EECS282 - Project 2

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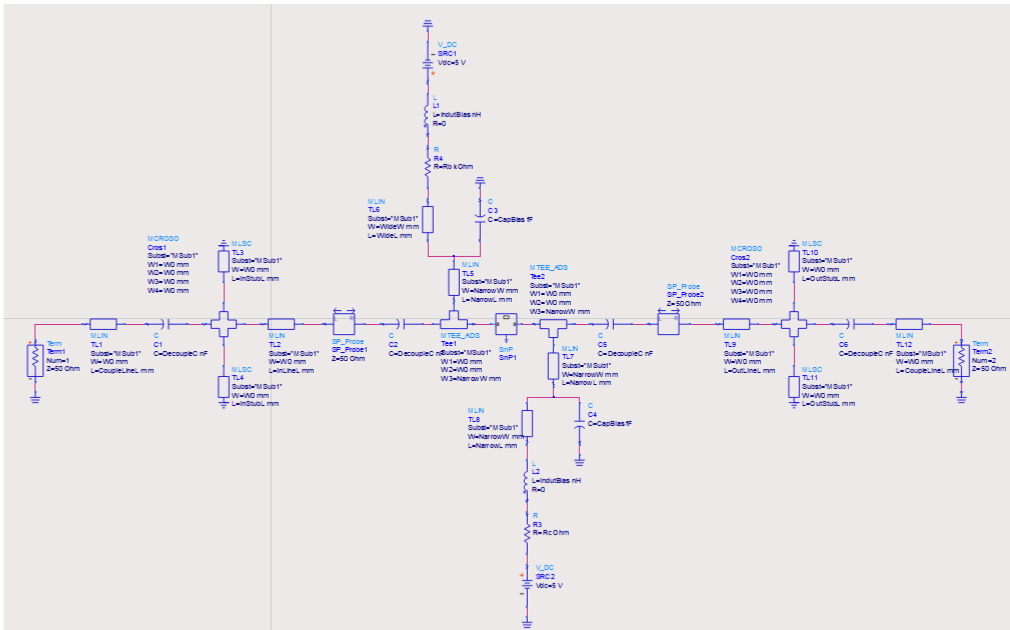

Figure 1: Amplifier realised in ADS.

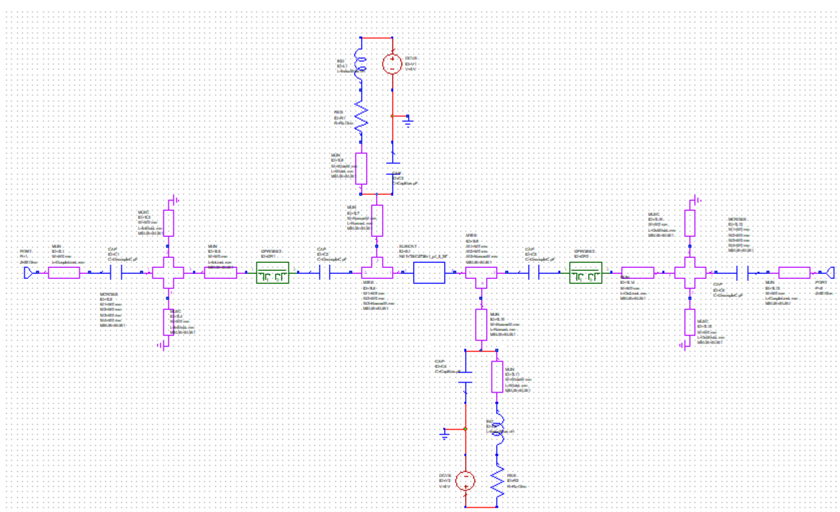

Figure 2: Amplifier realised in AWR.

Contents

1 Requirement Analysis

1.1 Specification

Table 1: Amplifier Specifications

Gain(G_A)	$> 7.4dB$
Gain flatness	$1dB$
Noise Figure (NF)	$\leq 1.8dB$
Frequency	$1.8 - 2.0GHz$
$VSWR_{In}$	$< 2 : 1$
$VSWR_{Out}$	$1.5 : 1$
Input Stability Margin	≥ 0.2
Output Stability Margin	≥ 0.2

1.2 Devices

1.2.1 2SC5736V1P1515

The first device had the following characteristics:

Table 2: Characteristics for the first device

Frequency	NF_{min}	S(2,2)	dBS(2,2)
1.8	1.69	1.90	5.58
1.9	1.76	1.80	5.09
2.0	1.83	1.72	4.69

For further noise figure calculations, frequency of $1.9GHz$ was used. Since the the noise figure was relatively low, this device was used analysed further with G_a and NF circles.

1.2.2 2SC5736V1P1517

The second device had the following characteristics:

Table 3: Characteristics for the second device

Frequency	NF_{min}	S(2,2)	dBS(2,2)
1.8	1.74	2.02	6.10
1.9	1.81	1.91	5.62
2.0	1.87	1.82	5.20

The second device was not tested further since the noise figure at all frequencies of interest was too high.

