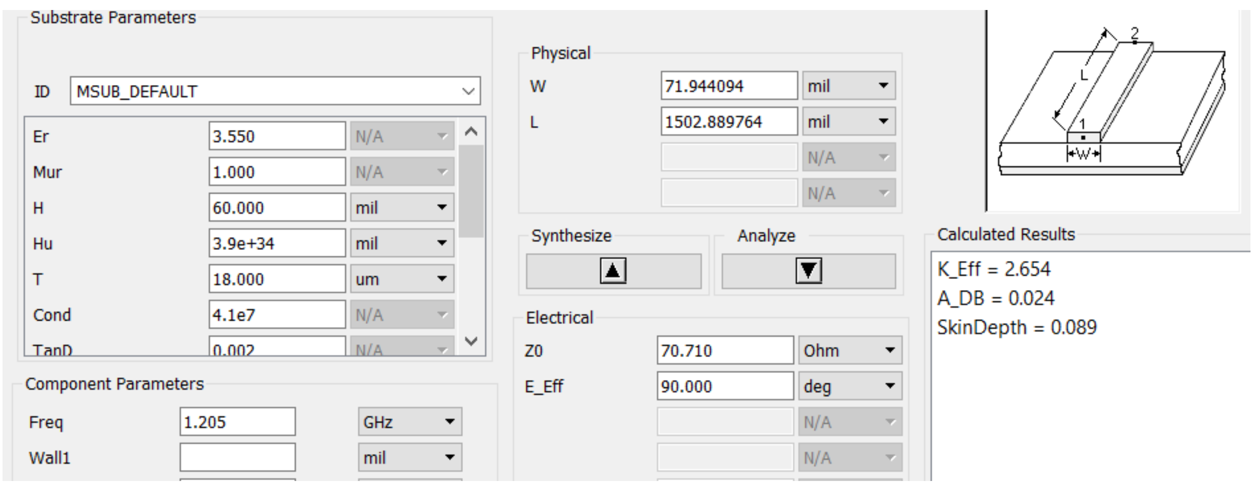
WR_770 specifications:

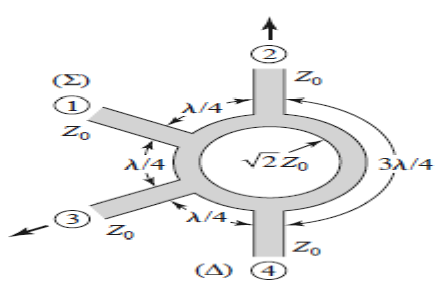
a=7.7 inches=19.558 cm , b=3.85 inches =9.779 cm→ $1.45GHz > f > 0.96GHz$→ f0=1.205GHz

RO4003 specifications:

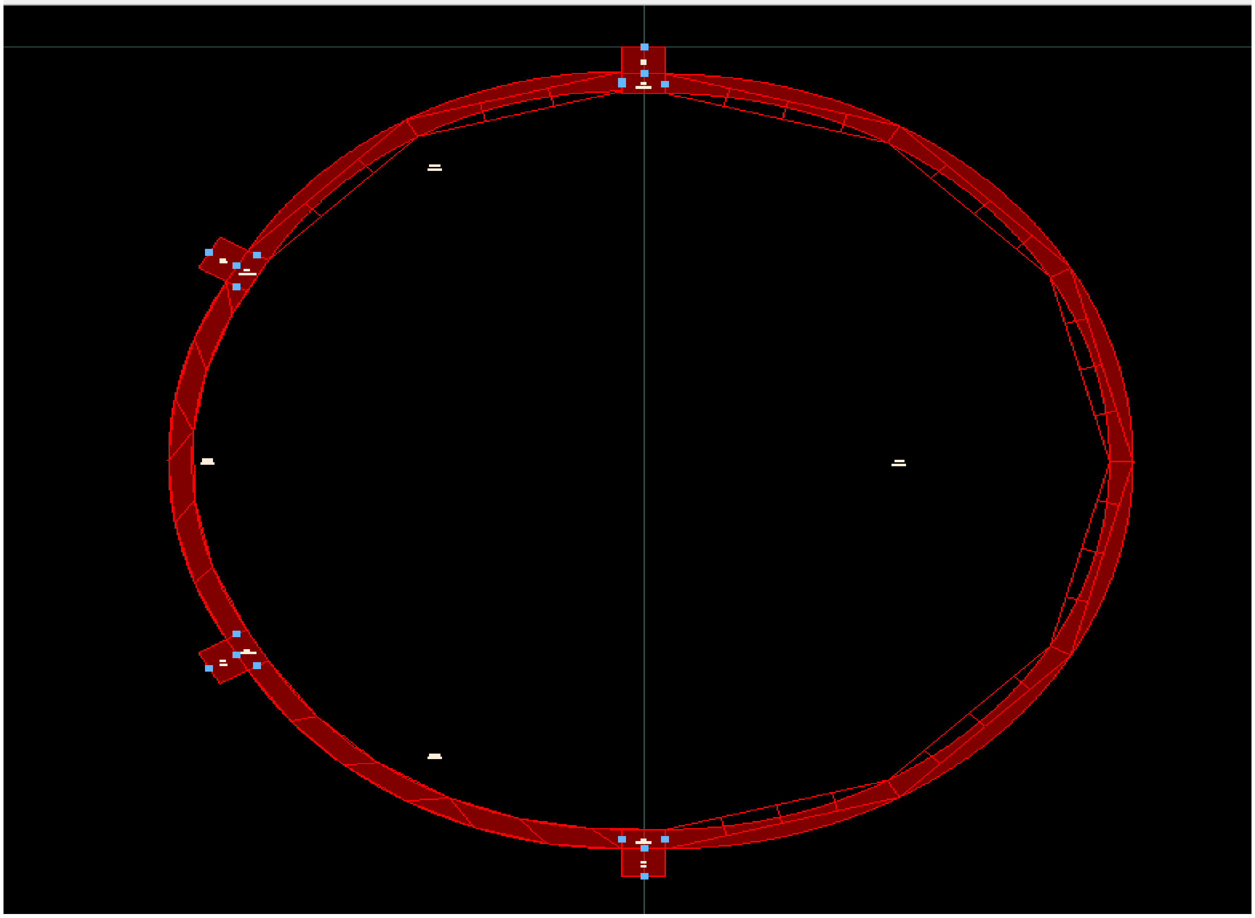
$$\epsilon_r = 3.55 \,, tan\delta = 0.0022 \ \,, H = 60\ mil \,, T = 18\mu m$$

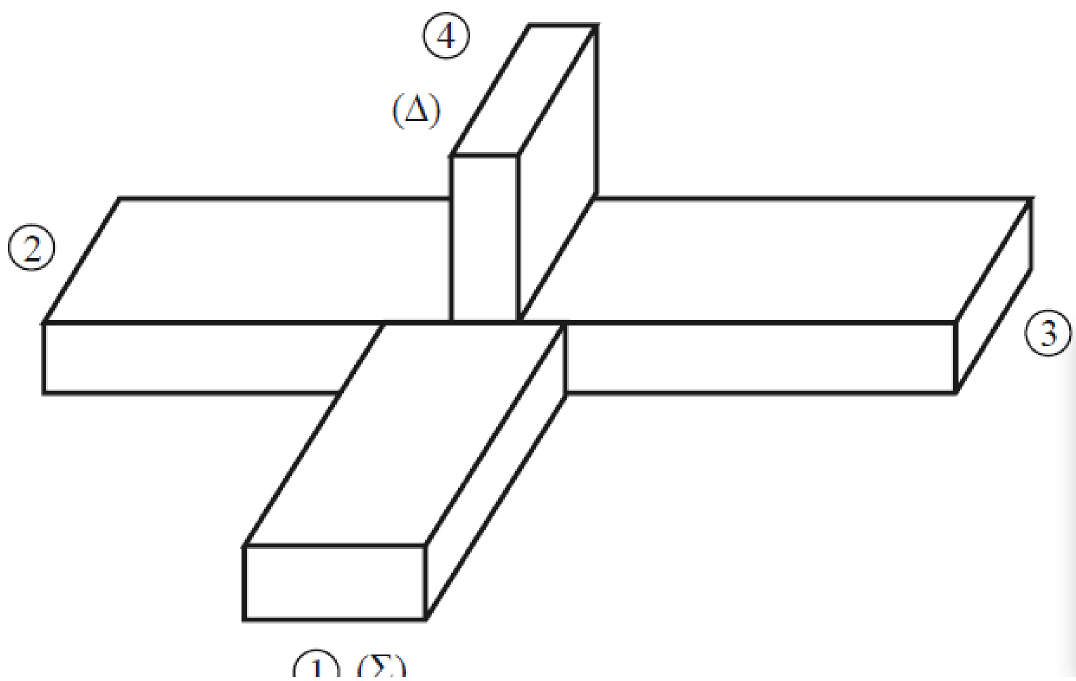




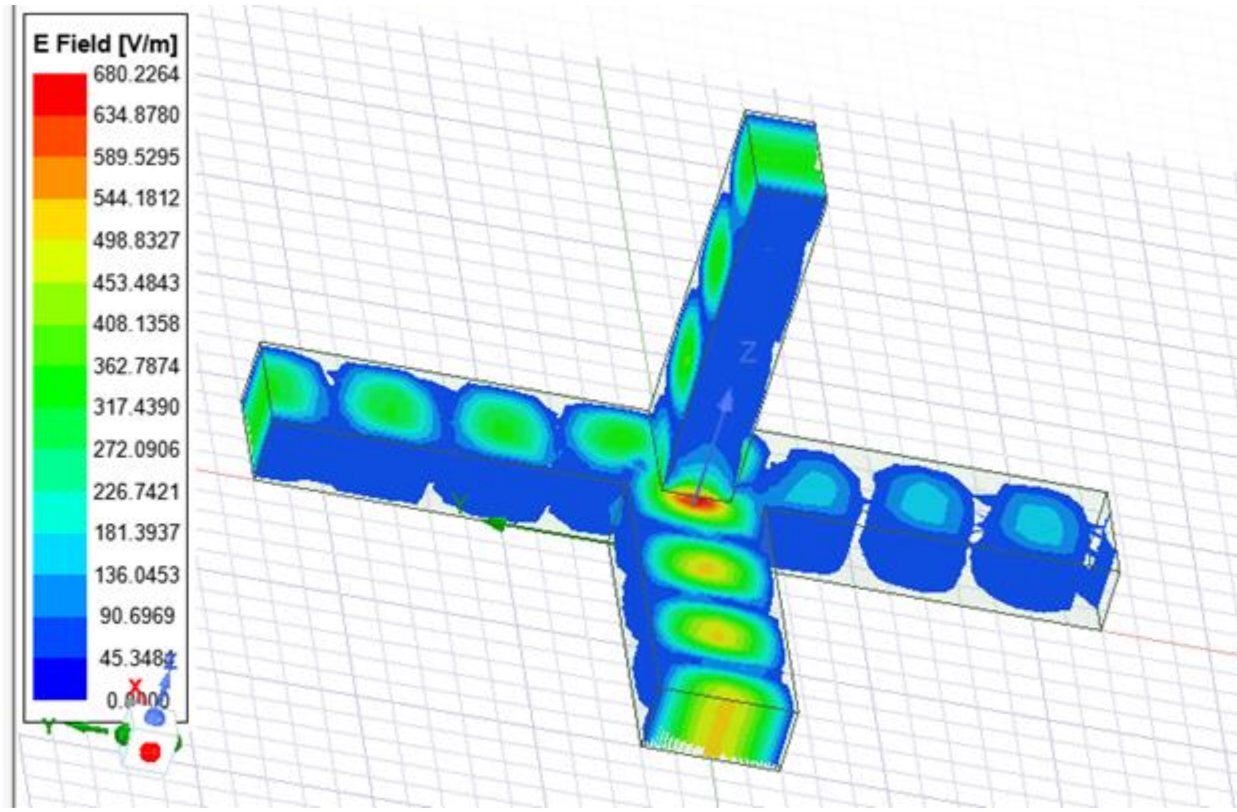


(a)



