Communication and Computer Engineering Program

كلية الهندسة بشبرا

FACULTY OF ENGINEERING AT SHOUBRA

WILKINSON DESIGN & ADS

2024

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FACULTY OF ENGINEERING AT SHOUBRA

CCE 410

Microwave Engineering

Wilkinson Design With ADS

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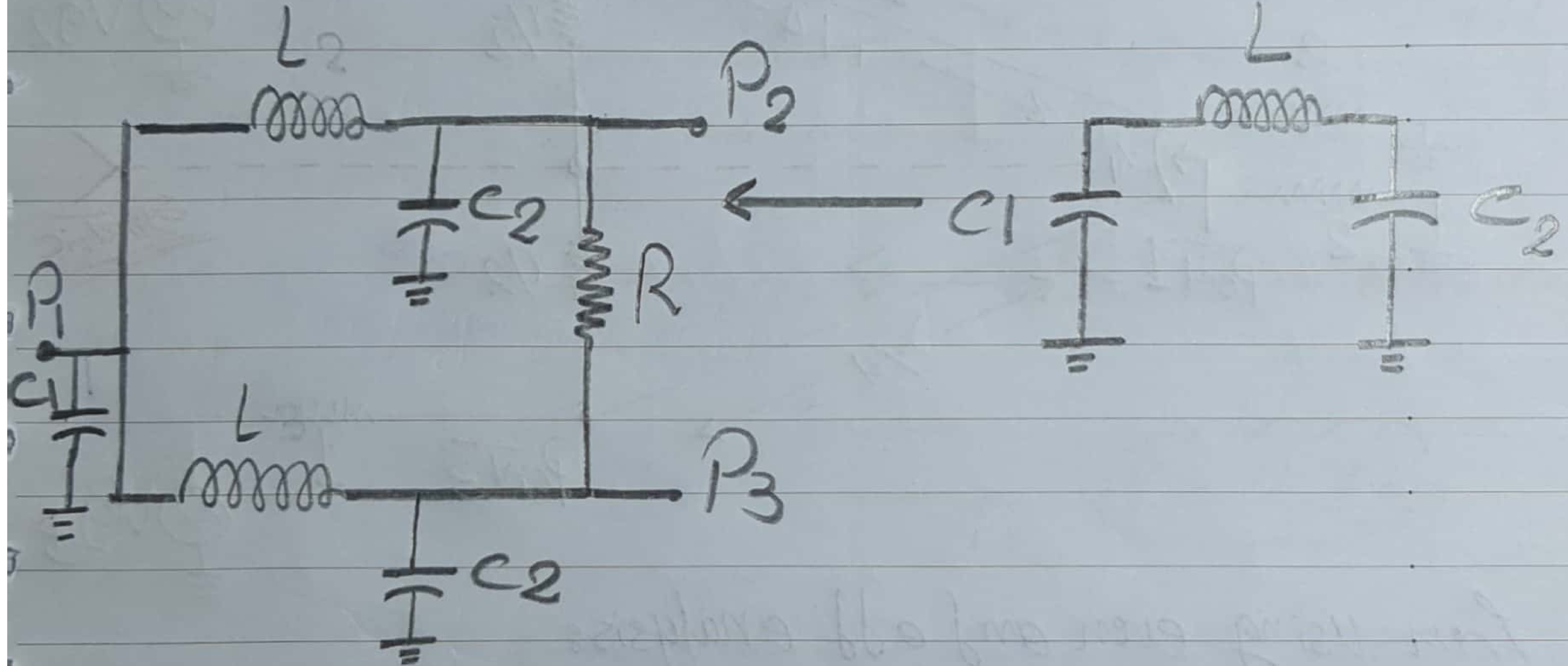
Subject : .... Mode :

Assignment Wilkinson

1 Draw Pi equivalent circuit of $\lambda/4$ assuming Transmformer impedence characteristic equals $70\,\Omega$ at $f = 2\,GHz$, find equivalent Lumped circuit if This branch one of Two Branches.

$$Z_{Tch} = 70\,\Omega \quad , \quad f = 2 * 10^9\ HZ$$

π equivalent circuit is:



$$C_2 = \frac{1}{\omega Z_{ch}} = \frac{1}{2\pi * 2*10^9 * 70} = 1.14\ PF$$

$$C_1 = 2C_2 = 2.274\ PF$$

$$L_3 = L_2 = Z_{ch}/\omega = \frac{70}{2\pi * 2*10^9} = 5.57\ nH$$

Date :   Subject :

[2] Design a wilkinson Power divider with a Power division ratio of $10 \log(P_3/P_2) = 6.99$ dB a source impedence 50Ω, and $f = 3$ GHz find [S]

