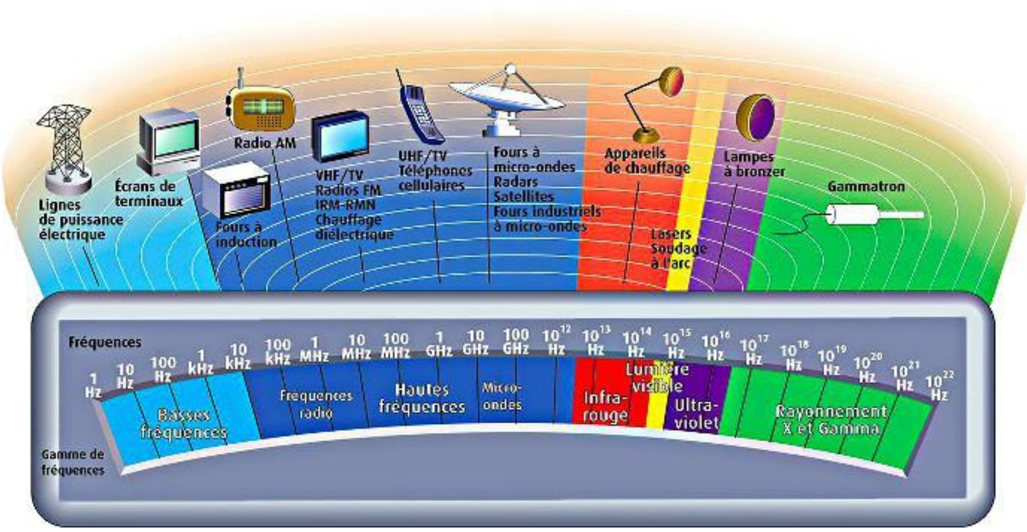
Introduction

In the modern telecommunications context, radio frequency (RF) and microwave devices play a fundamental role, covering an increasingly wide range of applications, from mobile telephony to radar and satellite communications systems. With the growing demand for integration and the increasing complexity of circuit architectures, precision and design efficiency are becoming critical to minimize manufacturing costs and lead times.

Computer-aided design tools (CAD) are essential for this purpose. Among them, the Advanced Design System (ADS) software from Agilent Technologies is a must-have reference. This software offers a complete suite of simulations and models to optimize the performance of RF and microwave electronic circuits before their manufacture.

This report is part of the RF Electronics Education, which aims to provide a thorough understanding of RF circuit design and modeling using ADS software. It covers the different stages of computer-aided design, from the analysis and optimization of linear and non-linear circuits to the precise modelling of components and the drawing of masks necessary for the manufacture of circuits.



In addition, this report presents a detailed practical study of an RF amplifier using a bipolar NPN transistor to illustrate theoretical and methodological concepts. The steps of modelling, stability analysis, impedance adaptation and determination of critical frequencies (fT and fmax) are discussed in detail, demonstrating the effectiveness and robustness of the techniques taught. Through this report, we will highlight the importance of simulation and optimization in RF circuit design, Highlighting the benefits of ADS software to ensure optimal and reliable performance of electronic devices in high-tech applications.

Objective of the study

The objective is to model an RF amplifier using a bipolar NPN transistor, specifically the BJTM1 model. This process involves the selection, modeling and parameterization of this transistor to evaluate its performance in an RF application.

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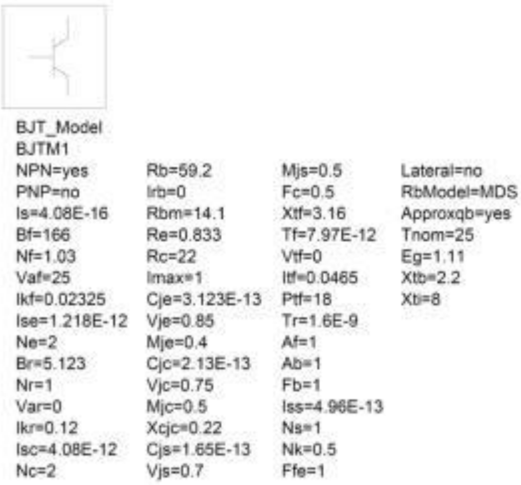
The NPN bipolar transistor has three electrodes: base (B), collector (C) and transmitter (E). Its operation is based on the control of the current between the collector and the transmitter by the current of the base. It works mainly in three modes:

1. **Active mode** : The base-emitter junction is polarized in direct and the base-collector junction in reverse. The collector current (IC) is proportional to the base current (IB) multiplied by the current gain (β), used for amplification.
2. **Saturation Zone: The two junctions are live polarized, and the transistor works as a closed switch.**
3. **Cut-off Zone** : The two junctions are polarised inversely, and the transistor acts as an open switch.