1.2.3 2SC5736V1P1520

The third device had the following characteristics:

Table 4: Characteristics for the third device

Frequency	NF_{min}	S(2,2)	dBS(2,2)
1.8	2.17	2.22	6.93
1.9	2.24	2.10	6.44
2.0	2.32	2.00	6.02

The third device was not tested further since the noise figure at all frequencies of interest was too high.

1.2.4 2SC5736V1P1525

The forth device had the following characteristics:

Table 5: Characteristics for the forth device

Frequency	NF_{min}	S(2,2)	dBS(2,2)
1.8	1.67	2.04	6.19
1.9	1.74	1.93	5.71
2.0	1.81	1.85	5.34

For further noise figure calculations, frequency of $1.9GHz$ was used. This device was used analysed further with G_a and NF circles since it had the best forward path gain and noise figure at all frequencies of interest.

1.3 First Device Analysis

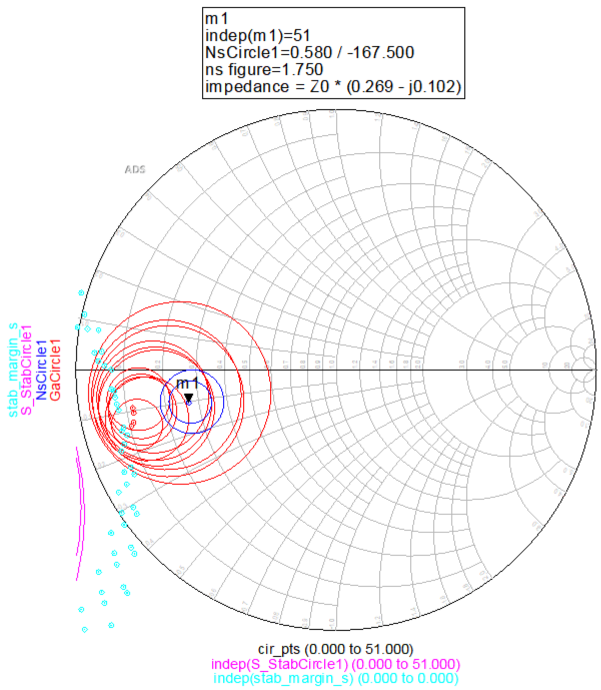

Figure 3: G_a and NF circles for the first device.

First device showed good gain (above $7.5dB$ and relatively low noise when a Γ_S close to the minimum noise figure was chosen). In addition, the values for Γ_L were within the stability region.
The $VSWR_{in}$ could be improved however. $VSWR_{out}$ was very low and within the specification.

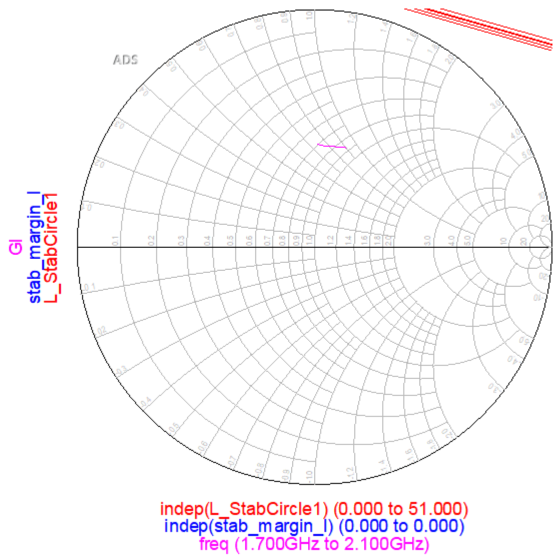

Figure 4: G_L plane for the first device.

freq	VSWRin	VSWRout
1.700 GHz	3.796	1.497
1.800 GHz	3.854	1.484
1.900 GHz	3.914	1.497
2.000 GHz	4.025	1.488
2.100 GHz	4.102	1.519

Figure 5: Table showing the input and output VSWR for the first device.

1.4 Forth Device Analysis

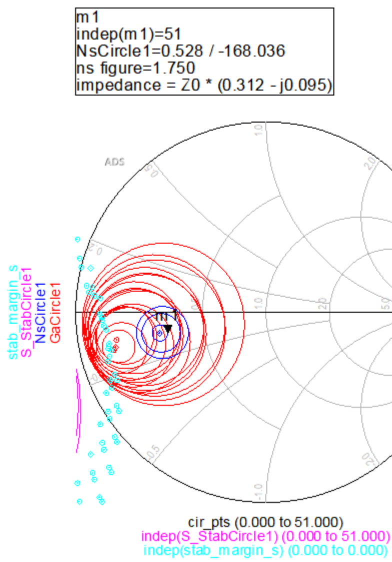

Figure 6: G_a and NF circles for the forth device.

Forth device showed even better gain (above $8.5dB$). The minimum noise figure was also much closer to the maximum gain point, hence allowing to design an amplifier with higher gain and lower noise when compared to the first device. In addition, the values for Γ_L were within the stability region. The $VSWR_{in}$ could be improved however. $VSWR_{out}$ was very low and within the specification. This device was chosen for the final amplifier design.