Because the Power divider is non equality:

$$K^2 = \frac{P_3}{P_2} = 6.99 \text{ dB} = 5 \text{ (non dimensional)}$$

$$\boxed{K = \sqrt{5}}$$

$$Z_0 = 50\Omega, \quad Z_{03} = Z_0 \sqrt{\frac{(1+K^2)}{K^3}}$$

$$Z_{03} = 50 * \sqrt{\frac{1+5}{(\sqrt{5})^3}} = 36.64\Omega$$

$$Z_{02} = K^2 * Z_{03} = (\sqrt{5})^2 * 36.64$$

$$Z_{02} = 183.14\Omega$$

$$R = Z_0 * (K + 1/K) = 50 * (\sqrt{5} + 1/\sqrt{5})$$

$$R = 134.164\Omega$$

$$Z_{0e} = \sqrt{K}\, Z_0 = \sqrt{\sqrt{5}} * 50 = 74.78\Omega$$

$$Z_{0d} = \sqrt{1/K}\, Z_0 = \sqrt{1/\sqrt{5}} * 50 = 33.44\Omega$$

Subject : ....   Mode :

from using ADS:

$$S_{23} = S_{32} = 5.469 * 10^{-5} \simeq 0$$

$$S = \begin{bmatrix} 0 & 0.408 & 0.913 \\ 0.408 & 0 & 0 \\ 0.913 & 0 & 0 \end{bmatrix}$$

verified by using ADS

Point 2 Verified S by using ADS:

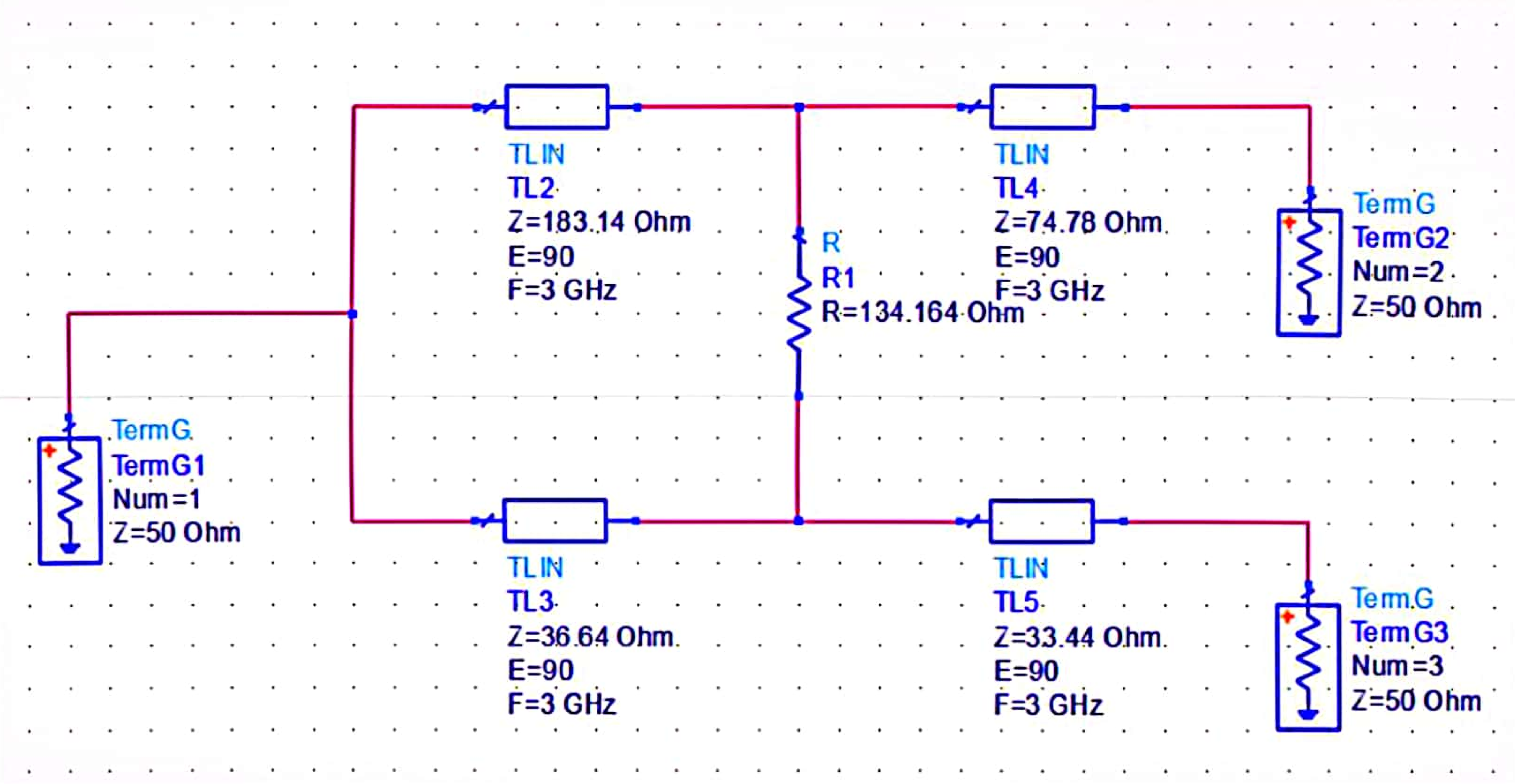


Figure 1, the TL circuit of point 2 according to the design.

freq	S(1,1)	S(1,2)	S(1,3)
3.000 GHz	1.592E-4 / 1.739E-...	0.408 / -180.000	0.913 / -180.000