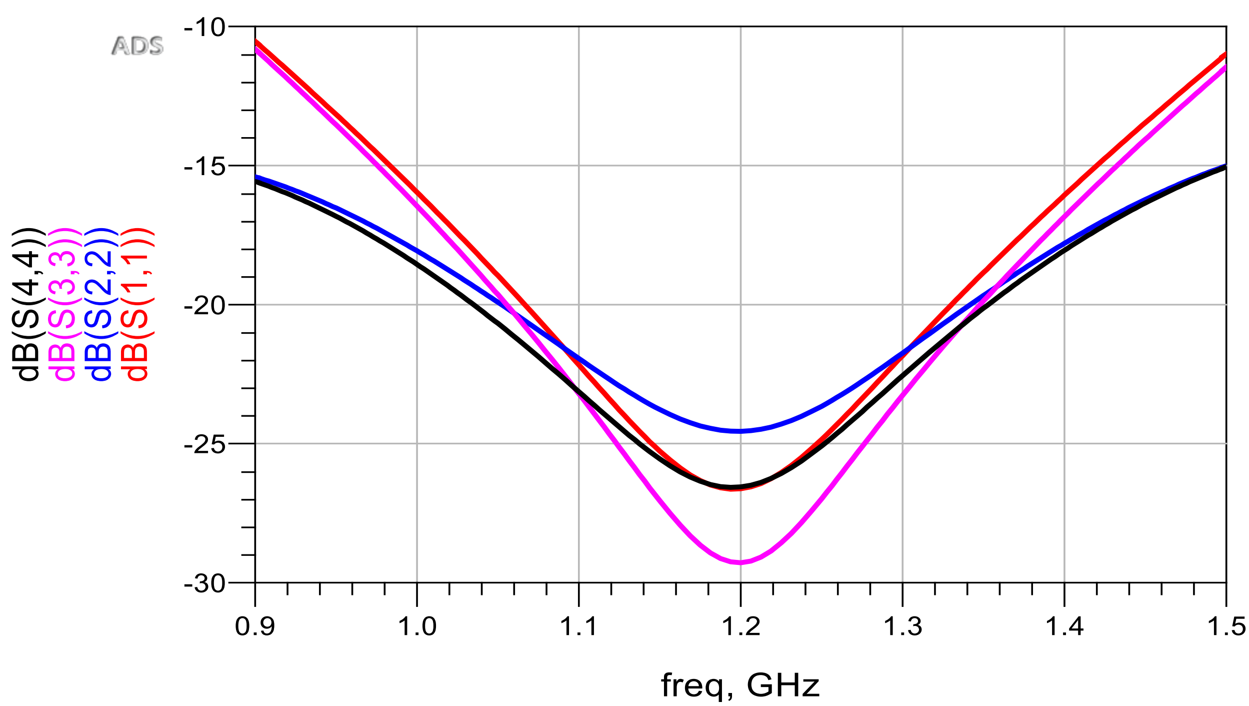


4
(Δ)
2
3
1 (Σ)

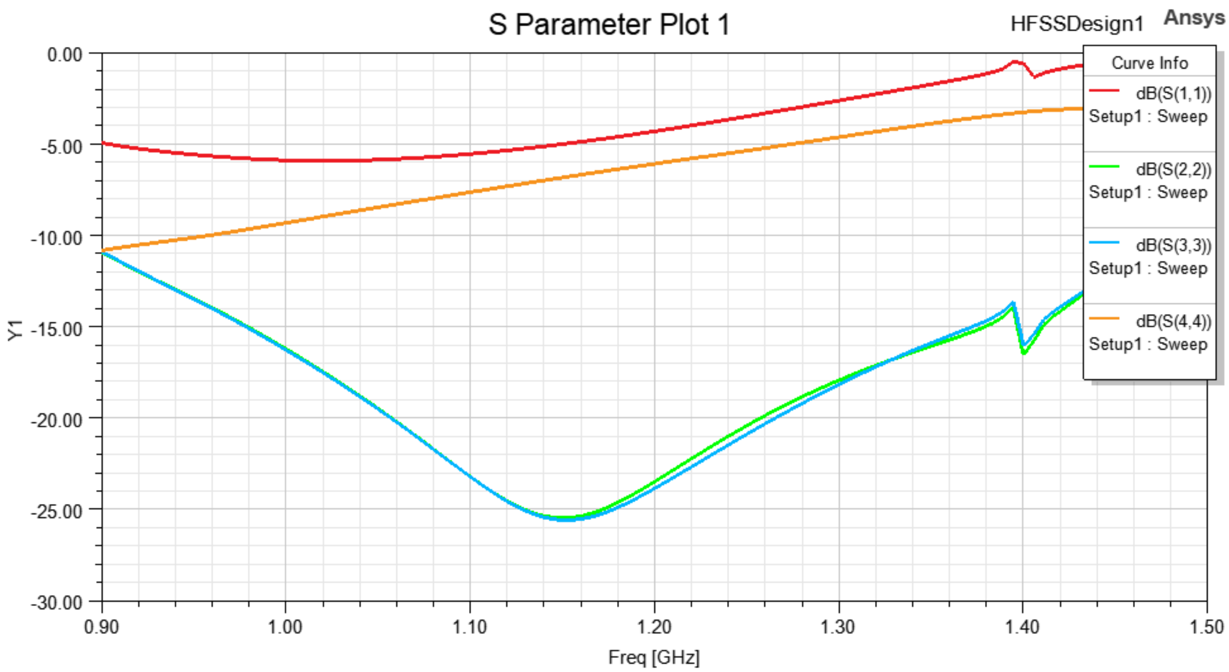


1.1

For rat race:



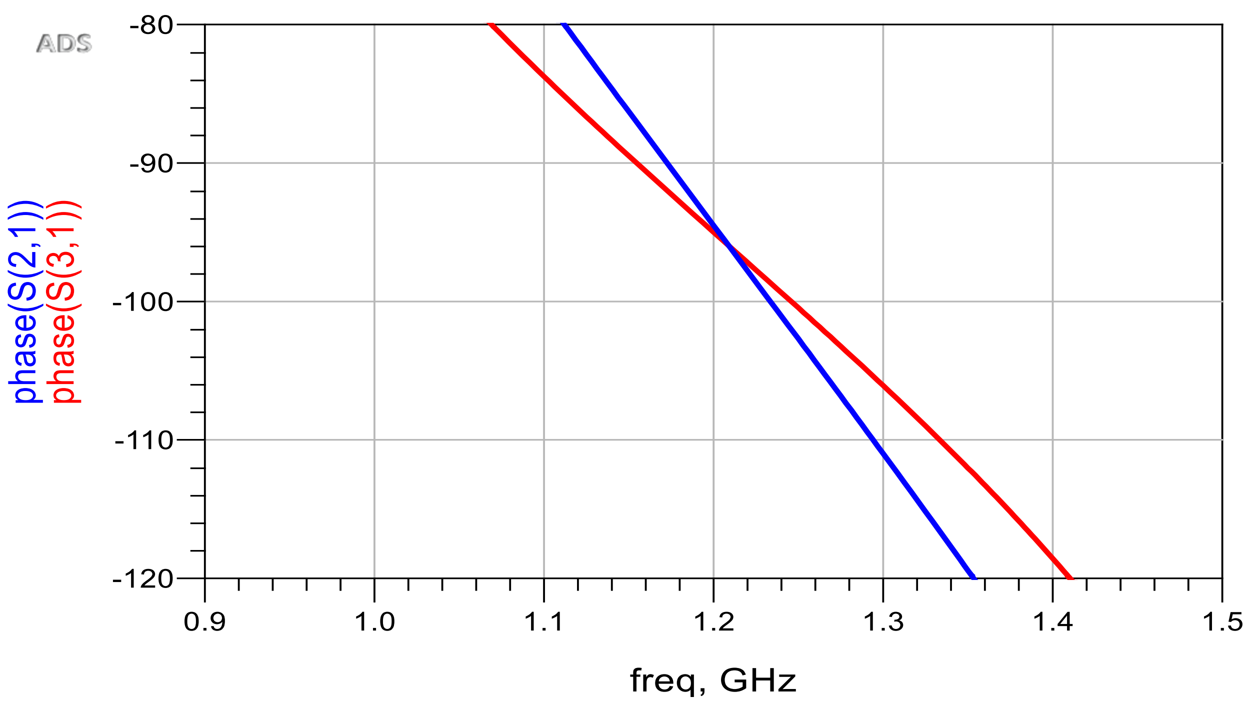
For magic Tee:



Magic Tee is not appropriately matched at ports 1 and 4 and at ports 2 and 3, rat race is wider than magic Tee.

1.2

Rat race:

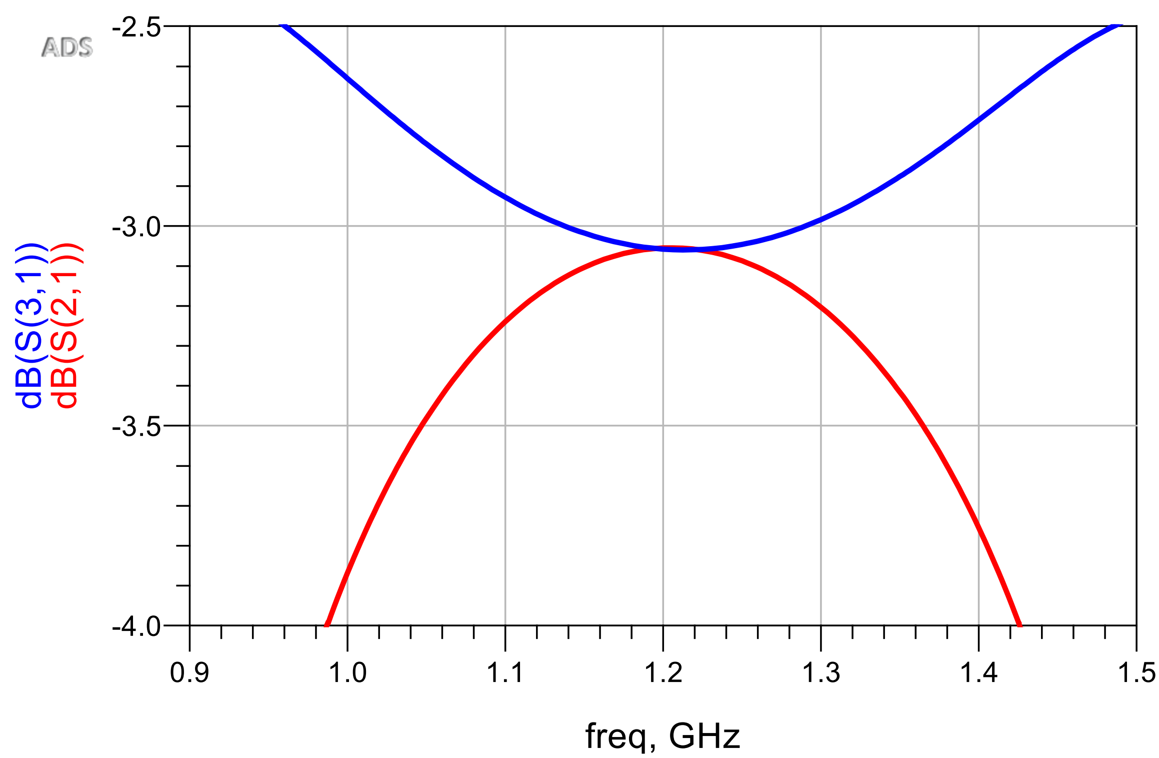


Magic Tee:

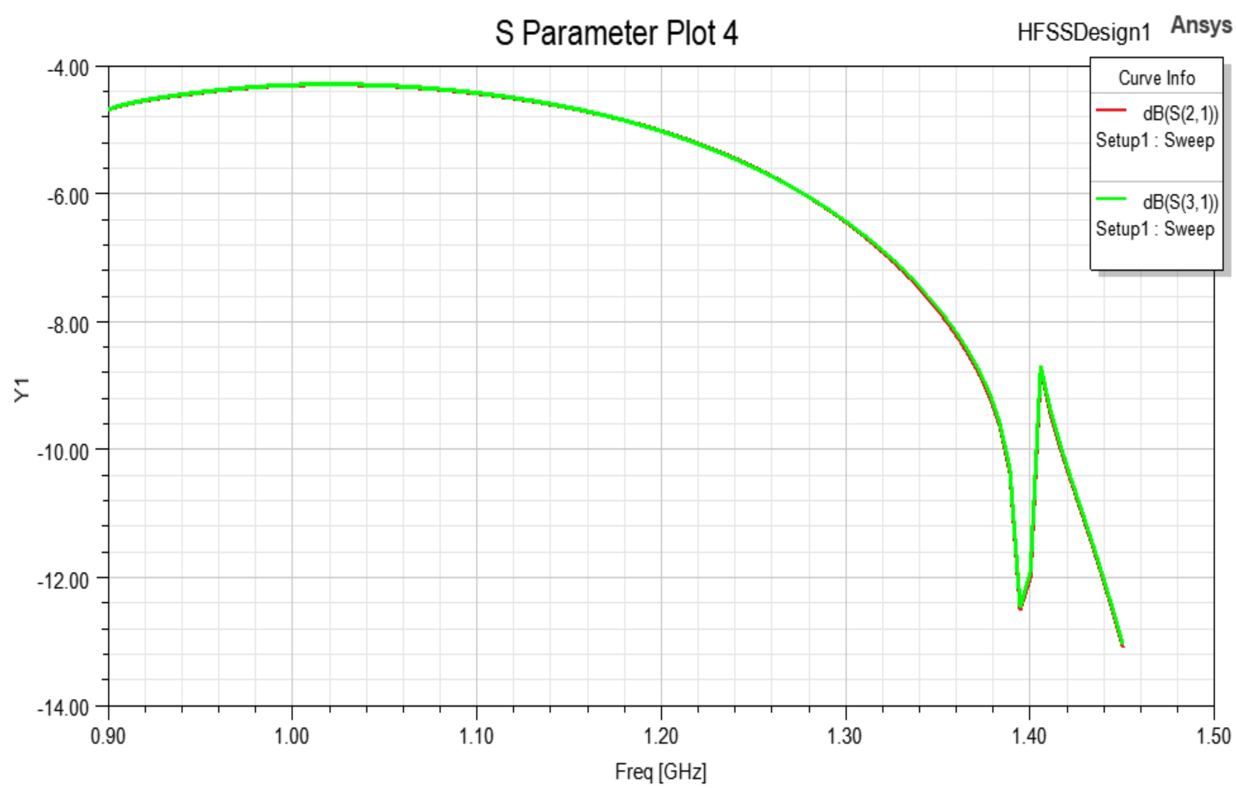
Magic Tee is better in this case because the phases don't change with frequency.

1.3

Rat race:



Magic tee:

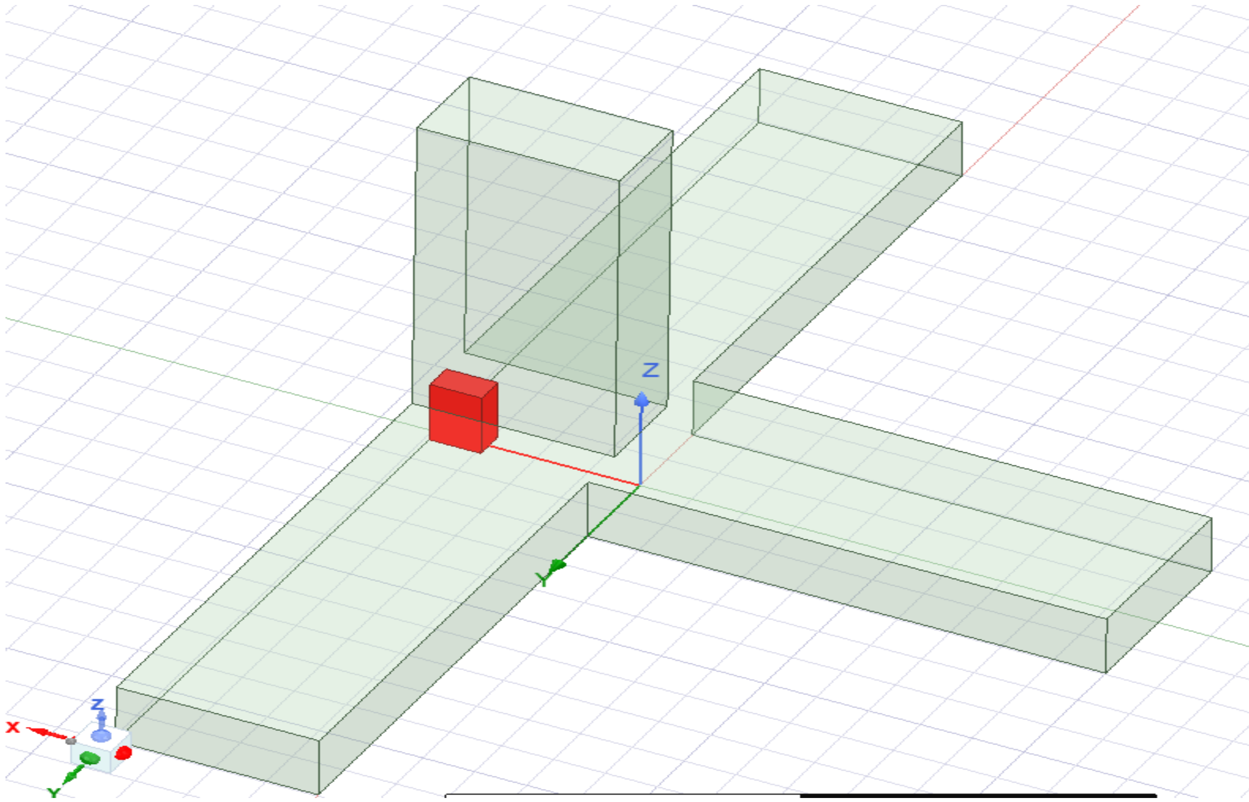


As seen from the plots above, the S21 and S31 in magic tee is always below -4dB. Thus, rat race is better in this case.

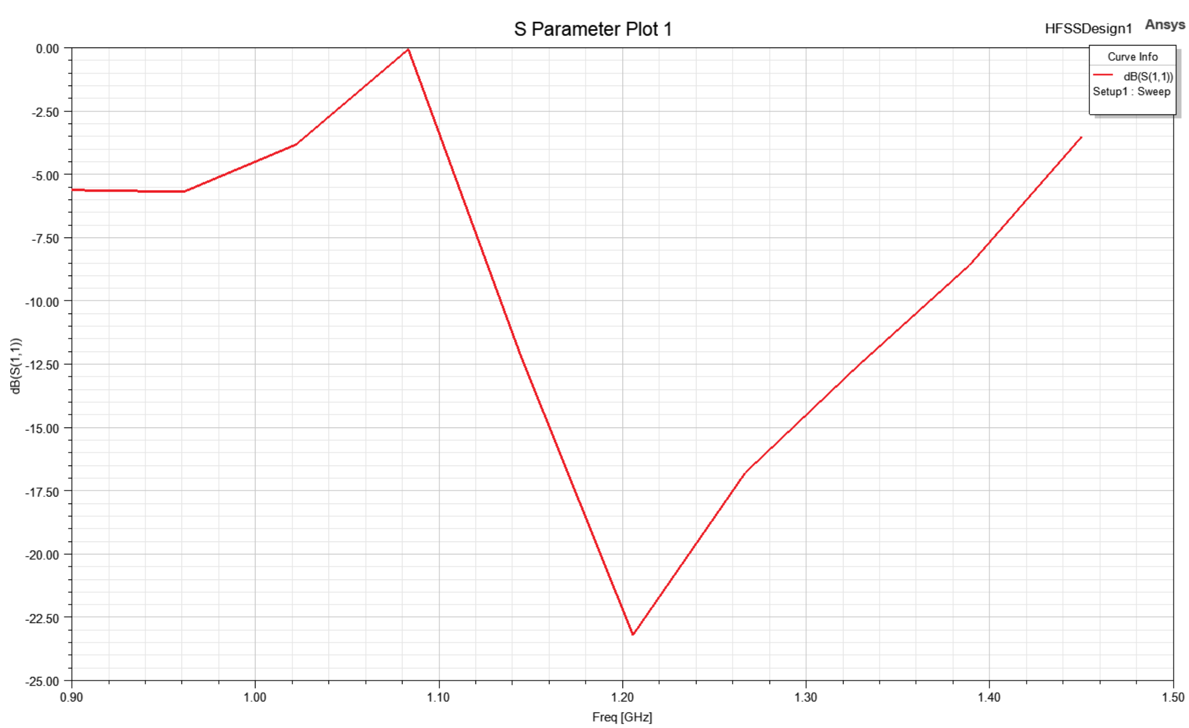
1.4

To match the first port, we use an iris at the end of the first port.

Name	Value	Unit	Evaluated V...	D
Command	CreateBox			
Coordinate ...	Global			
Position	a-lx ,-ly/2 ,0mm		14.558cm , -...	
XSize	lx		5cm	
YSize	ly		3cm	
ZSize	lh		10cm	