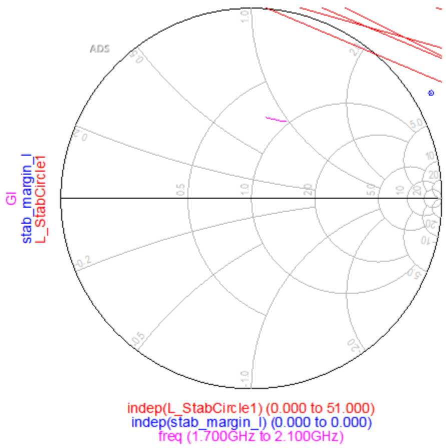

Figure 7: G_L plane for the forth device.

freq	VSWRin	VSWRout
1.700 GHz	3.556	1.587
1.800 GHz	3.598	1.564
1.900 GHz	3.651	1.567
2.000 GHz	3.751	1.551
2.100 GHz	3.819	1.567

Figure 8: Table showing the input and output VSWR for the forth device.

2 Amplifier Design Using Ideal Components

2.1 ADS

2.1.1 Overall Schematic

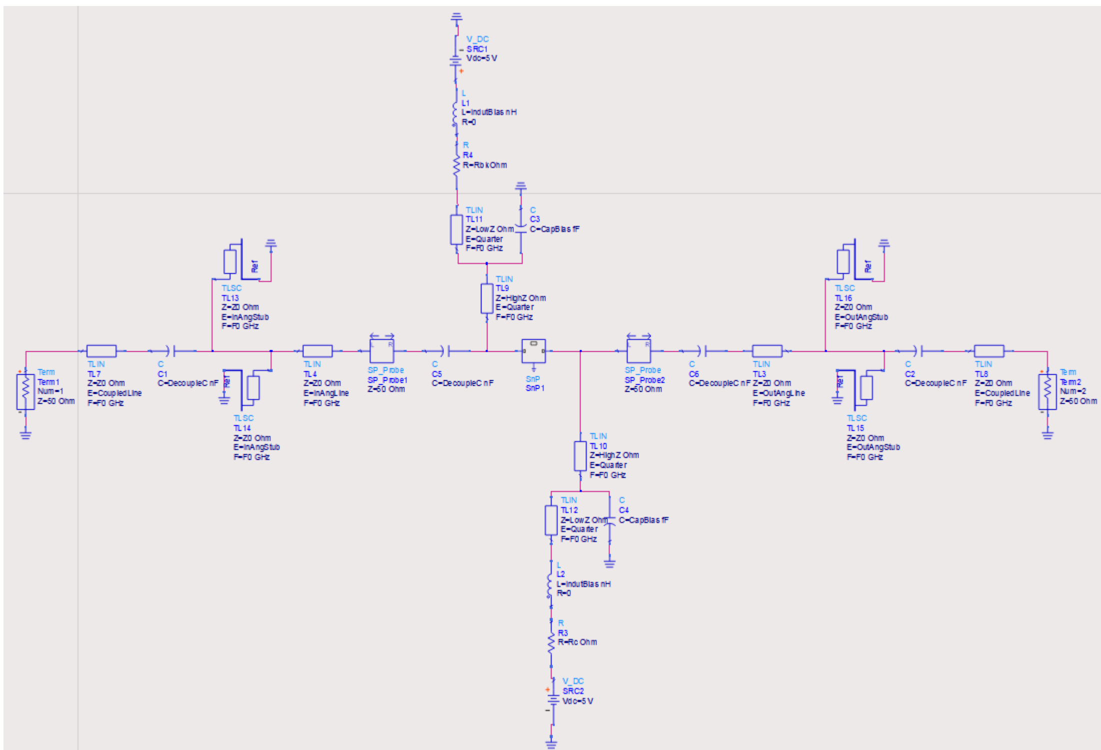

Figure 9: Amplifier designed with ideal components.

2.1.2 Input Matching Network

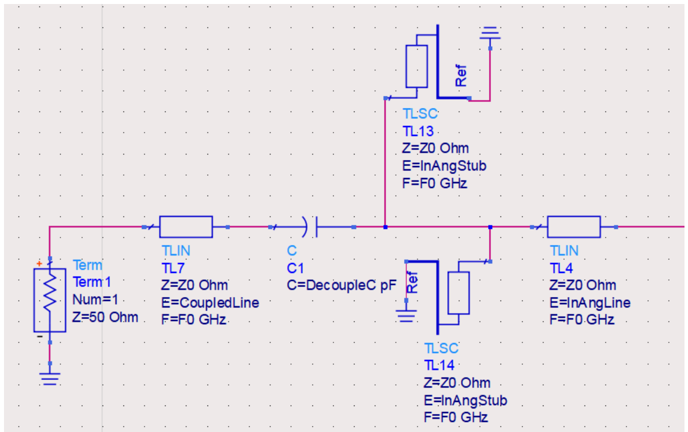

Figure 10: Input matching network.