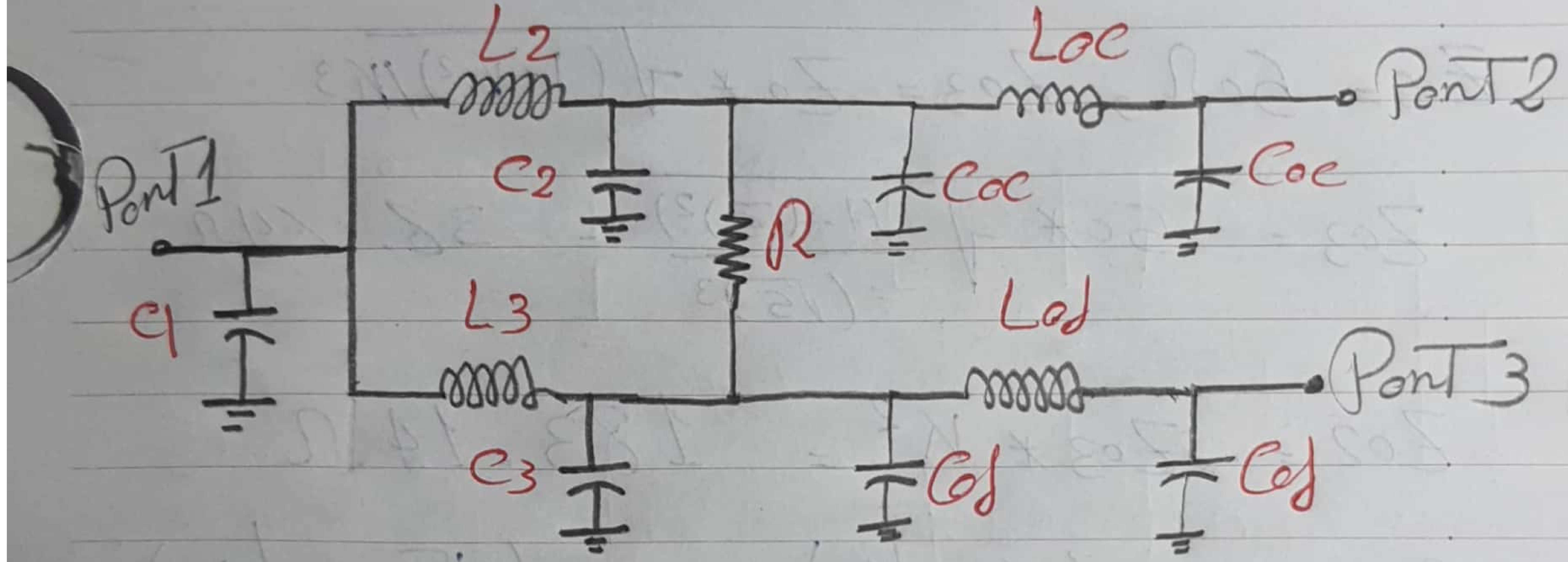
freq	S(2,1)	S(2,2)	S(2,3)
3.000 GHz	0.408 / -180.000	1.701E-4 / -1.200...	5.693E-5 / 180.000

freq	S(3,1)	S(3,2)	S(3,3)
3.000 GHz	0.913 / -180.000	5.693E-5 / 180.0...	1.742E-4 / 180.0...

From S matrix we find that port 2 and port 3 were isolated from each other.

[3] Draw The equivalent circuit (using lumped element) for the Power divider Point 2, and Then find the corresponding value of lumped elements.

the circuit of non equality wilkinson, so the equivalent circuit is:



from Point 2:

$$K^2 = (\sqrt{5})^2 \longrightarrow K = \sqrt{5}$$

$Z_{03} = 36.64\,\Omega$, $Z_{02} = 183.19\,\Omega$

$R = 134.164\,\Omega$

$Z_{oc} = 74.78\,\Omega$, $Z_{od} = 33.44\,\Omega$

Subject : .... Mode :

$$C_2 = \frac{1}{Z_{02}\,\omega} = \frac{1}{183.14 * 2\pi * 3*10^9}$$

$$C_2 = 0.29\ PF$$

$$C_3 = \frac{1}{Z_{03}\,\omega} = \frac{1}{36.64 * 2\pi * 3*10^9}$$

$$C_3 = 1.448\ PF$$

$$C_1 = C_2 + C_3 = 0.29\,PF + 1.448\,PF$$

$$C_1 = 1.74\ PF$$

$$L_2 = \frac{Z_{02}}{\omega} = \frac{183.14}{2\pi*3*10^9} = 9.72\ nH$$

$$L_3 = \frac{Z_{03}}{\omega} = \frac{36.64}{2\pi*3*10^9} = 1.944\ nH$$

$$L_{oe} = \frac{Z_{oe}}{\omega} = \frac{74.78}{2\pi*3*10^9} = 3.97\ nH$$

$$L_{od} = \frac{Z_{od}}{\omega} = \frac{33.44}{2\pi*3*10^9} = 1.77\ nH$$

$$C_{oe} = \frac{1}{Z_{oe}\,\omega} = \frac{1}{74.78*2\pi*3*10^9} = 0.71\ PF$$

$$C_{od} = \frac{1}{Z_{od}\,\omega} = \frac{1}{33.44*2\pi*3*10^9} = 1.59\ PF$$

Point 3 Draw the equivalent circuit (using lumped elements) for the power divider at point (2), and then find the corresponding values of the lumped elements.