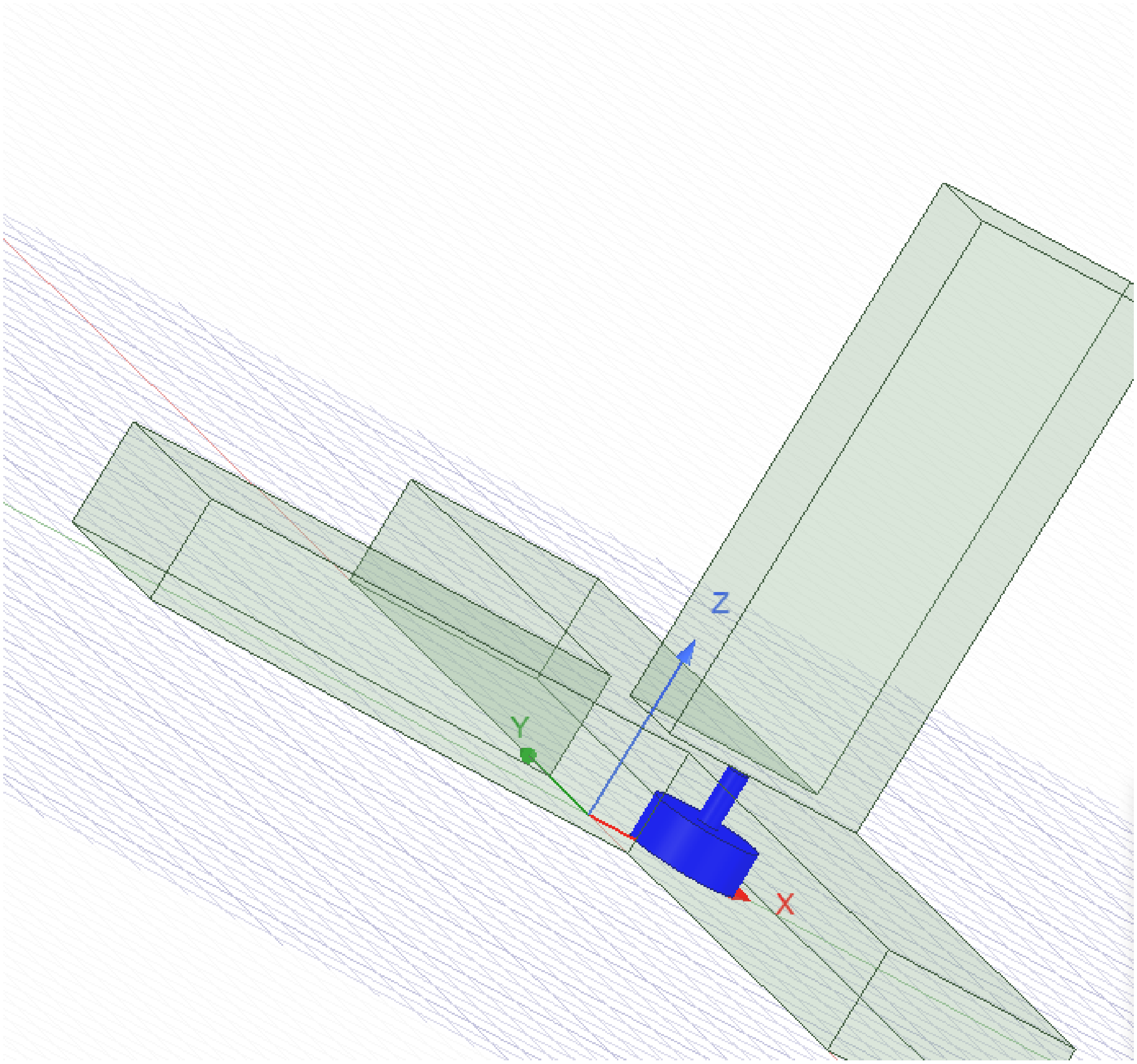
Z
Y
X
Z
Y

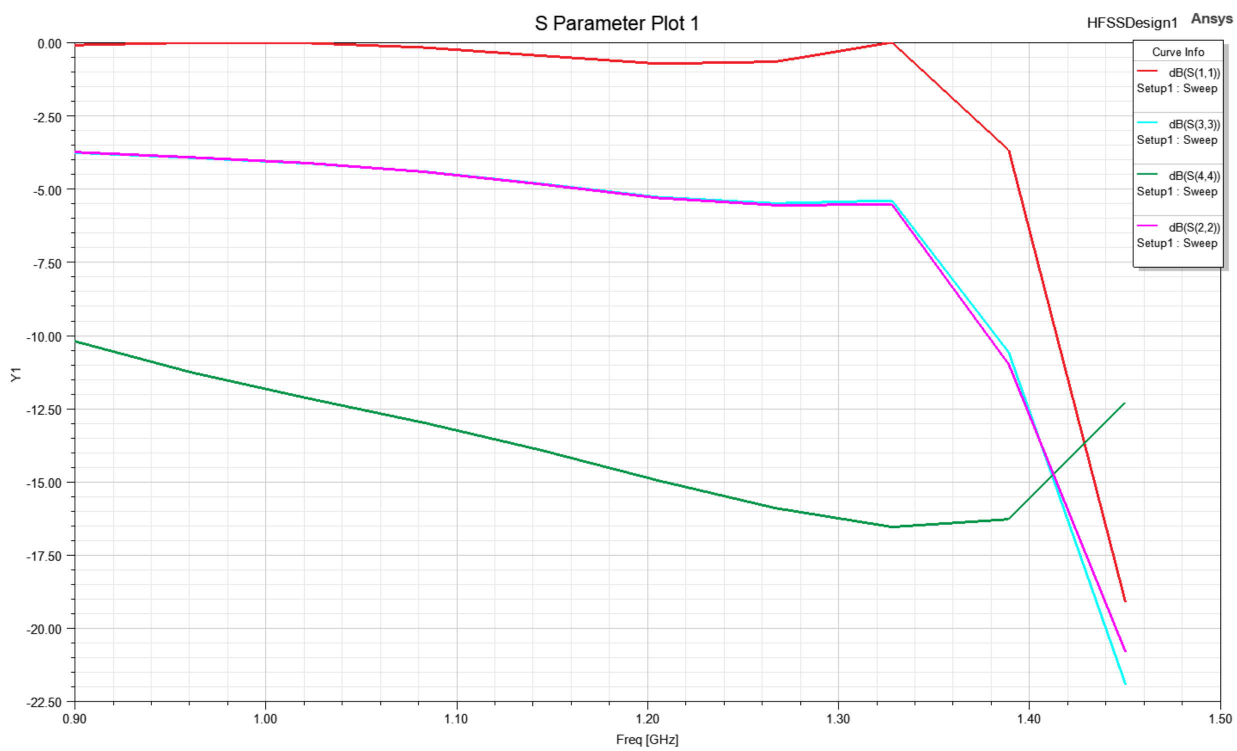


S Parameter Plot 1
HFSSDesign1
Ansys
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(1,1))
Freq [GHz]
0.00
-2.50
-5.00
-7.50
-10.00
-12.50
-15.00
-17.50
-20.00
-22.50
-25.00
0.90
1.00
1.10
1.20
1.30
1.40
1.50

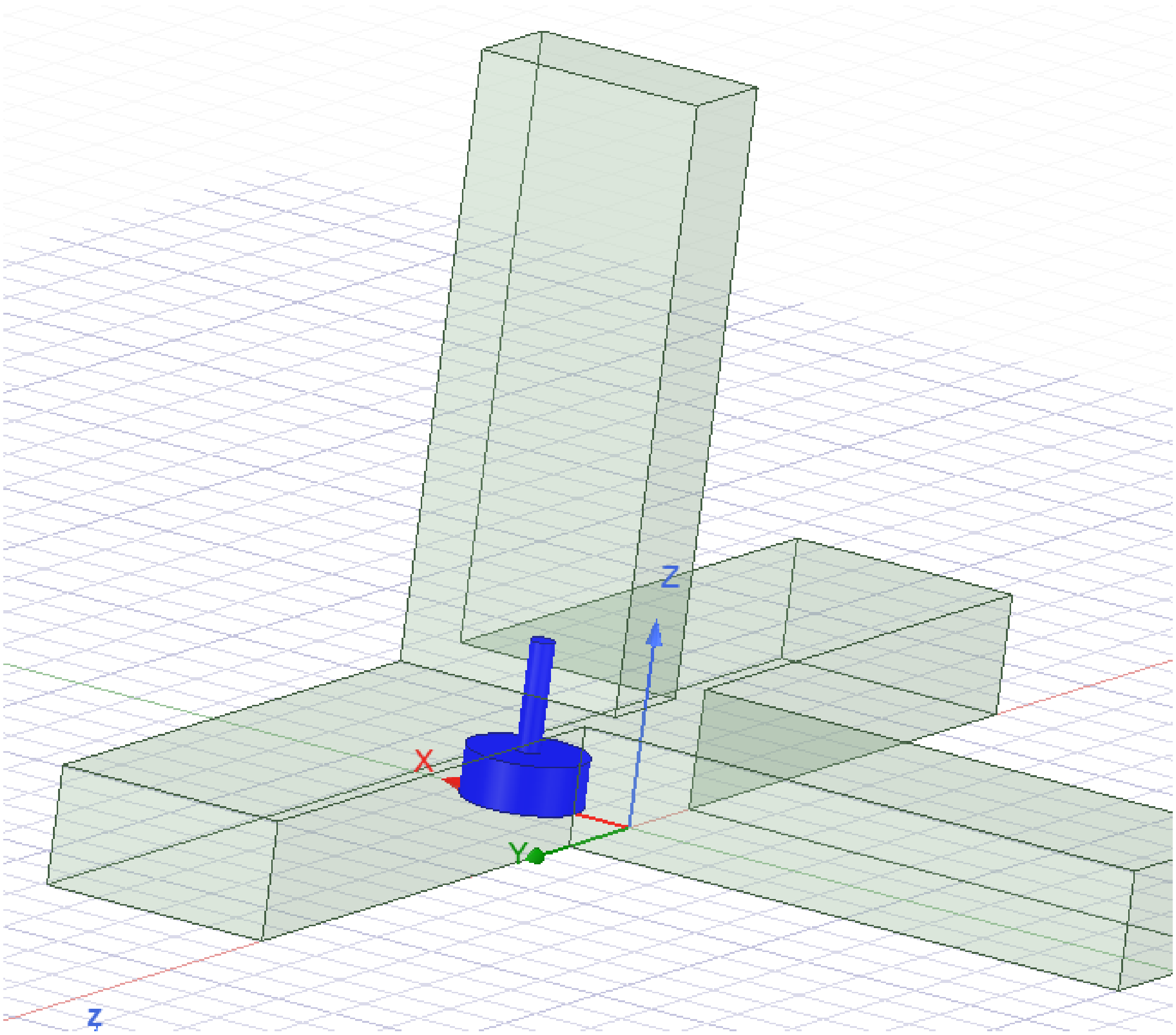
Another method:

Using an interior stepped post:

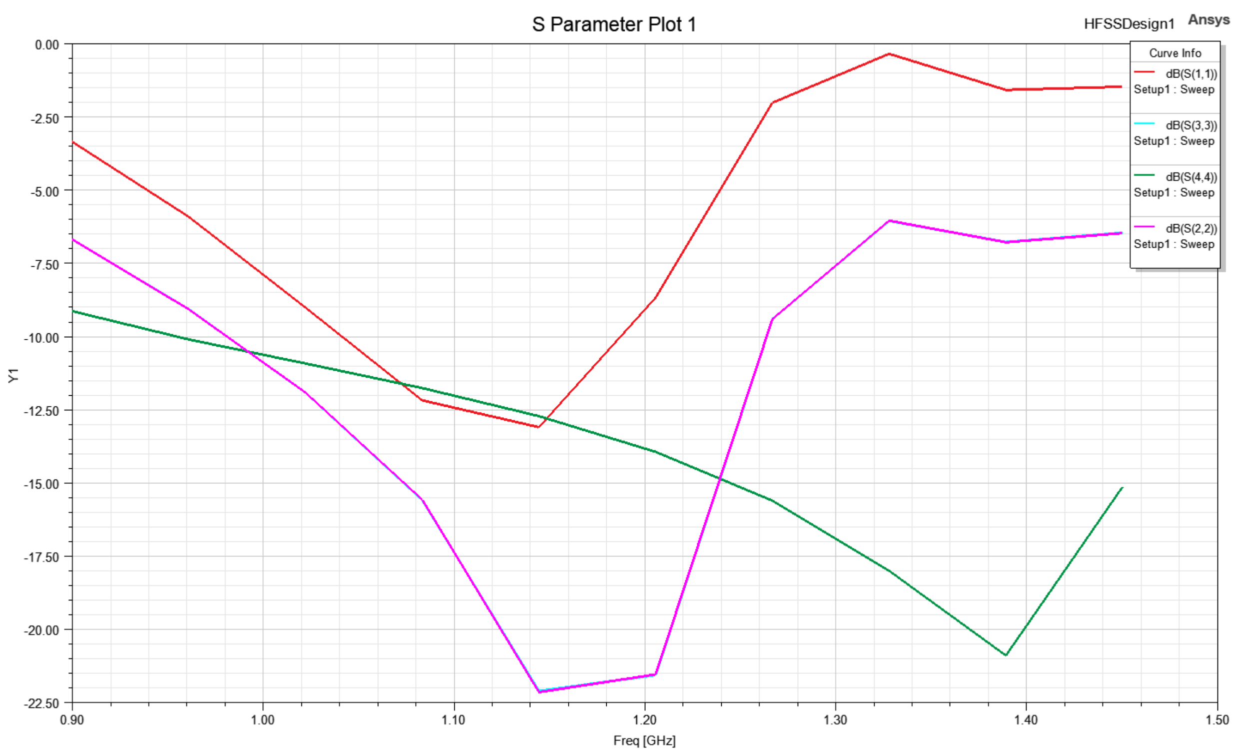



S Parameter Plot 1
HFSSDesign1
Ansys
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(3,3))
Setup1 : Sweep
dB(S(4,4))
Setup1 : Sweep
dB(S(2,2))
Setup1 : Sweep
Y1
0.00
-2.50
-5.00
-7.50
-10.00
-12.50
-15.00
-17.50
-20.00
-22.50
0.90
1.00
1.10
1.20
1.30
1.40
1.50
Freq [GHz]

Optimizing :