2.1.3 Output Matching Network

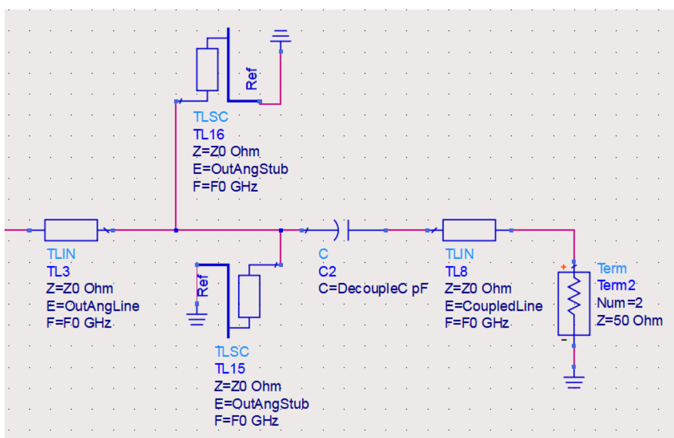

Figure 11: Output matching network.

2.1.4 Base Bias

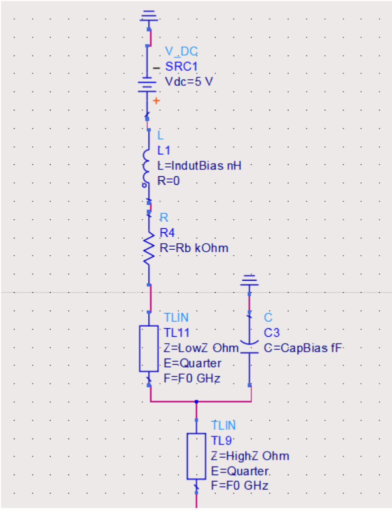

Figure 12: Base bias.

2.1.5 Collector Bias

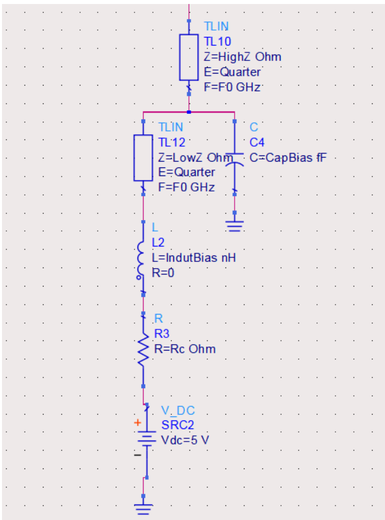

Figure 13: Collector bias.

2.1.6 Parameter Values

All analysis was performed at $1.9GHz$ (assuming that the amplifier will operate mostly around this region).

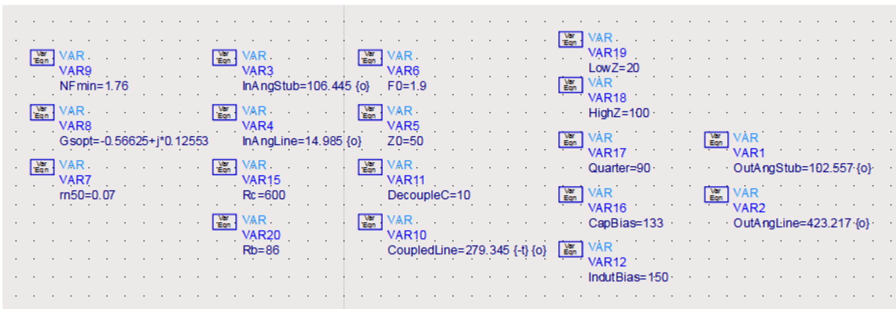

Figure 14: Parameters for the ideal amplifier.

The resistors were calculated using the following equations.

$$R_B = \beta \frac{(V_{CC} - V_{BE})}{I_C} = 86k\Omega \tag{1}$$

$$R_C = \frac{(V_{CC} - V_{CE})}{I_C} = 600\Omega \tag{2}$$

The following parameters were assumed to have the following values in order to calculate R_B and R_C resistors.

Table 6: Transistor Parameters

V_{CC}	V_{BEon}	I_C	β
$5V$	$0.7V$	$5mA$	100

2.2 AWR

The amplifier was designed similarly to ADS.