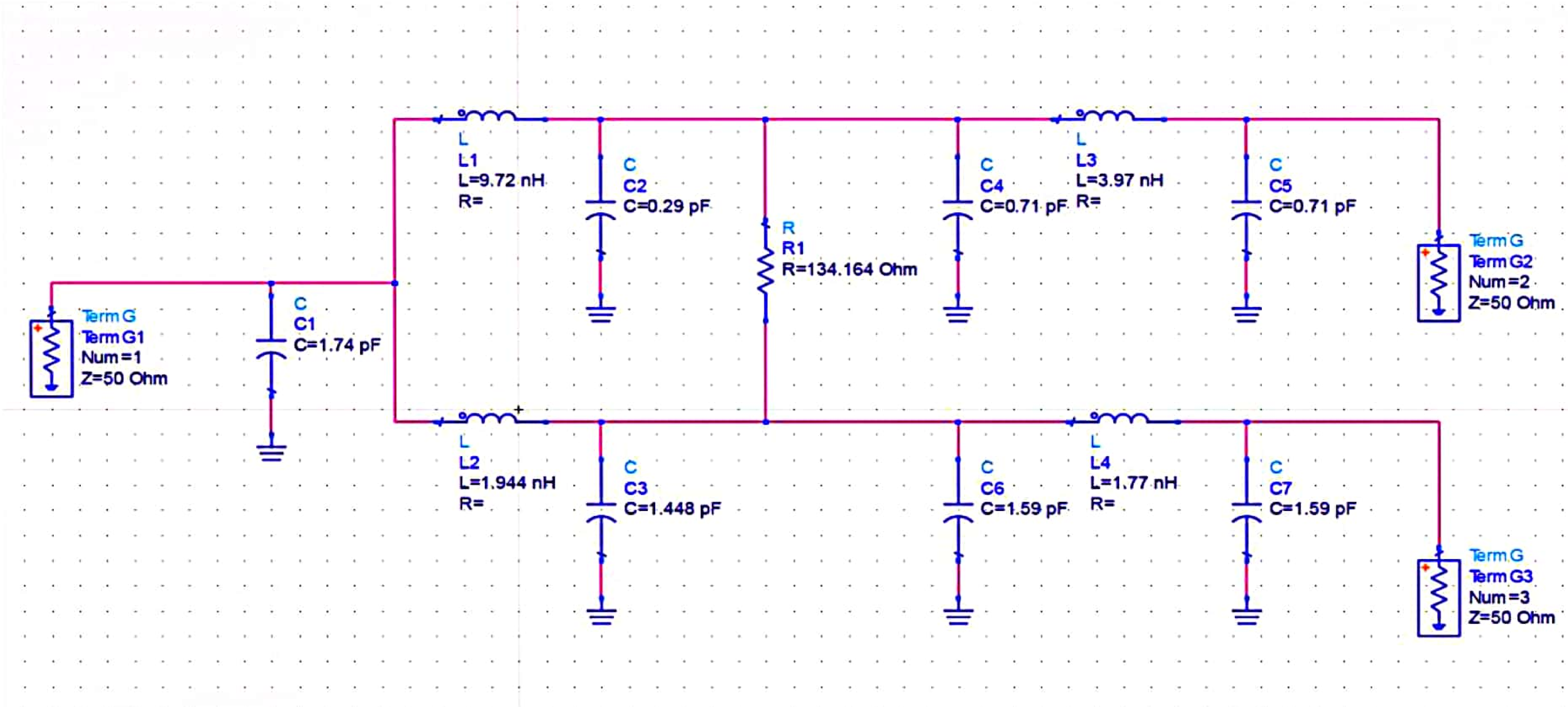


Figure 2, lumped circuit equivalent to the TL in point 2

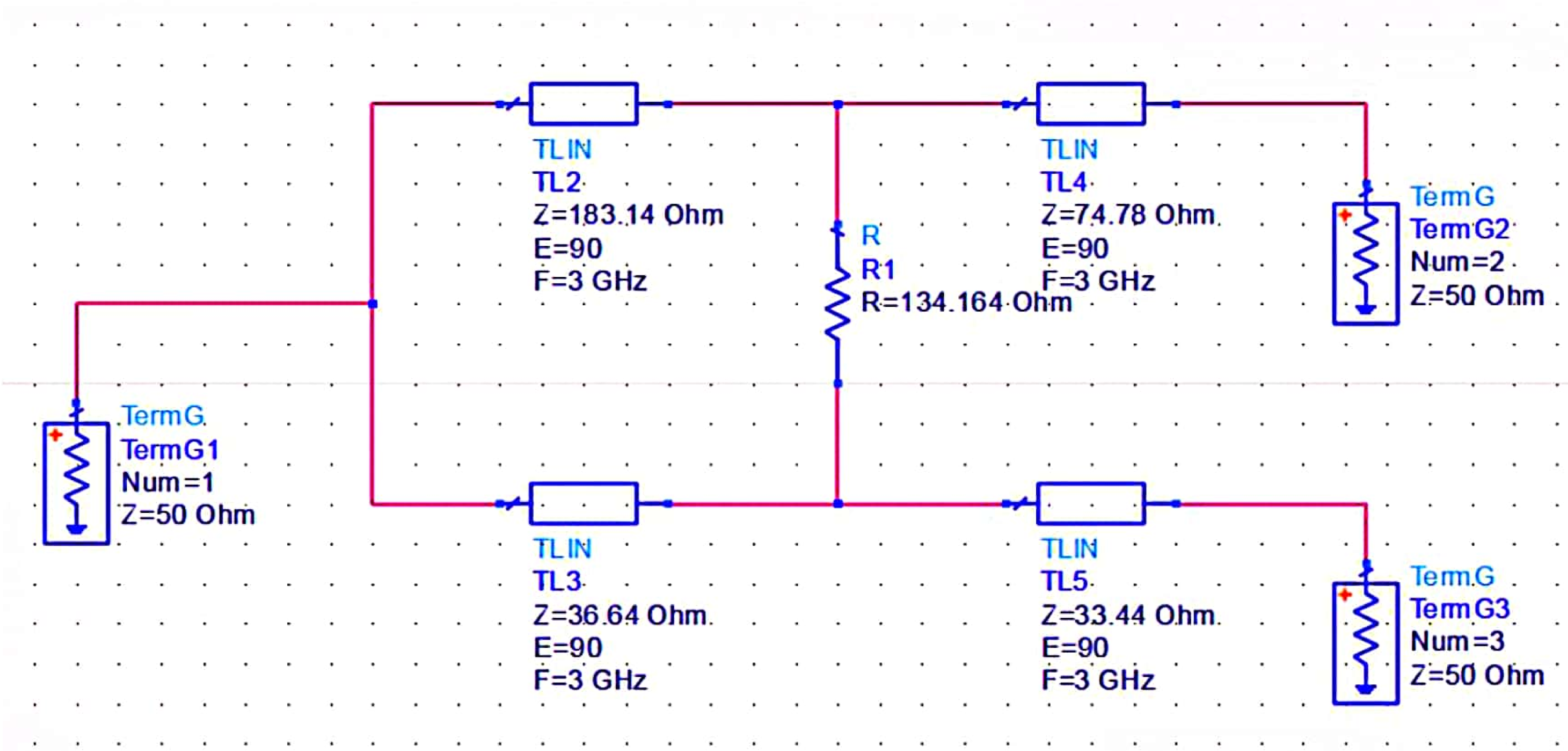
freq	S(1,1)	S(1,2)	S(1,3)
3.000 GHz	0.002 / -25.956	0.408 / 179.808	0.913 / 179.929