Z
X
Y

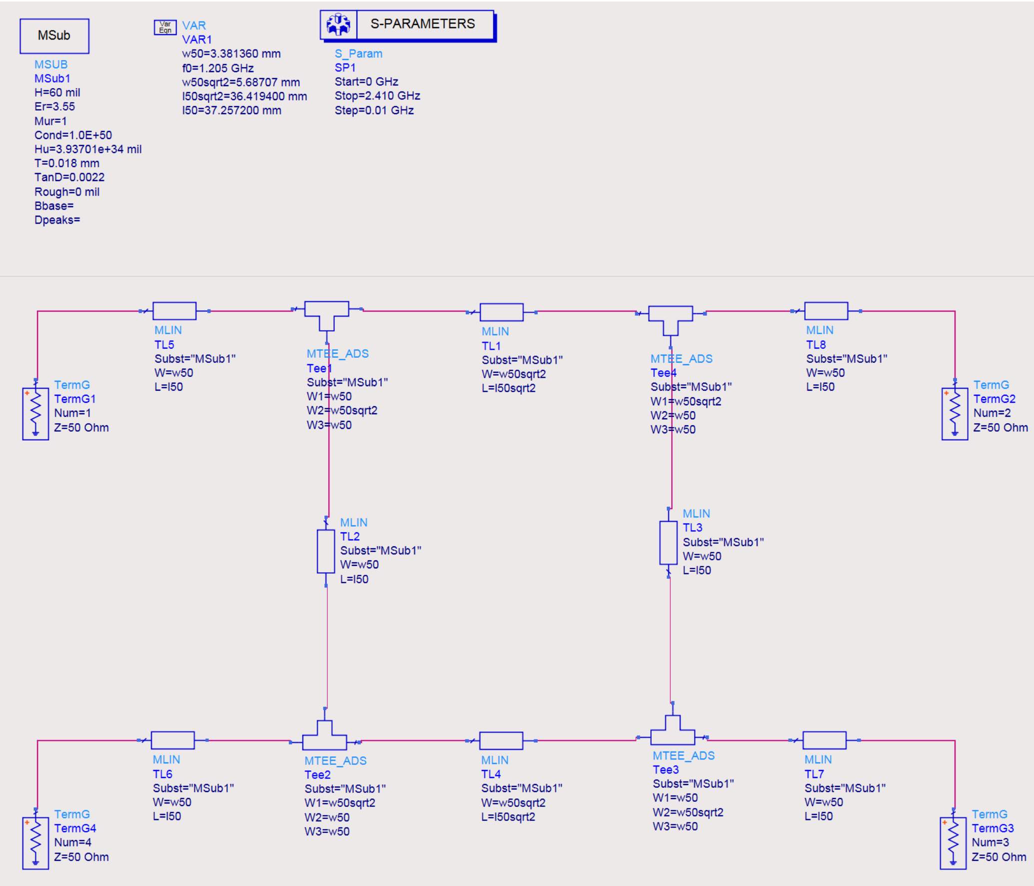


S Parameter Plot 1
HFSSDesign1
Ansys
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(3,3))
Setup1 : Sweep
dB(S(4,4))
Setup1 : Sweep
dB(S(2,2))
Setup1 : Sweep
Y1
0.00
-2.50
-5.00
-7.50
-10.00
-12.50
-15.00
-17.50
-20.00
-22.50
0.90
1.00
1.10
1.20
1.30
1.40
1.50
Freq [GHz]

Question 2

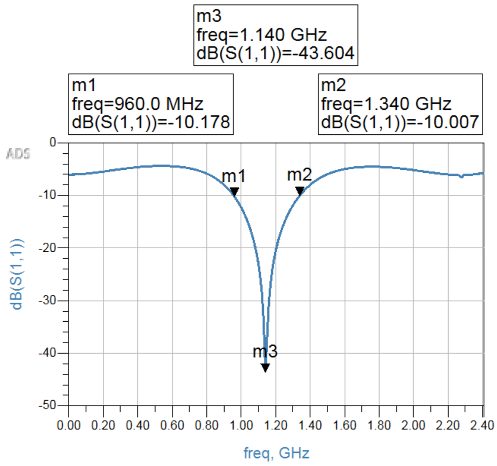
2.1

In this part, we are going to simulate a branch line which is a hybrid 90 coupler.
First of all we create the schematic in the ADS software:



Note that the substrate parameters were extracted from the intended material which is RO4003.
The line widths and lengths were calculated using LineCalc tool in ADS.
The MTEE element was used because of the difference in line widths.

S_{11} of the above schematic is as follows:

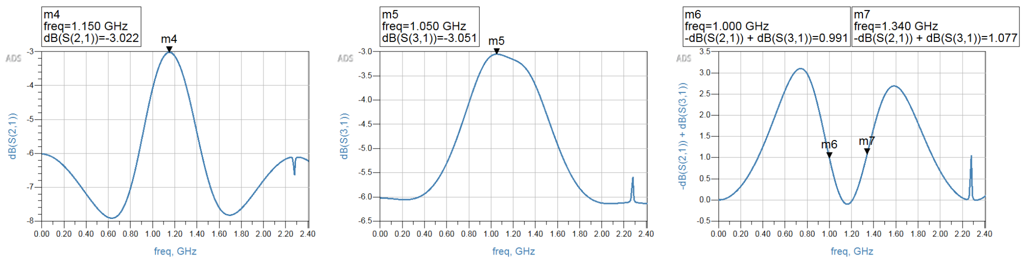


The matching bandwidth which is the frequency interval in which S_{11} is lower than $-10d\beta$ is approximately:

$$1.340 - 0.960 = 0.380\ GHz = 380\ MHz$$

Note that the center frequency is slightly $(65MHz)$ lower than the intended one which is acceptable.

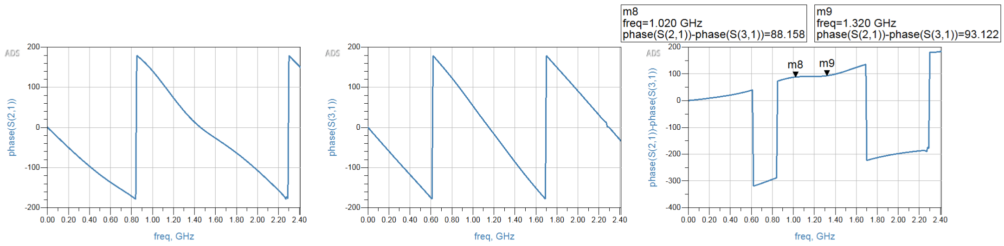
S_{21}, S_{31}, and their difference are as follows:



The balance bandwidth which is the frequency interval in which the difference between S_{21} and S_{31} is lower than $1d\beta$ is approximately:

$$1.340 - 1 = 0.340\ GHz = 340\ MHz$$

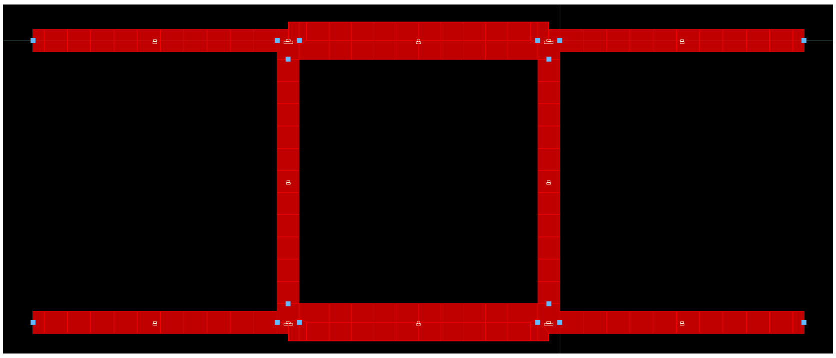
The phase of S_{21}, S_{31}, and their difference are as follows:



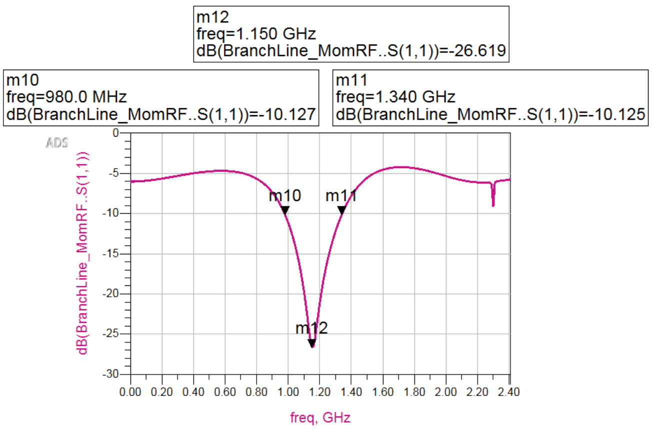
The phase-difference bandwidth which is the frequency interval in which the difference between the phase of S_{21} and S_{31} is between 88 and 92 degrees is approximately:

$$1.320 - 1.020 = 0.300\ GHz = 300\ MHz$$

The layout of the mentioned schematic is as follows (Ports are 50Ω):

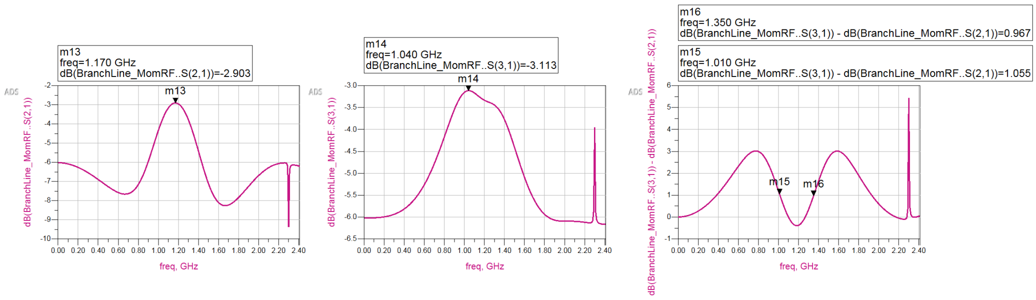


The results for the schematic will change slightly in the momentum RF simulation. The results are as follows:



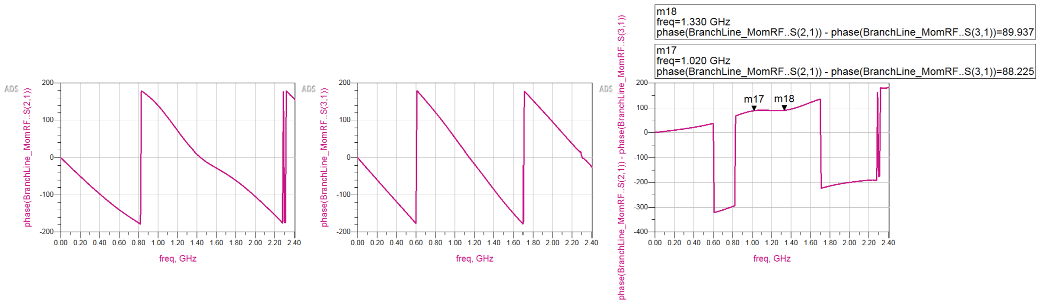
$$\text{matching bandwidth} = 1.340 - 0.980 = 0.360\ GHz = 360\ MHz$$

As we see, the matching bandwidth is reduced slightly in the momentum RF simulation.



$$\text{balance bandwidth} = 1.350 - 1.010 = 0.340\ GHz = 340\ MHz$$

The balance bandwidth remained the same.