For modeling, the BJTM1 model in ADS is selected and the model parameters are configured to meet the required specifications. The characteristics of the transistor to be chosen are as follows.



BJT_Model
BJTM1

NPN=yes	Rb=59.2	Mjs=0.5	Lateral=no
PNP=no	Irb=0	Fc=0.5	RbModel=MDS
Is=4.08E-16	Rbm=14.1	Xtf=3.16	Approxqb=yes
Bf=166	Re=0.833	Tf=7.97E-12	Tnom=25
Nf=1.03	Rc=22	Vtf=0	Eg=1.11
Vaf=25	Imax=1	Itf=0.0465	Xtb=2.2
Ikf=0.02325	Cje=3.123E-13	Ptf=18	Xti=8
Ise=1.218E-12	Vje=0.85	Tr=1.6E-9	
Ne=2	Mje=0.4	Af=1	
Br=5.123	Cjc=2.13E-13	Ab=1	
Nr=1	Vjc=0.75	Fb=1	
Var=0	Mjc=0.5	Iss=4.96E-13	
Ikr=0.12	Xcjc=0.22	Ns=1	
Isc=4.08E-12	Cjs=1.65E-13	Nk=0.5	
Nc=2	Vjs=0.7	Ffe=1	

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Determination of the optimum transistor bias point

To choose the bias current I plotted the gain according to the base current and the collector current according to the voltage between collector and transmitter The simulation which gave me the results shown below.

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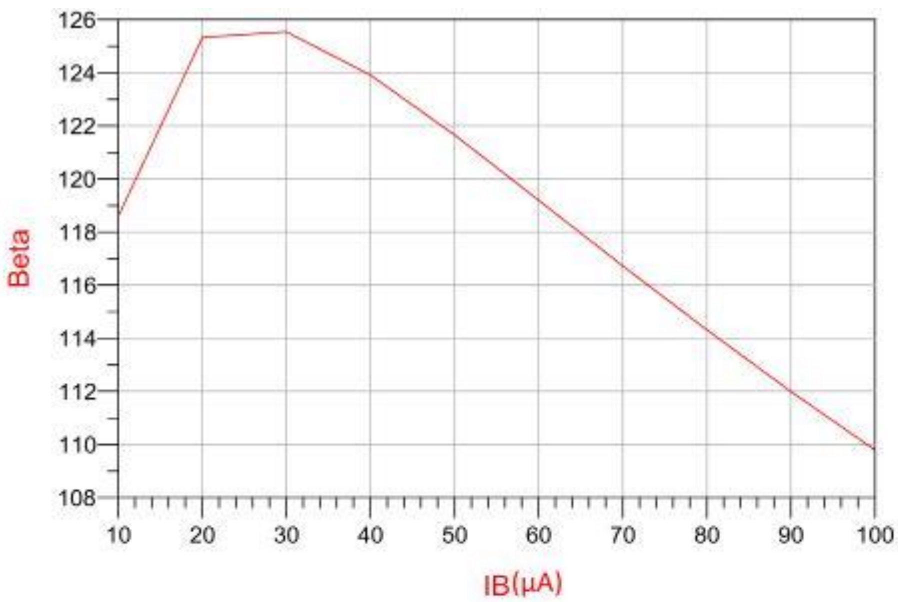
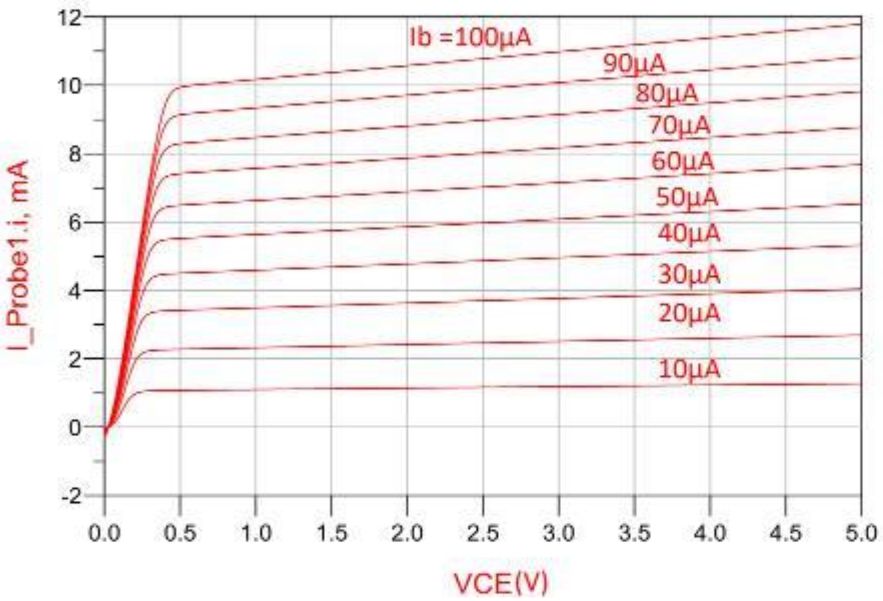