freq	S(2,1)	S(2,2)	S(2,3)
3.000 GHz	0.408 / 179.808	0.001 / 47.408	4.934E-4 / -108...

freq	S(3,1)	S(3,2)	S(3,3)
3.000 GHz	0.913 / 179.929	4.934E-4 / -10...	0.003 / -159.002

4- Check your answer using HFSS simulator or ADS. It is required to Draw Circuits at points (2) and (3), run the simulation and find the corresponding [S] for each.

The TL Circuit with S Parameters Matrix:

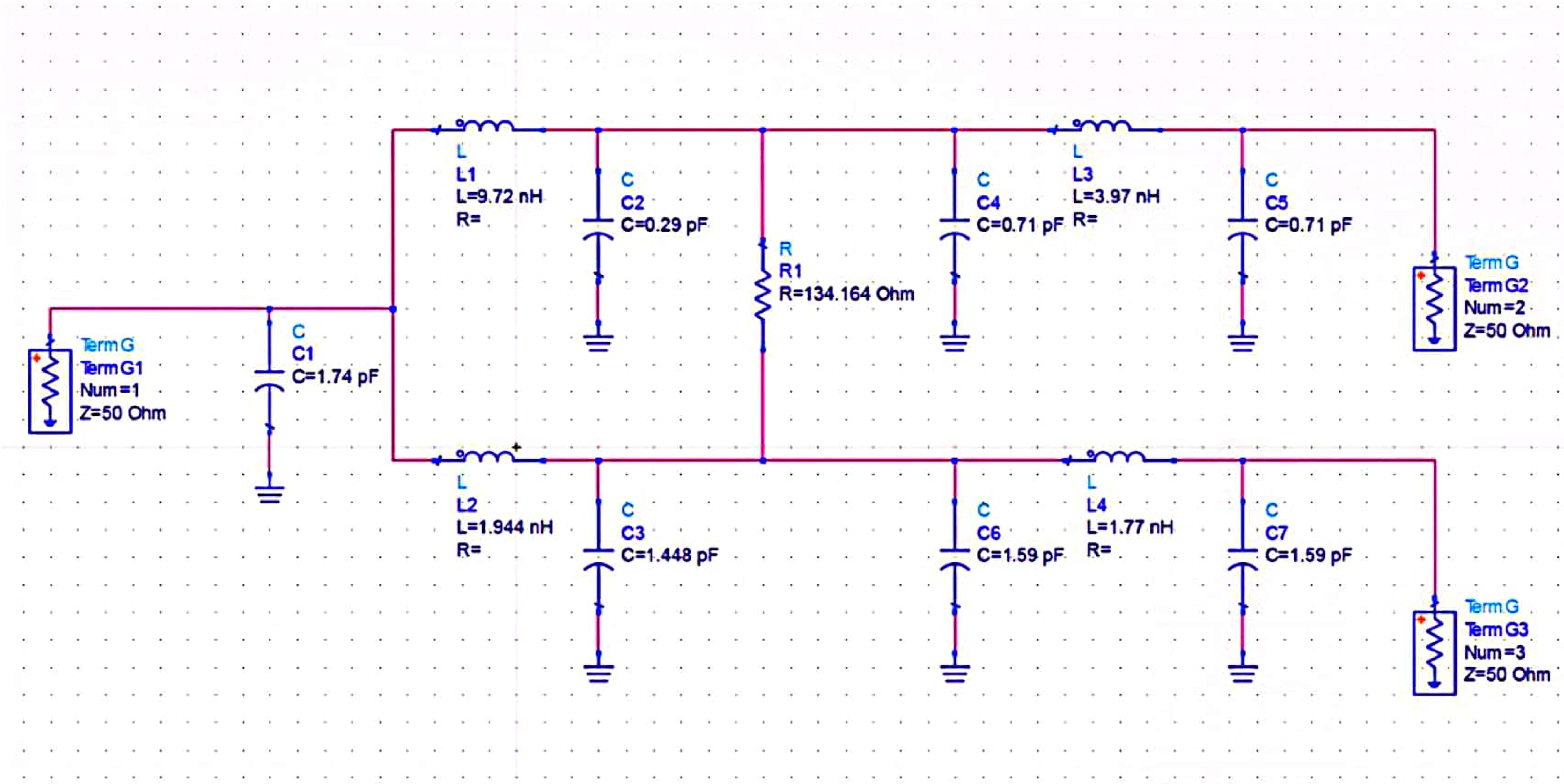


freq	S(1,1)	S(1,2)	S(1,3)
3.000 GHz	1.592E-4 / 1.739E-...	0.408 / -180.000	0.913 / -180.000

freq	S(2,1)	S(2,2)	S(2,3)