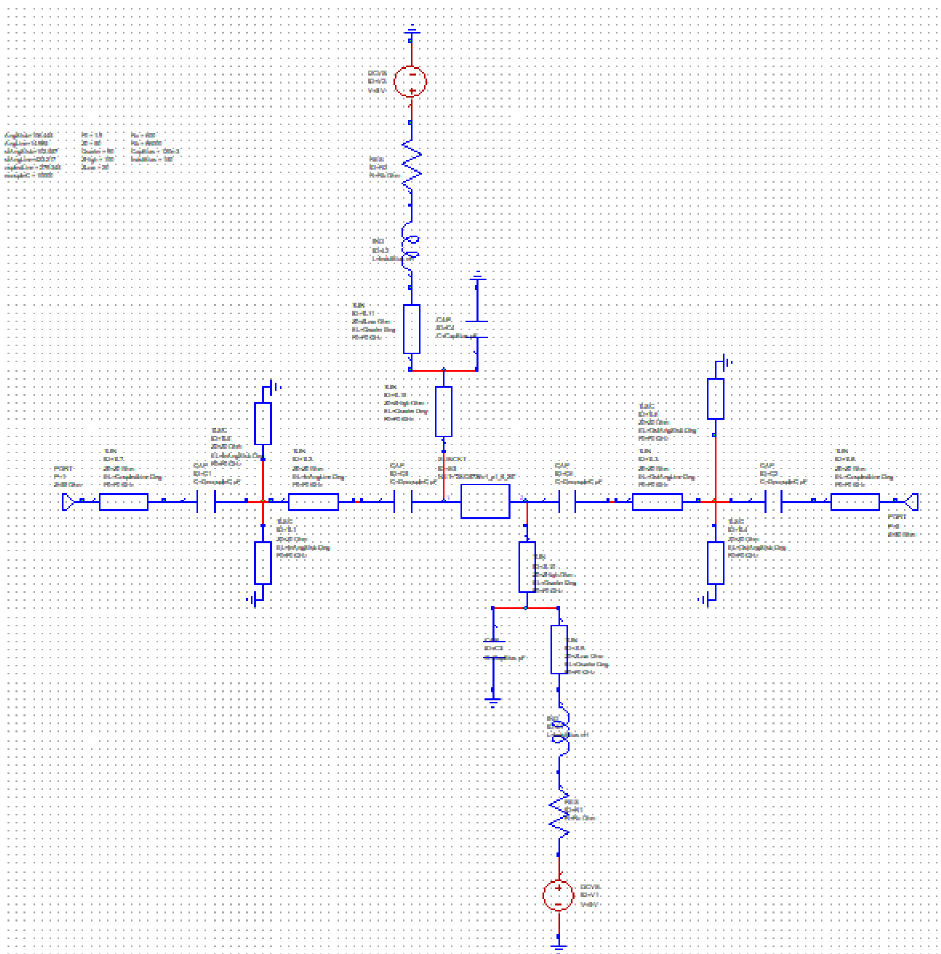

Figure 15: Amplifier designed with ideal components.

2.3 Performance

freq	VSWRin	VSWRout
1.700 GHz	3.261	1.561
1.800 GHz	2.693	1.818
1.900 GHz	2.634	1.705
2.000 GHz	2.620	1.130
2.100 GHz	1.880	2.078

freq	SP_Probe1.L.S(1,1)	SP_Probe2.R.S(1,1)	GA	NF
1.700 GHz	0.091 / -122.061	0.031 / -128.982	14.438	2.134
1.800 GHz	0.188 / -129.240	0.125 / -178.998	13.100	2.045
1.900 GHz	0.283 / -136.419	0.217 / 131.029	12.381	1.962
2.000 GHz	0.375 / -143.599	0.308 / 81.065	13.539	1.887
2.100 GHz	0.464 / -150.778	0.396 / 31.109	14.772	1.823

Figure 16: Amplifier parameter results from ADS.

Optimisation was used to bring the amplifier closer to the specification. In the end, the amplifier's G_A gain was much higher than the specified minimum of $7.4dB$ and the gain flatness was within $1dB$. Unfortunately, both the noise figure and $VWSR_{in}$ were outside the specification, however the $VSWR_{out}$ was within specification for $2.0GHz$.
Similar results were obtained in AWR.

Frequency (GHz)	DB(|S(2,1)|) amp_dev_ideal_25	NF(2,1) amp_dev_ideal_25	Re(Eqn(VSWRout)) Equations	Re(Eqn(VSWRin)) Equations
1.8	6.6257	1.7274	1.8185	2.6925
1.9	6.6522	1.689	1.7053	2.6339
2	7.0493	1.6383	1.1296	2.6201

Figure 17: Amplifier parameter results from AWR.

3 Amplifier Design using Microstrip Line

3.1 Converting Electrical TL to Physical

In order to implement a microstrip line design, the ideal transmission length (in degrees) and characteristic impedance were converted to physical length and width of the microstrip line. The following parameters for the microstrip substrate were used:

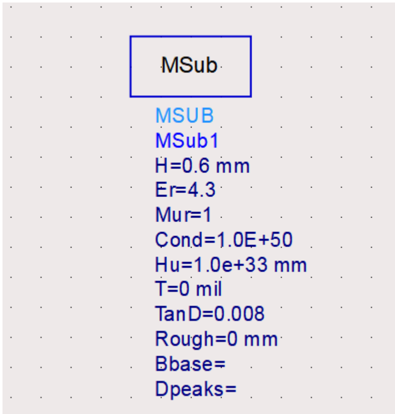

Figure 18: Microstrip substrate parameters in ADS.

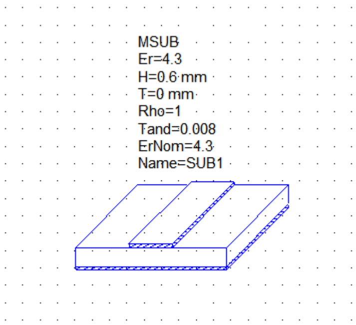

Figure 19: Microstrip substrate parameters in AWR.