According to these simulations, the maximum gain is found for a base current between 20 and 30 µA. In addition, a lower base current results in a less pronounced bias current slope as a function of VCE, which ensures good linearity. The design principles of an amplifier in class A state that the higher the polarization current, the more powerful the amplifier.

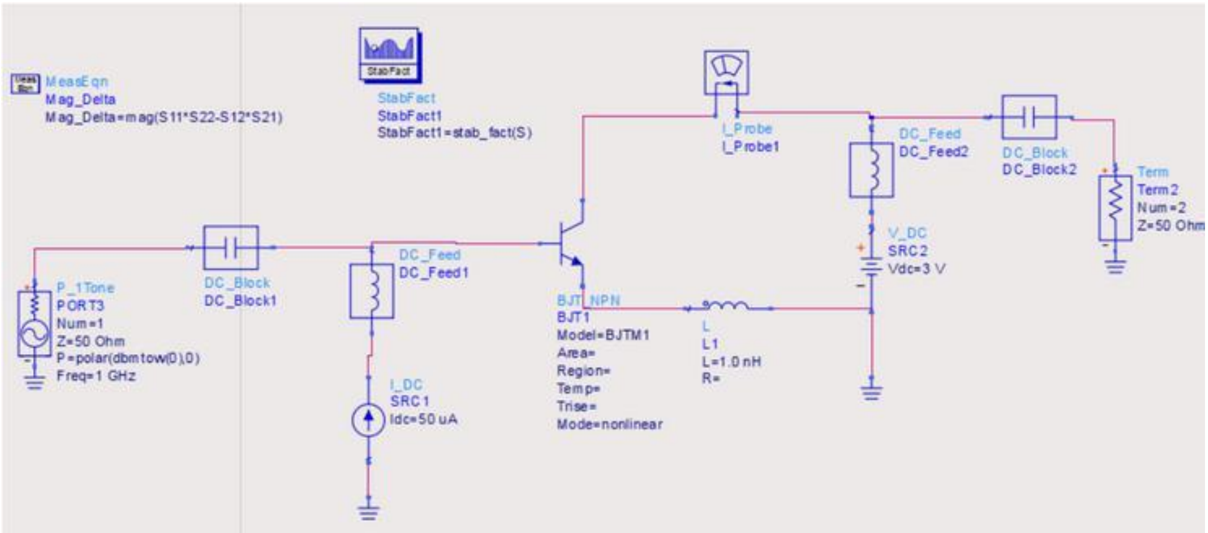
To design a versatile amplifier, I opted for a polarization current of 50 µA under a voltage of 3V.

Small signals study

Study of stability

The rollet factor is used, as well as Δ.