3.000 GHz	0.408 / -180.000	1.701E-4 / -1.200...	5.693E-5 / 180.000

freq	S(3,1)	S(3,2)	S(3,3)
3.000 GHz	0.913 / -180.000	5.693E-5 / 180.0...	1.742E-4 / 180.0...

The Equivalent Circuit to Previous Matrix is:



freq	S(1,1)	S(1,2)	S(1,3)
3.000 GHz	0.002 / -25.956	0.408 / 179.808	0.913 / 179.929

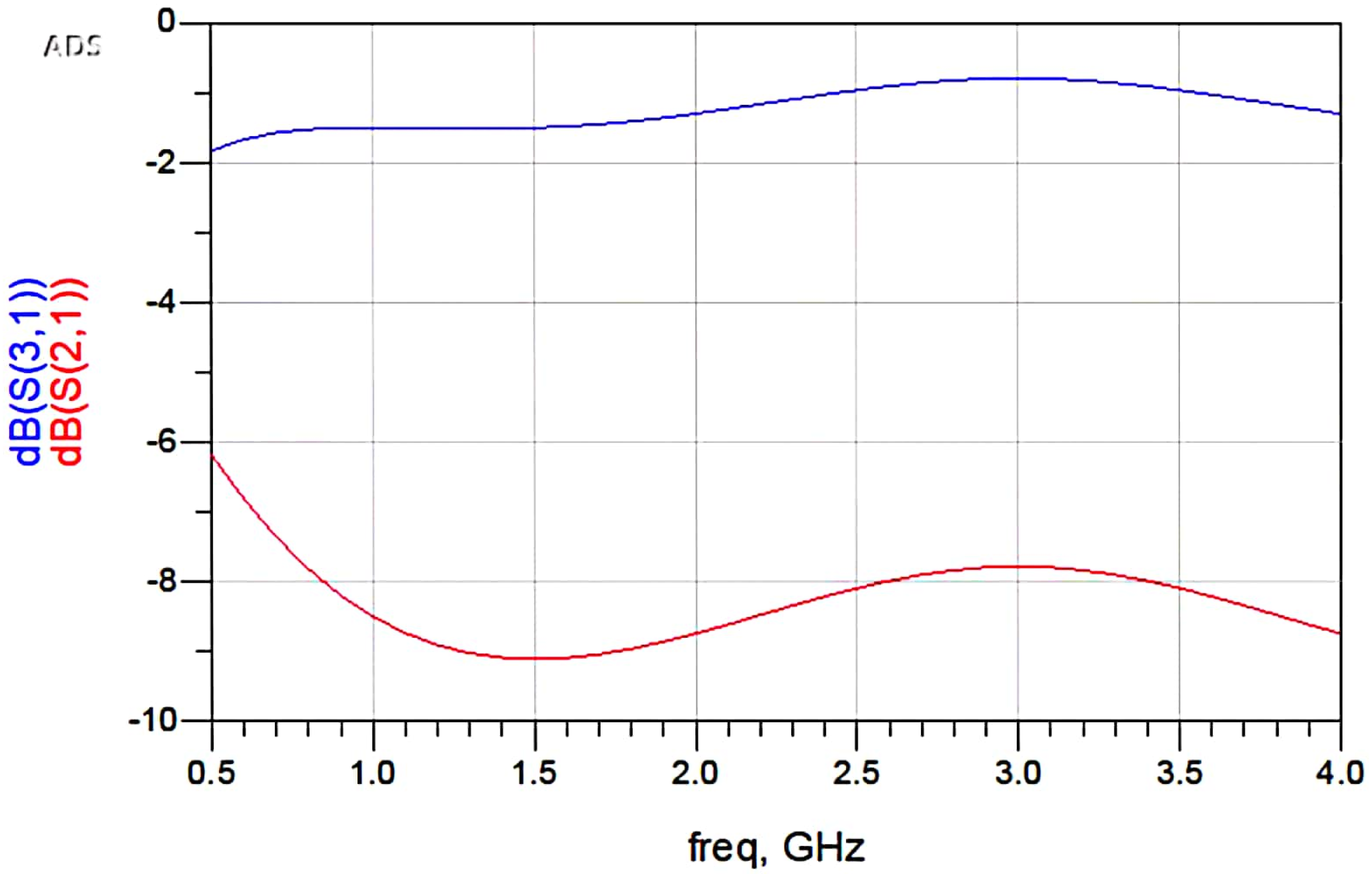
freq	S(2,1)	S(2,2)	S(2,3)
3.000 GHz	0.408 / 179.808	0.001 / 47.408	4.934E-4 / -108...

freq	S(3,1)	S(3,2)	S(3,3)
3.000 GHz	0.913 / 179.929	4.934E-4 / -10...	0.003 / -159.002

That's Verified that the TL Circuit has this equivalent circuit.