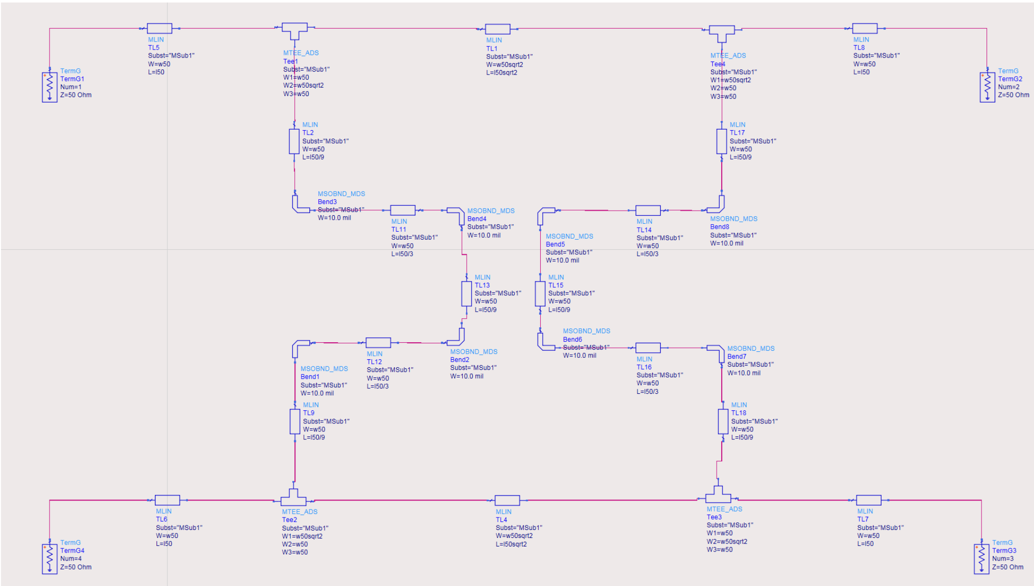


$$\text{phase-difference bandwidth} = 1.330 - 1.020 = 0.310\ GHz = 310\ MHz$$

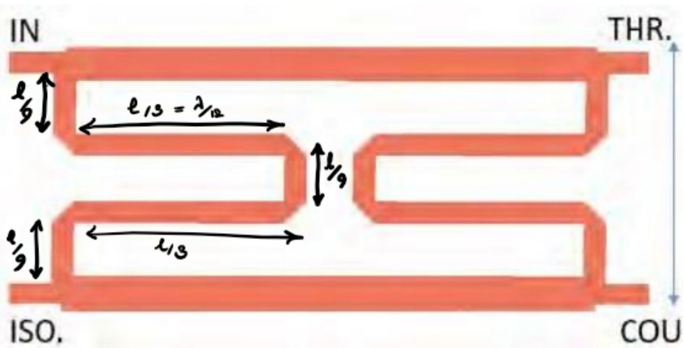
The phase-difference bandwidth increased in compare with the first simulation.

2.2

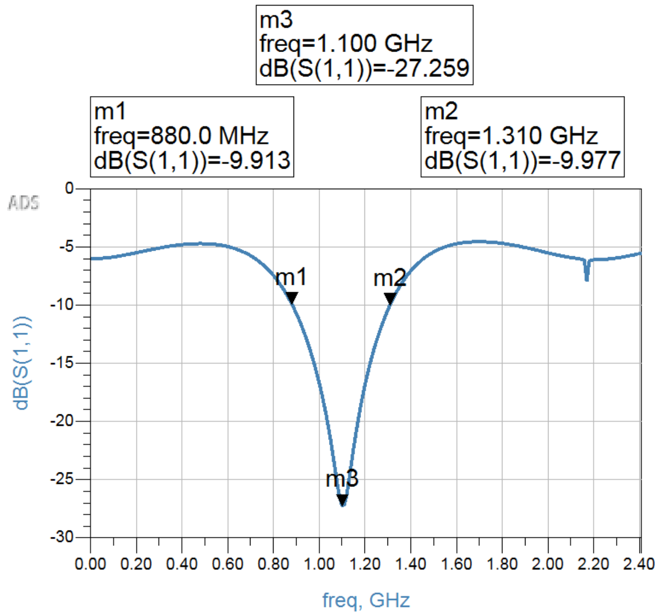
In this part we are going to simulate a meandered branch line. The schematic is as follows:



Note that we have used MSOBND element in order to simulate the 90 degree bends.
The parameters are as for the branch line. The lengths of the meandered parts are considered as follows:

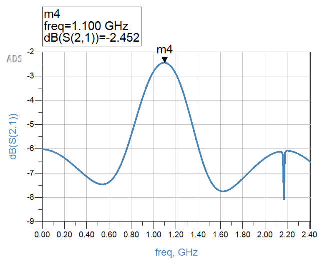


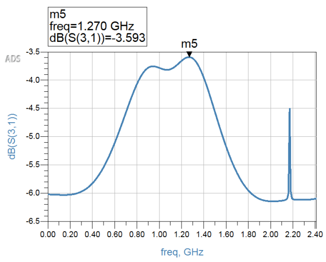
The results for the schematic are as follows:

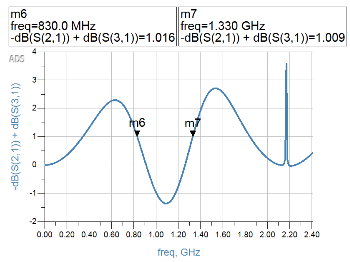


$$\text{matching bandwidth} = 1.310 - 0.880 = 0.430\ GHz = 430\ MHz$$

As we see, the matching bandwidth is increased in compare with the normal branch line.

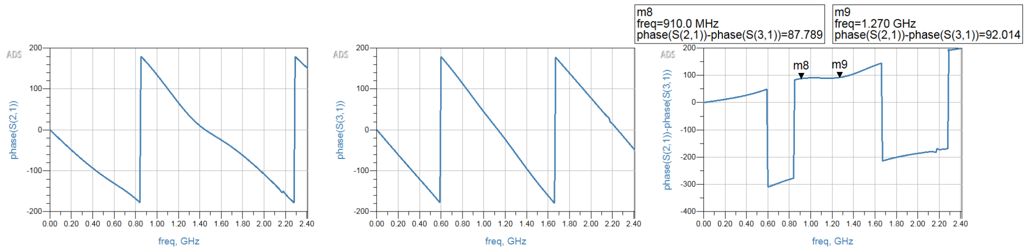






$$\text{balance bandwidth} = 1.330 - 0.830 = 0.500\ GHz = 500\ MHz$$

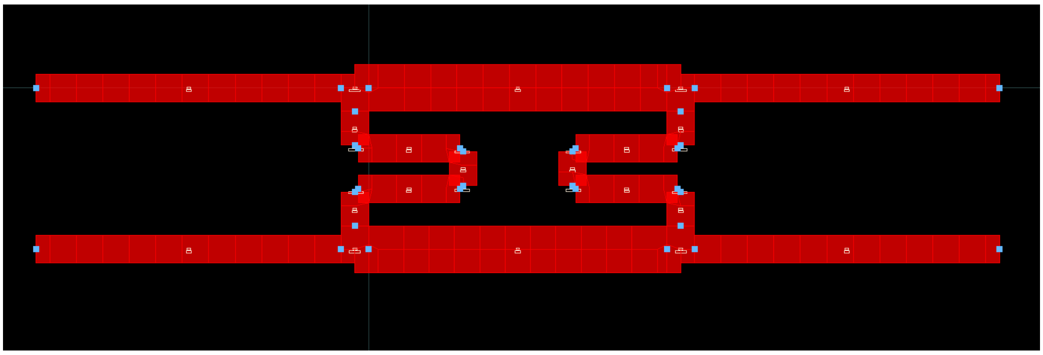
The balance bandwidth also increased.



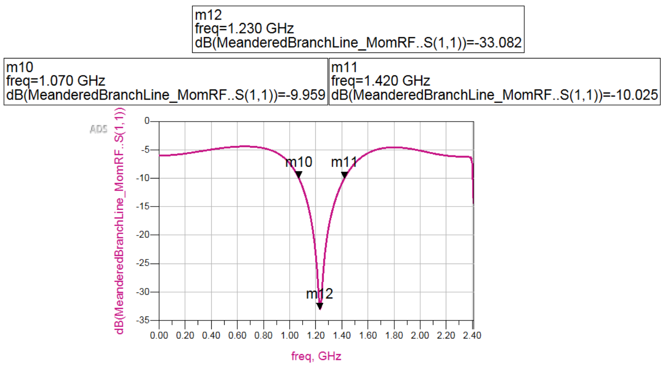
$$\text{phase-difference bandwidth} = 1.270 - 0.910 = 0.360\ GHz = 360\ MHz$$

The phase-difference bandwidth increased as well.

The layout of the meandered branchline is as follows (Ports are 50Ω):

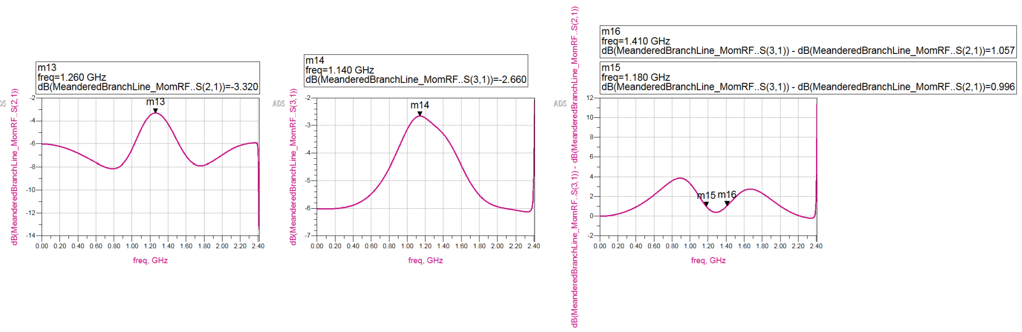


The intended bandwidths for momentum RF simulation are as follows:



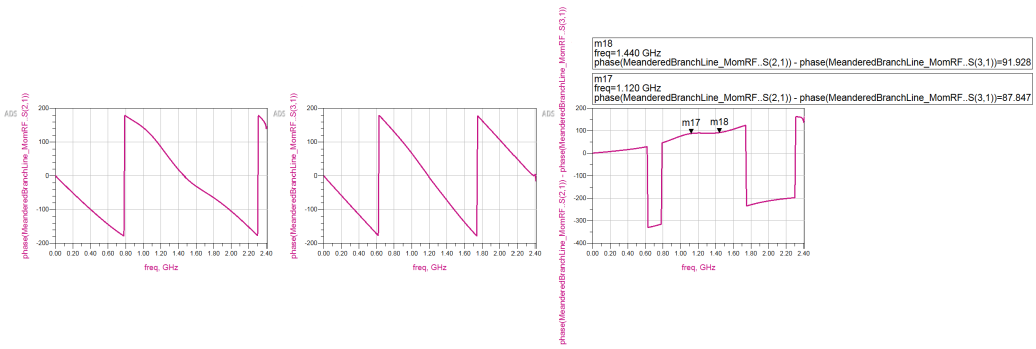
$$\text{matching bandwidth} = 1.420 - 1.070 = 0.350\ GHz = 350\ MHz$$

As we see, the matching bandwidth is reduced slightly in the momentum RF simulation of the meandered branchline in compare with the same simulation of normal branchline.



$$\text{balance bandwidth} = 1.410 - 1.180 = 0.230\ GHz = 230\ MHz$$

The balance bandwidth also reduced in compare with the momentum RF of normal branchline.



$$\text{phase-difference bandwidth} = 1.440 - 1.120 = 0.320\ GHz = 320\ MHz$$

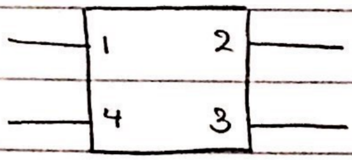
The phase-difference bandwidth increased slightly in compare with the momentum RF simulation of normal branchline.