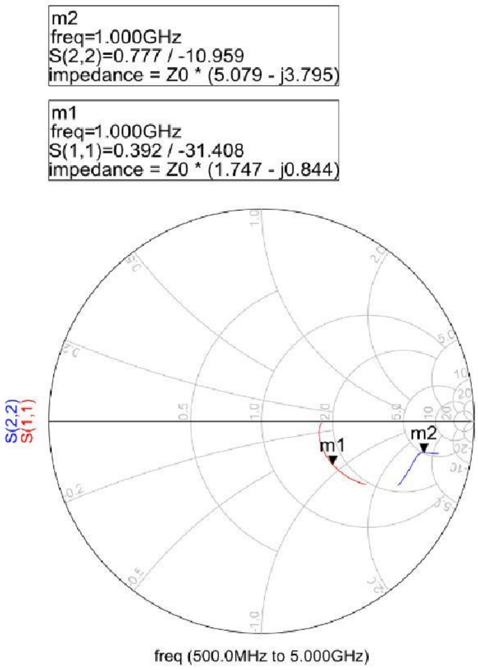
With a polarization current of 50µA the amplifier is not unconditionally stable the factor of Rollet k = 1.004 is certainly >1 but very close to 1.
Stabilization requires the addition of a stabilizing coil, which will have the role of a counter-reaction. It will indeed, drop the VCE as soon as Ic increases. The following figure shows the final scheme chosen.

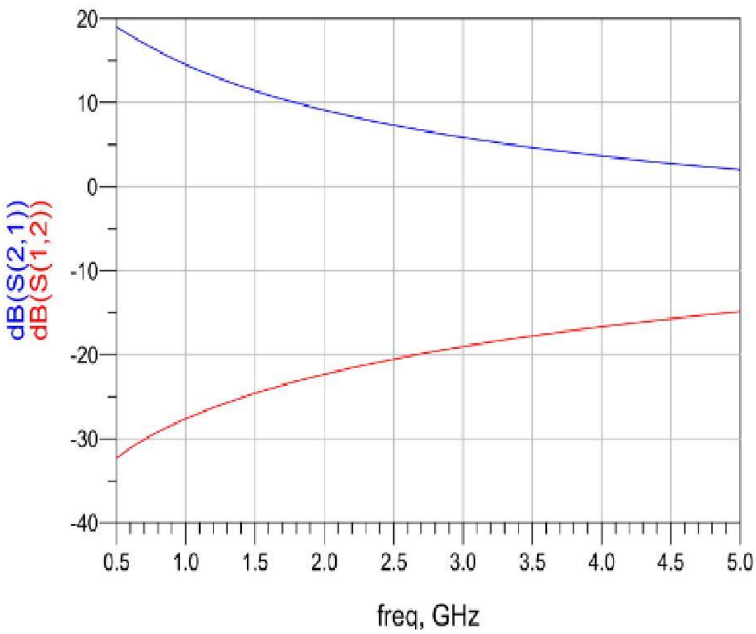


The value of the inductande L = 1nH allowed us to have a rollet factor k = 1.041, and a Δ = 0.498.

Study of S parameters

Now that the assembly is stable, it can be adapted thanks to its non linear behaviour. The figure below shows the S parameters before adaptation.