Comments on Results:

1- Power Division using Extracted S21,S31:



From the plot of S21 and S31 we find that:

S21(*at F = 3 GHz*) = -7.999 dB = $10^{\frac{-7.999}{20}}$ = 0.398

S31(*at F = 3 GHz*) = -0.98 dB = $10^{\frac{-0.98}{20}}$ = 0.893

Note that the value of power division in dB called Insertion losses if incident from port and reflected on another different port:

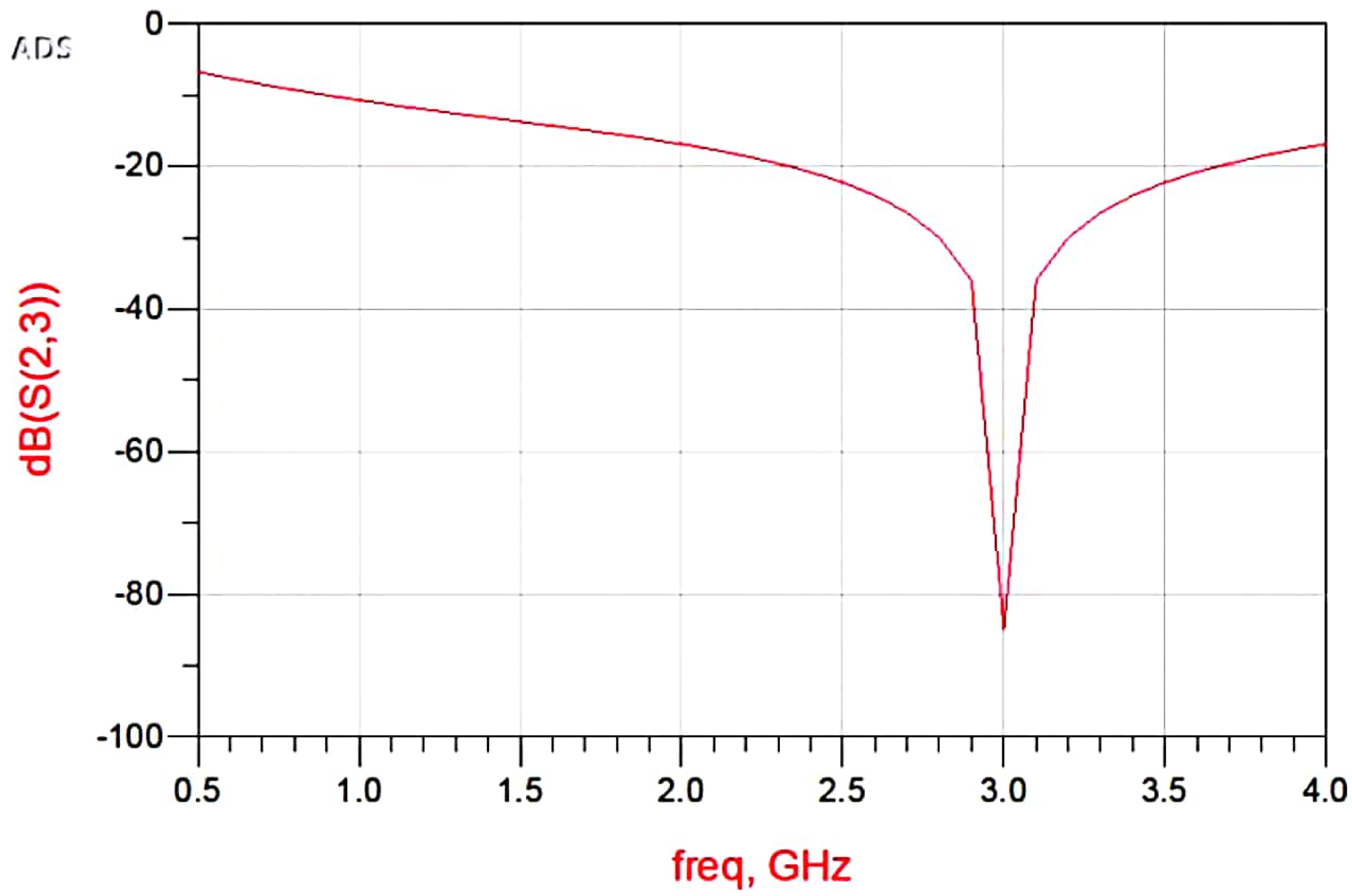
$$|S21|^2 = \frac{P_2^-}{P_1^+} = 0.398$$

$$|S31|^2 = \frac{P_3^-}{P_1^+} = 0.893$$

-10 log($\frac{P_2^-}{P_1^+}$) + 10 log($\frac{P_3^-}{P_1^+}$) = 10 log($\frac{P_1^+}{P_2^-}$) + 10 log($\frac{P_3^-}{P_1^+}$) = 10 log($\frac{P_1^+}{P_2^-} x \frac{P_3^-}{P_1^+}$) = 10 log($\frac{P_3^-}{P_2^-}$)