The tools LineCalc (ADS) and TXLINE (AWR) were used to convert between electrical and physical dimensions.

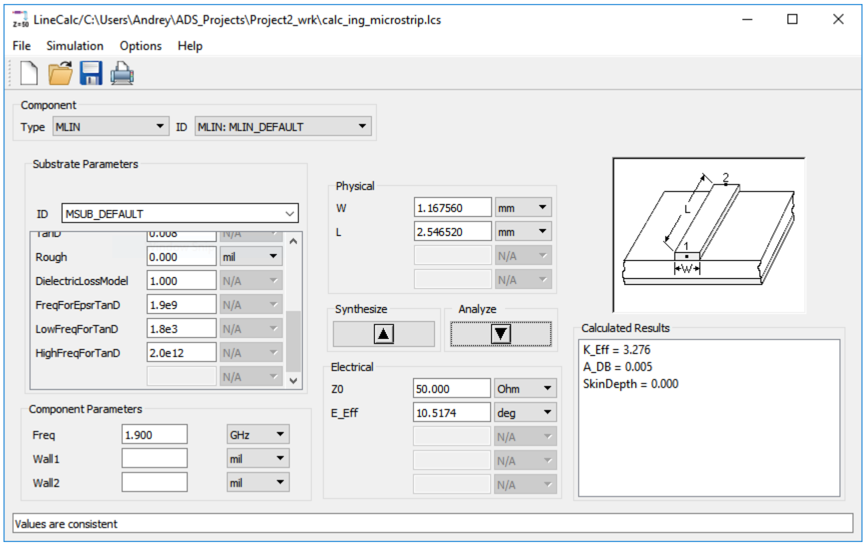

Figure 20: Microstrip line calculator tool in ADS.

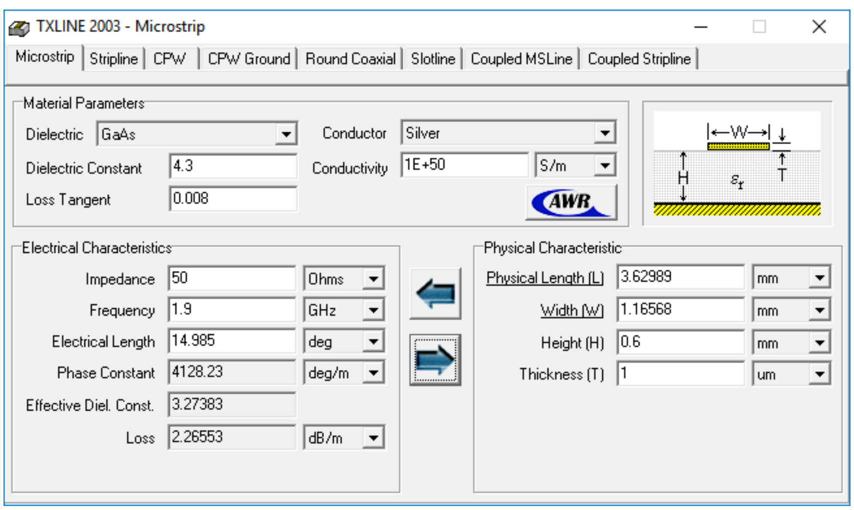

Figure 21: Microstrip line calculator tool in AWR.

3.2 ADS

3.2.1 Overall Schematic

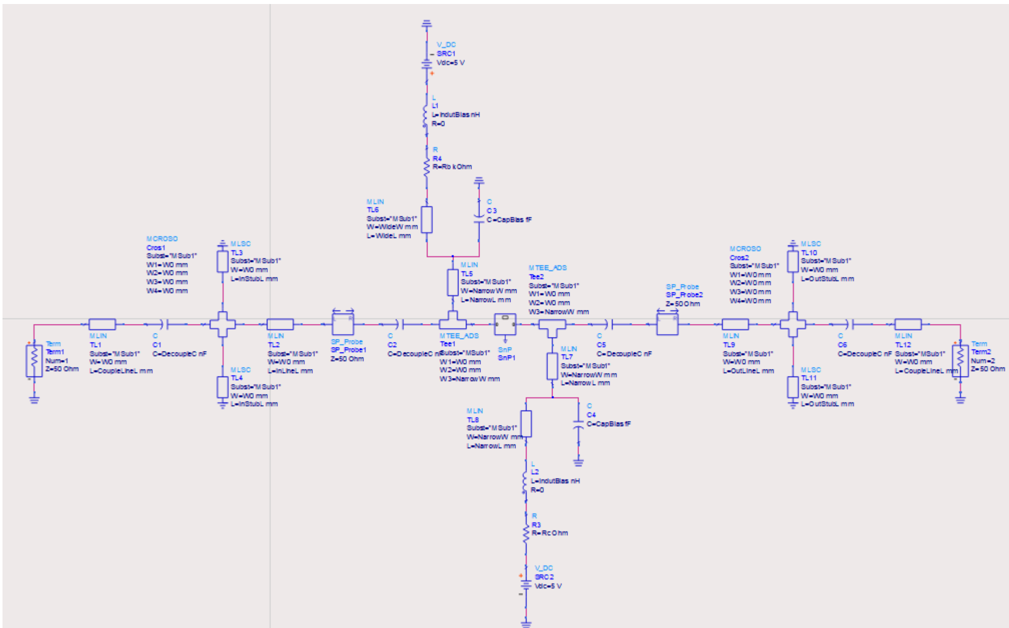

Figure 22: Amplifier designed with microstrip line.