Finally, to sum up:

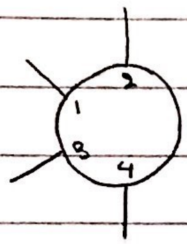
	Matching BW	Balanced BW	Phase_Difference BW
Normal Branchline	380 MHz	340 MHz	300 MHz
Normal Branchline Mom. RF	360 MHz	340 MHz	310 MHz
Meandered Branchline	480 MHz	500 MHz	360 MHz
Meandered Branchline Mom. RF	350 MHz	230 MHz	320 MHz

Question 3

For this question, first of all, we have to know the S parameter of both branch line and rat race. Also, we set the ports so that we work with the following order of ports in the rest of the project:

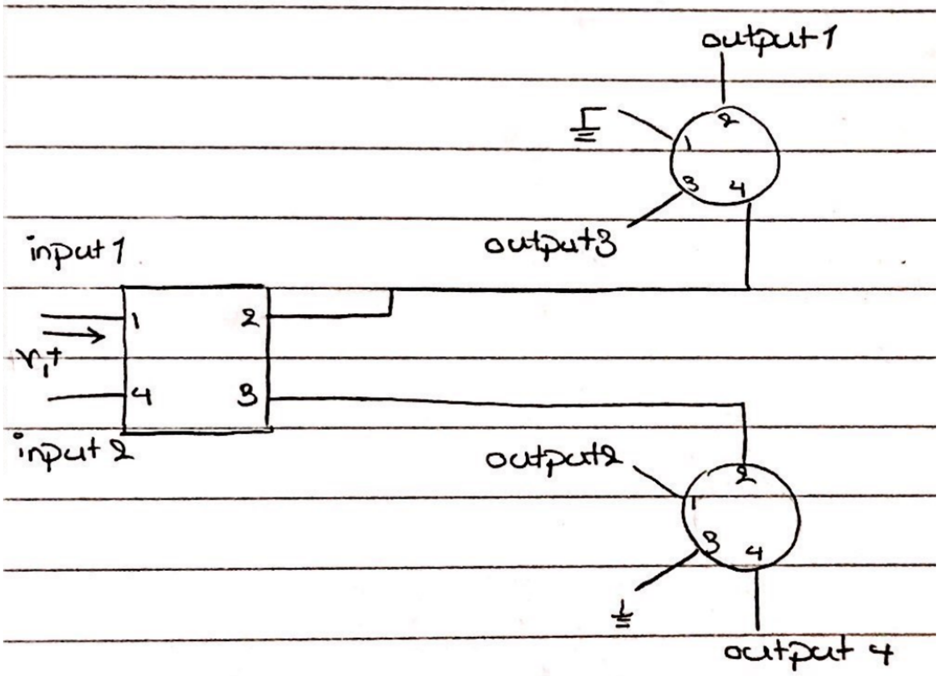


$$S_{BL} = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$



$$S_{RR} = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

If we choose to use one branch line and one rat race, the intended inputs and outputs won't be achieved. Assume that we set port 1 of the branch line as input. Among the remaining ports, we have to choose either port 2 or port 3 to be connected to the rat race. Because port 4 is isolated from port 1 and can't transmit the signal from the branch line to the rat race. Now, assume that the signal is received by the rat race. Based on the rat race's S parameter, the input port is isolated from one of the ports. Therefore, just 2 ports remain as output with the potential to receive the signal. In the branch line, apart from port 1 which was set as input, and port 3 or 2 which is connected to the rat race, just 2 ports remain, from which, port 4 is isolated and can't be set as an output port (Can be set as the second input port). Therefore just 1 port remains as an output port in the branch line. All together, 3 ports have the potential to be set as output ports in the whole structure. However, we need 4 output ports. This is the reason that we have to use at least 2 branch line or rat race. In this project, we have used 2 rat races and 1 branch line with the following structure in order to meet the requirements.



Now we analyze the schematic in order to ensure it meets the requirements. First, we excite port 1:

Port 1 excited $\rightarrow V_{port2\,BL} = V_1^+ S_{21_{BL}} \rightarrow$

$$V_{output1} = V_{port2\,BL}\, S_{24_{RR}} = V_1^+ S_{21_{BL}} S_{24_{RR}} = \frac{+V_1^+}{2}$$

$\rightarrow$ phase difference output1 & input1 = 0°

$$V_{port3\,BL} = V_1^+ S_{31_{BL}} \rightarrow V_{output2} = V_{port3\,BL}\, S_{12_{RR}} = V_1^+ S_{31_{BL}} S_{12_{RR}}$$

$= \frac{j}{2} V_1^+ \rightarrow$ phase difference output2 & input1 = 90°

$$V_{output3} = V_{port2\,BL}\, S_{34_{RR}} = V_1^+ S_{21_{BL}} S_{34_{RR}} = \frac{-V_1^+}{2}$$

$\rightarrow$ phase difference output3 & input1 = 180°

$$V_{output4} = V_{port3\,BL}\, S_{42_{RR}} = V_1^+ S_{31_{BL}} S_{42_{RR}} = \frac{-j}{2} V_1^+$$

$\rightarrow$ phase difference output 4 & input1 = 270°

Now for port 4 excitement, the process is the same:

port 4 excited $\rightarrow V_{output\,1} = V_4^+ \underset{BL}{S_{24}} \underset{RR}{S_{24}} = \frac{-j}{2} V_4^+ \rightarrow -90^\circ$

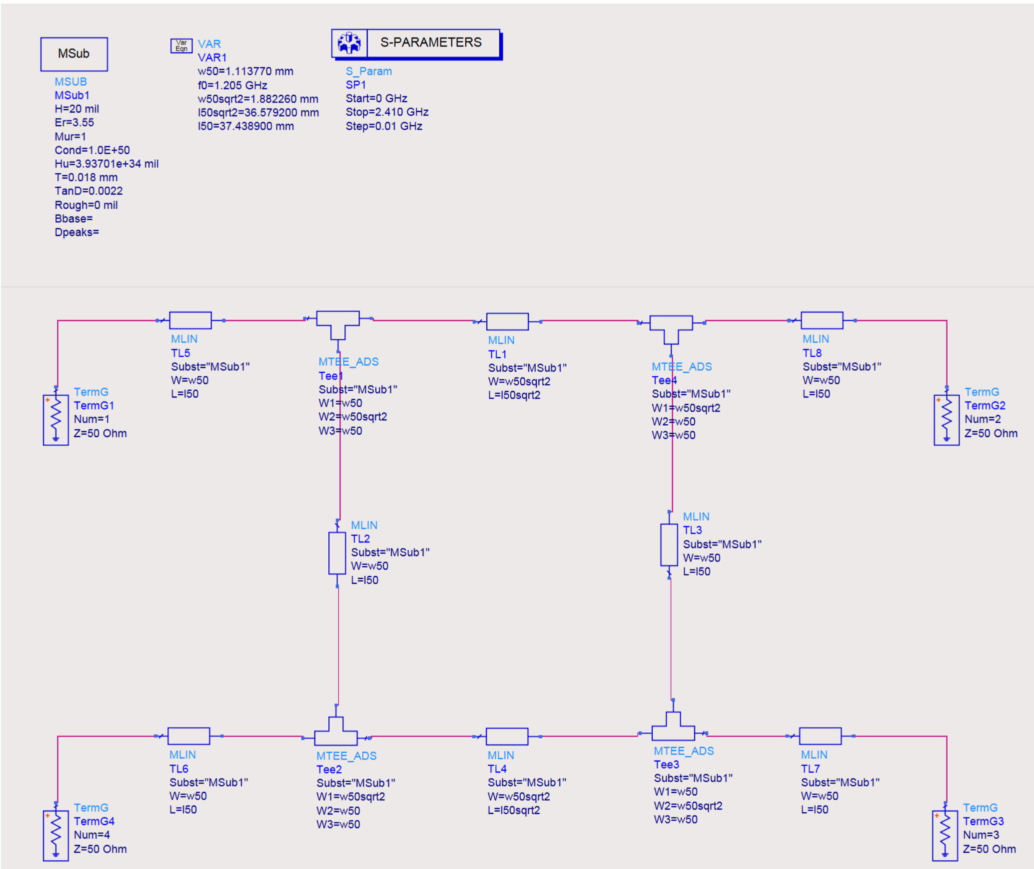
$V_{output\,2} = V_4^+ \underset{BL}{S_{34}} \underset{RR}{S_{12}} = \frac{-1}{2} V_4^+ \rightarrow -180^\circ$

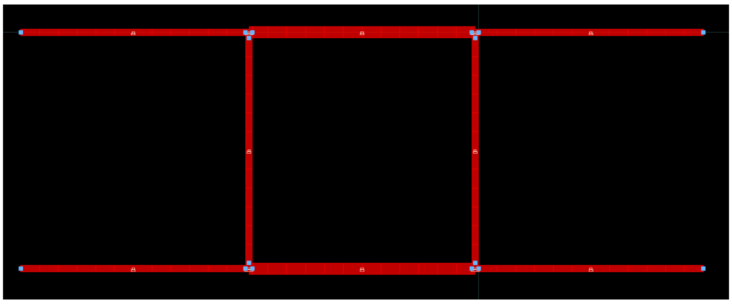
$V_{output\,3} = V_4^+ \underset{BL}{S_{24}} \underset{RR}{S_{34}} = \frac{j}{2} V_4^+ \rightarrow -270^\circ$

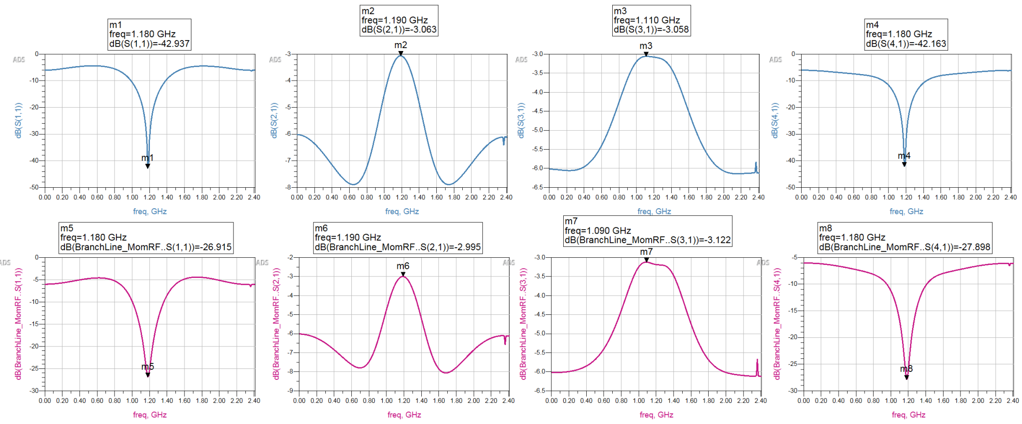
$V_{output\,4} = V_4^+ \underset{BL}{S_{34}} \underset{RR}{S_{42}} = \frac{1}{2} V_4^+ \rightarrow 0^\circ$ (-360°)

Also, the two input ports are port 1 and port 4 of the branch line. Therefore, they are isolated from each other.