10 log($\frac{P_3^-}{P_2^-}$) = 6.99 dB = $10^{\frac{6.99}{10}}$ = 5 (non-Dimensional), so the ratio of power division is $\frac{5}{1}$

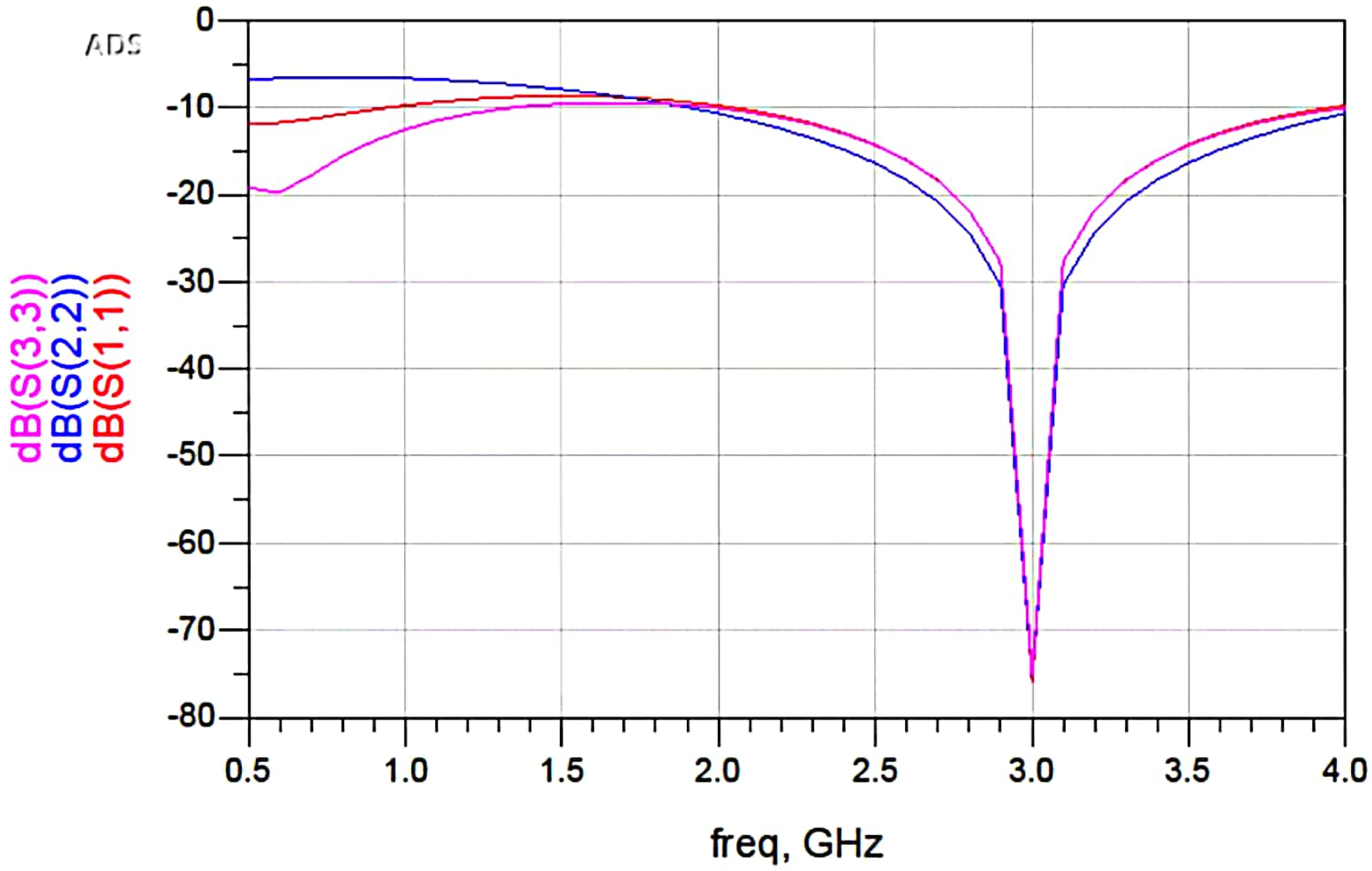
2- isolation Using extracted S23:



S23(*at F = 3 GHz*) = -85.242 dB = $10^{\frac{-85.242}{20}}$ = 5.469 x $10^{-5} \approx Zero$

From the above calculations we find that S23 give the Insertion Losses between port 2 and port 3 this value is too small or closely to zero that's means the better isolation between port 2 and port 3, no signal incident from port 2 not inserted to port 3.

3- matching at all ports using extracted S11,S22,S33:



S11(*at F = 3 GHz*) = -75.595 dB = $10^{\frac{-75.595}{20}} \approx Zero$

S22(*at F = 3 GHz*) = -75.595 dB = $10^{\frac{-75.595}{20}} \approx Zero$

S33(*at F = 3 GHz*) = -75.595 dB = $10^{\frac{-75.595}{20}} \approx Zero$

From the previous calculation we find that the value of S11 and S22 and S33 were to small that's means matched between all ports.

S11 and S22 and S33 in dB were called Reflection losses these values are very small that means they were small Reflection losses between port 1 and port 2 and port 3, that means all ports are matched.