3.2.2 Input Matching Network

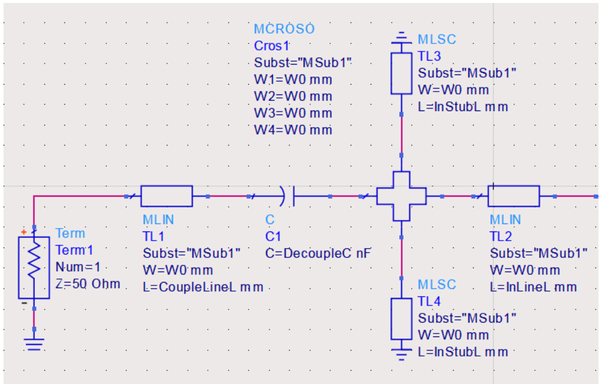

Figure 23: Input matching network.

3.2.3 Output Matching Network

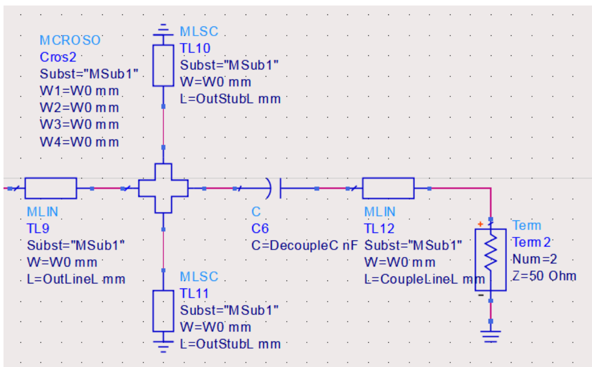

Figure 24: Output matching network.

3.2.4 Base Bias

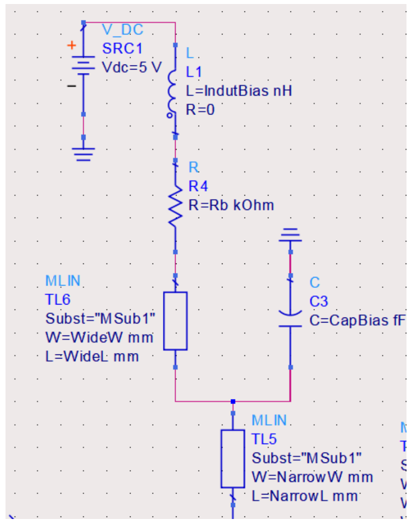

Figure 25: Base bias.

3.2.5 Collector Bias

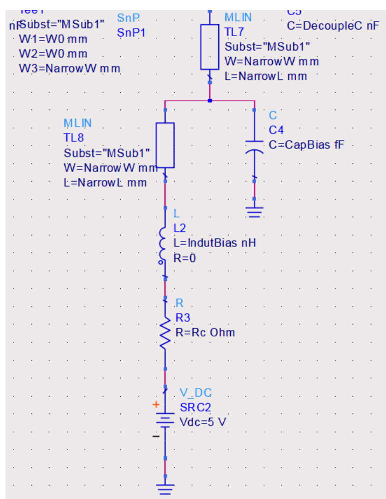

Figure 26: Collector bias.

3.2.6 Parameter Values

All analysis was performed at $1.9GHz$ (assuming that the amplifier will operate mostly around this region).

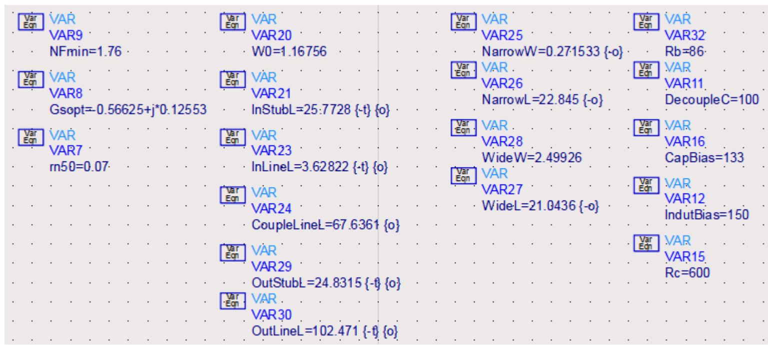

Figure 27: Parameters for the ideal amplifier.

The bias inductors and capacitors were calculated using the following equations.

$$L = \frac{X_L}{\omega} = \frac{1000}{2\pi * 1.9e^9} = 83.8nH \approx 150nH$$
$$C = \frac{1}{\omega X_C} = \frac{1}{2\pi * 1.9e^9 * 1000} = 83.8fF \approx 133fF$$

Since exact values were not important, the values from the previous project were taken and multiplied by ten.