In the next step, we have to change the rat race and branch line we designed previously, so that they meet the conditions of this question.
Branch Line:

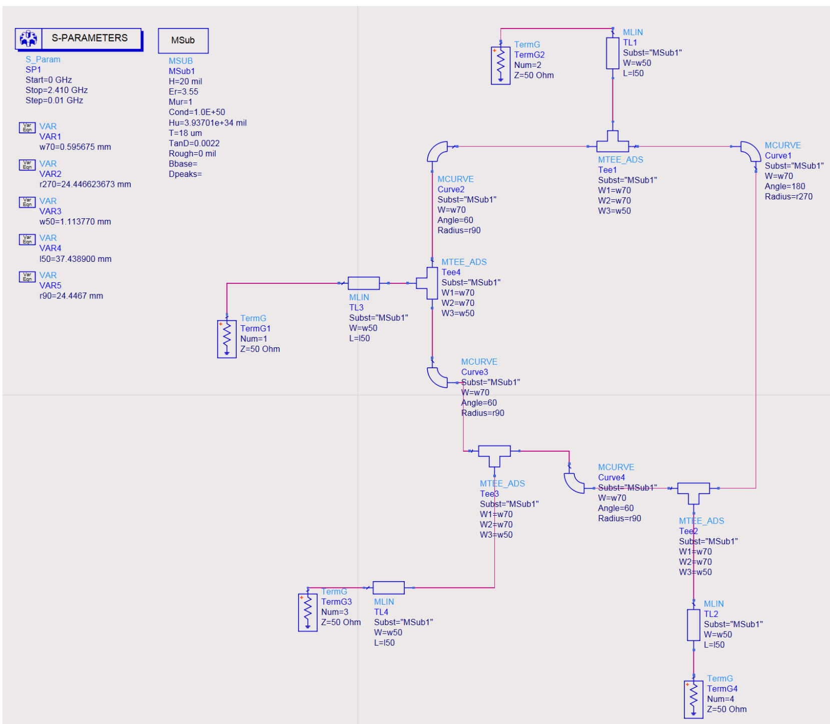


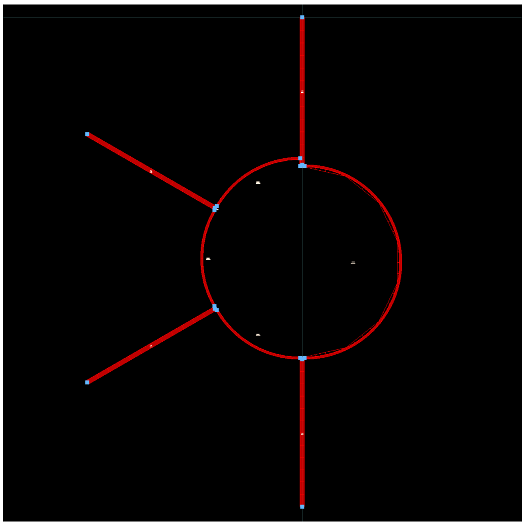


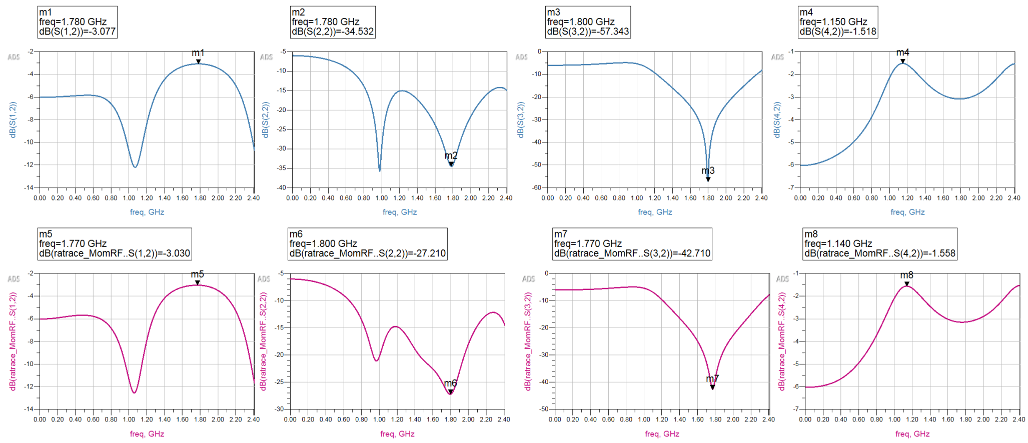


We also generate an ”S4P” file which contains the S parameter of the branch line. We can use this file in our new structure’s schematic.

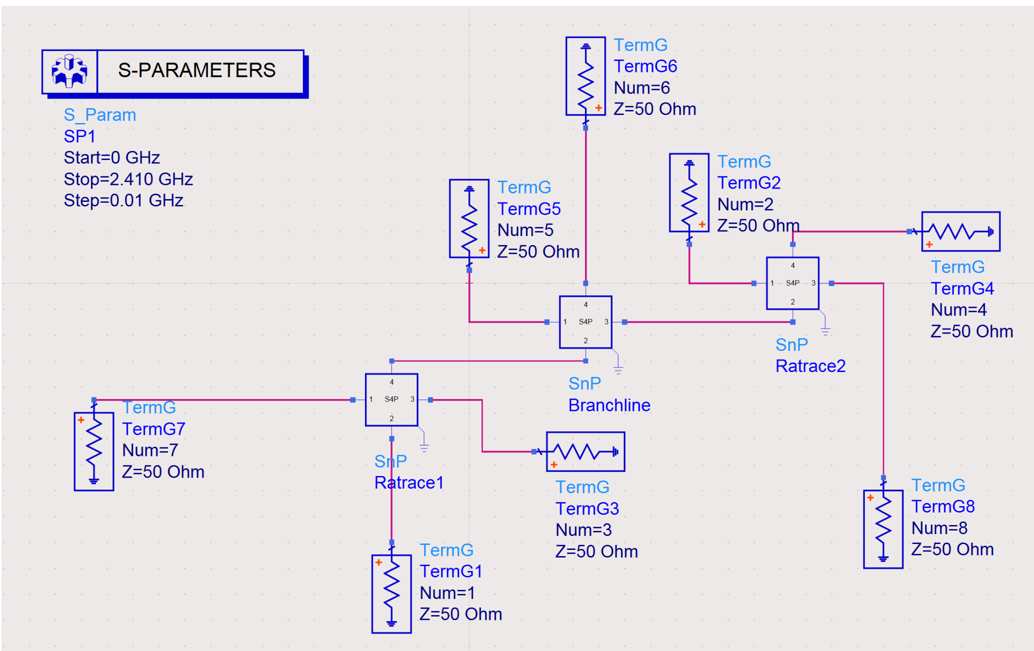
The same thing goes for the rat race:



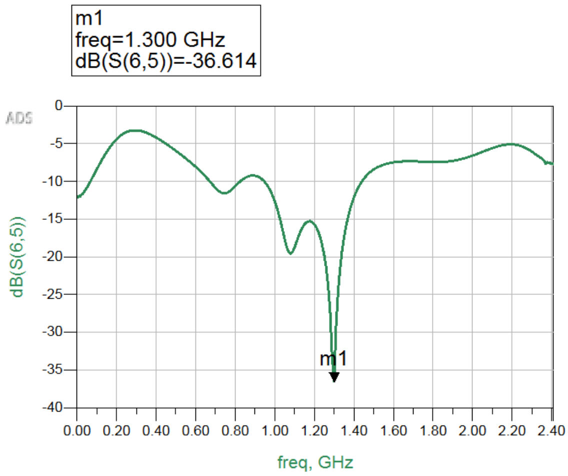




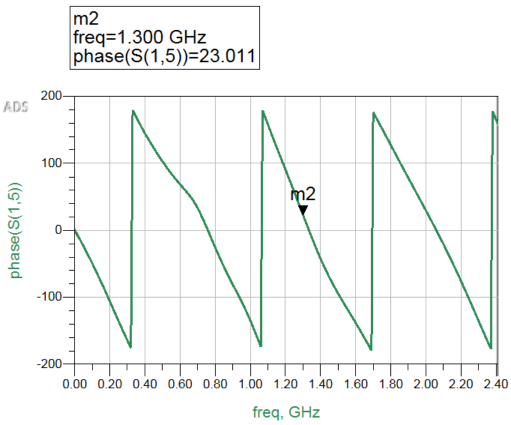
Now, in a new workspace, we can use the SnP element and inject our .s4p files into it. This makes the element perform as the rat race or branch line we designed. Then we create the schematic as mentioned earlier.

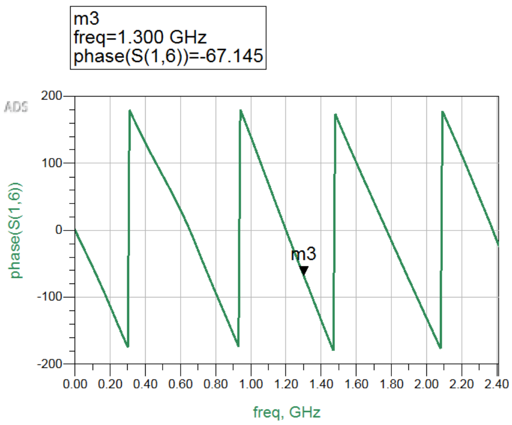


Now we check the results:

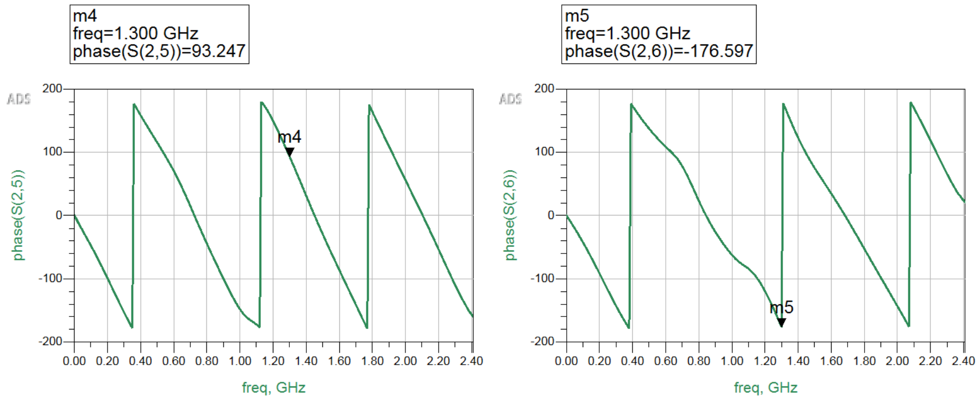


As we see, the two input ports are totally isolated.

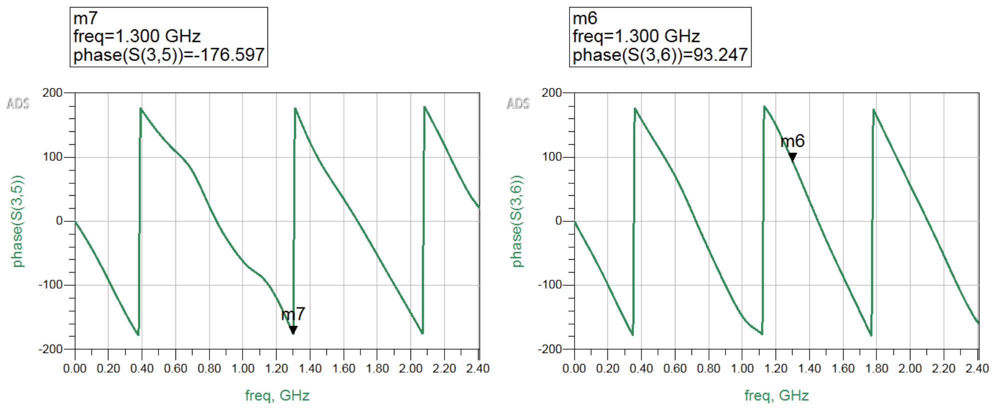




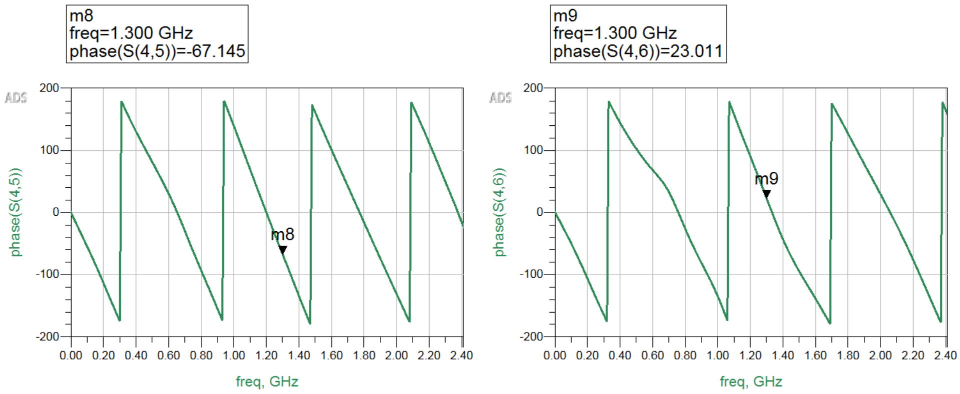
The first output port's phase difference with the first input port is near 0 degrees but they are not perfectly in-phase. Also, the phase difference with the second input port has to be -90 degrees. This is also not perfectly designed but it is close.



This port is quite well-designed. The phase difference with the first input port is roughly 90 degrees and with the second input port is roughly -180 degrees.



This port is also well-designed. The phase differences are 180 and -270 degrees respectively. Note that the phases indicated on the plot are -180 and 90 which are equivalent to the mentioned phases.



This port's phase differences is not well-designed but it is close. The first phase different has to be -90 and the second has to be 0.