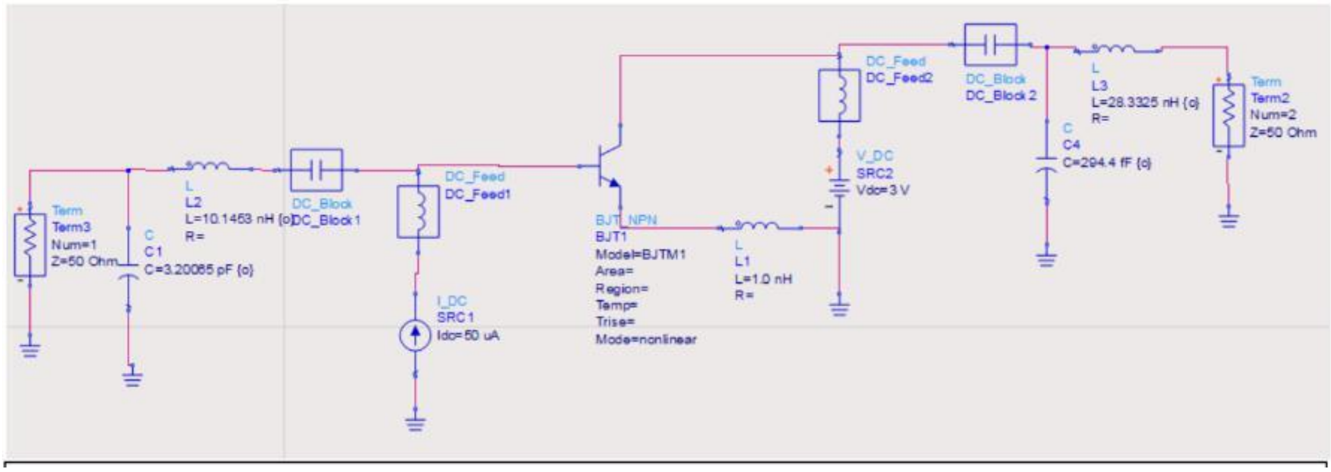


I see that the inputs and outputs need to be adapted. Indeed, the reflection coefficient exceeds 0.22 (corresponding to 5% of losses), and there is a strong capacitive component due to the semiconductor.

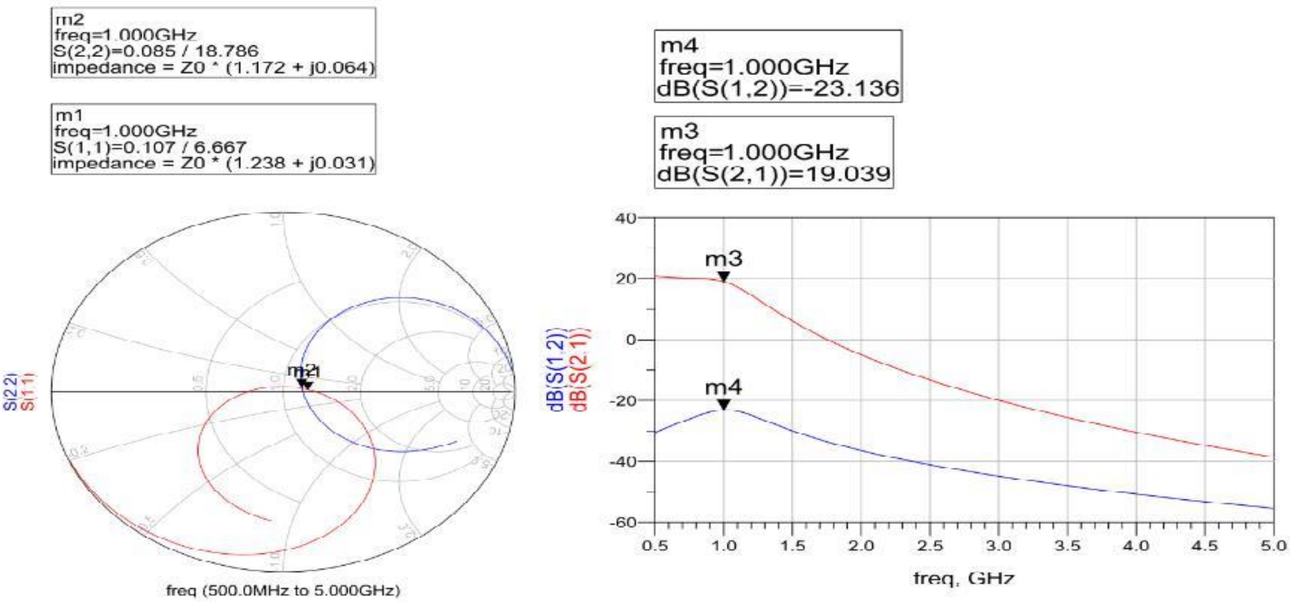
The gain at 1 GHz is slightly low, but it can be increased to about 20 dB with an appropriate adaptation. In addition, the amplifier is not unilateral, because the S12 is above -40 dB. This means that a significant amount of the power reflected at the output may reappear at the input, which may distort the signal. This aspect must be taken into account in the case of a PA driver or an LNA.