3.3 AWR

The amplifier was designed similarly to ADS.

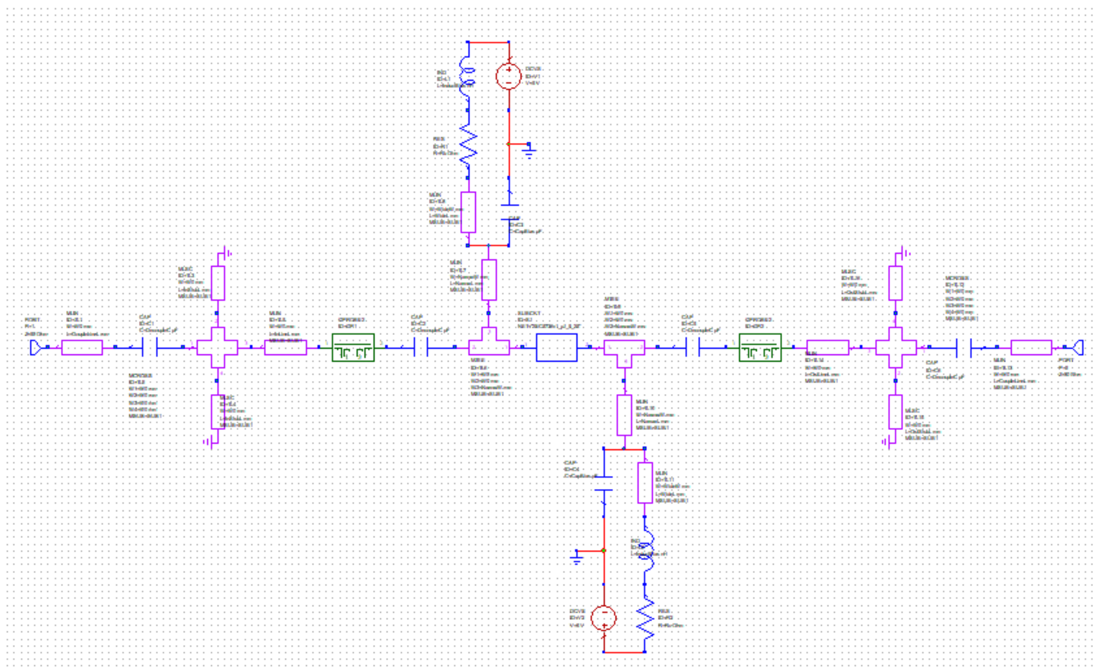

Figure 28: Amplifier designed with microstrip line.

3.4 Performance

freq	VSWRin	VSWRout
1.700 GHz	3.395	1.300
1.800 GHz	2.751	1.575
1.900 GHz	2.530	1.523
2.000 GHz	2.381	1.058
2.100 GHz	1.767	2.051

freq	...Probe1.L.S(1,1)	...Probe2.R.S(1,1)	GA	NF
1.700 GHz	0.059 / -130.078	0.007 / 125.853	13.245	2.154
1.800 GHz	0.152 / -132.897	0.086 / 176.076	11.854	2.061
1.900 GHz	0.245 / -139.093	0.174 / 128.730	11.047	1.974
2.000 GHz	0.335 / -145.895	0.258 / 79.819	11.843	1.895
2.100 GHz	0.422 / -152.893	0.338 / 30.405	11.409	1.828

Figure 29: Amplifier parameter results from ADS.

Optimisation was used to bring the amplifier closer to the specification. In the end, the amplifier's G_A gain was much higher than the specified minimum of $7.4dB$ and the gain flatness was within $1dB$. Unfortunately, both the noise figure and $VWSR_{in}$ were outside the specification, however the $VSWR_{out}$ was close to the specification for all frequencies.
Similar results were obtained in AWR.

Frequency (GHz)	DB(|S(2,1)|) amp_dev_real_25	NF(2,1) amp_dev_real_25	Re(Eqn(VSWRout... Equations	Re(Eqn(VSWRinR... Equations
1.8	5.7641	1.9081	1.6128	2.9369
1.9	5.6447	1.898	1.4773	2.7009
2	5.4178	1.8666	1.7249	2.2405

Figure 30: Amplifier parameter results from AWR.

4 Conclusion

As expected, replacing the transmission lines and shorts stubs with microstrip lines had caused a reduction in both the gain, noise figure and VSWR characteristics. In addition, the bias networks and decoupling capacitors had also introduced additional mismatch and loss (since RF signal had two additional paths to flow to).
Meeting the specification with the proposed design was not possible. Most of the spec has been met however. The gain was above $7.4dB$ and had a flatness of less than $1dB$. The output VSWR was very close to the required $1.5dB$ for low frequencies and was lower for higher frequencies. The input VSWR was bigger than $2dB$ by at minimum $0.4dB$ and the noise figure, though close, was about $0.15dB$ higher then the required $1.8dB$. The $VSWR_{Out}$, G_A and gain flatness were prioritised over the other parameters and hence the $VSWR_{In}$ and NF characteristics were not met.