Adaptation

To adapt the impedances I placed on both sides of the amp L-circuits composed of an inductance and a capacitor. The value of these components to enable a correct impedance adaptation must now be determined. To do this, I implement an optimization with the following parameters:
S11 : -20dB maximum
S22: -20dB maximum
S21: 15dB minimum
Optimization method: Gradient



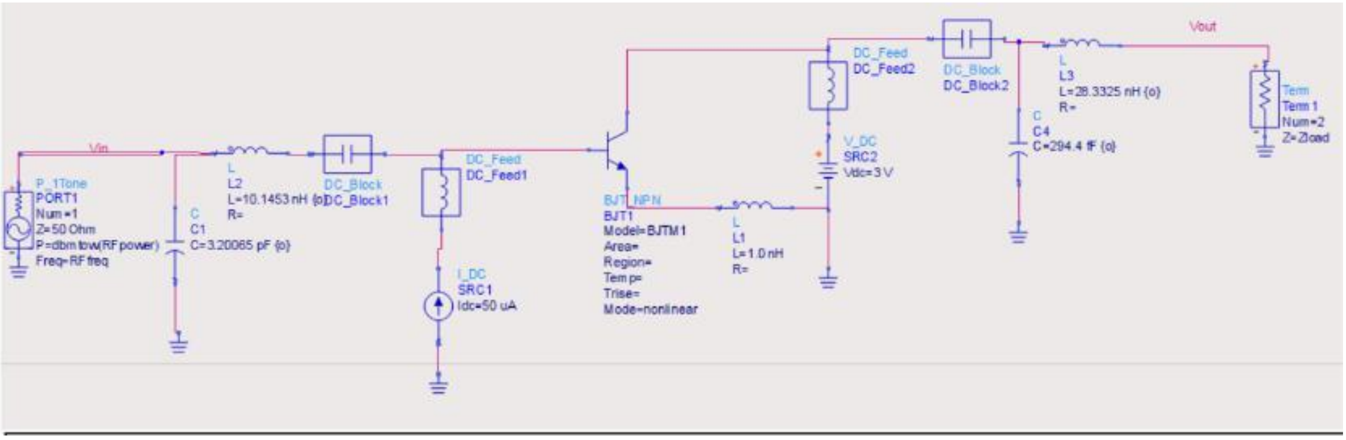
We get the values of the adaptation cells present in the figure above. The new S parameters are as follows.



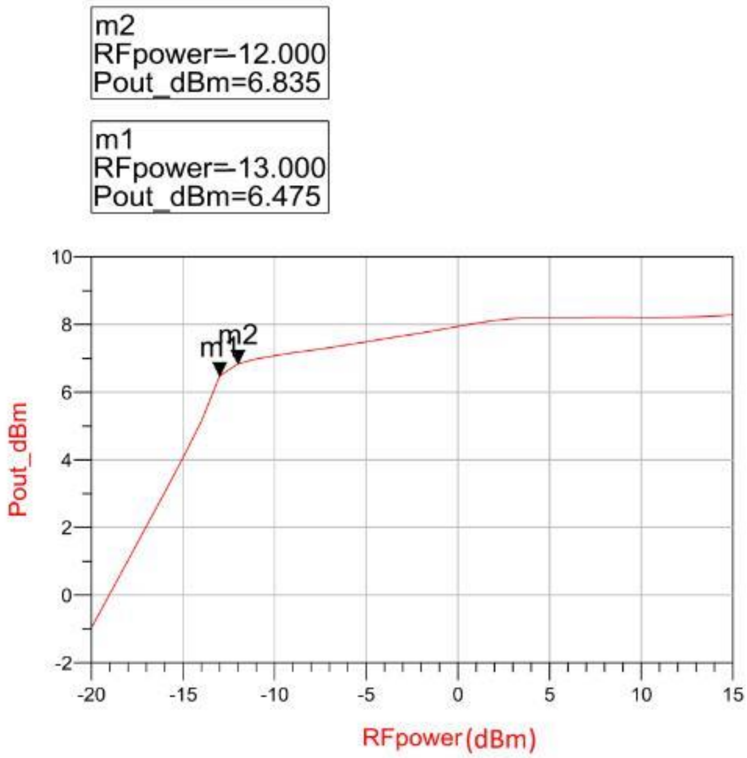
It is important to note that this adaptation has an influence on the stability however the transistor remains unconditionally stable.

Study of strong signals

The strong signal is studied to study compression at 1dB. The simulation scheme is as follows.



Ps is plotted against Pe.

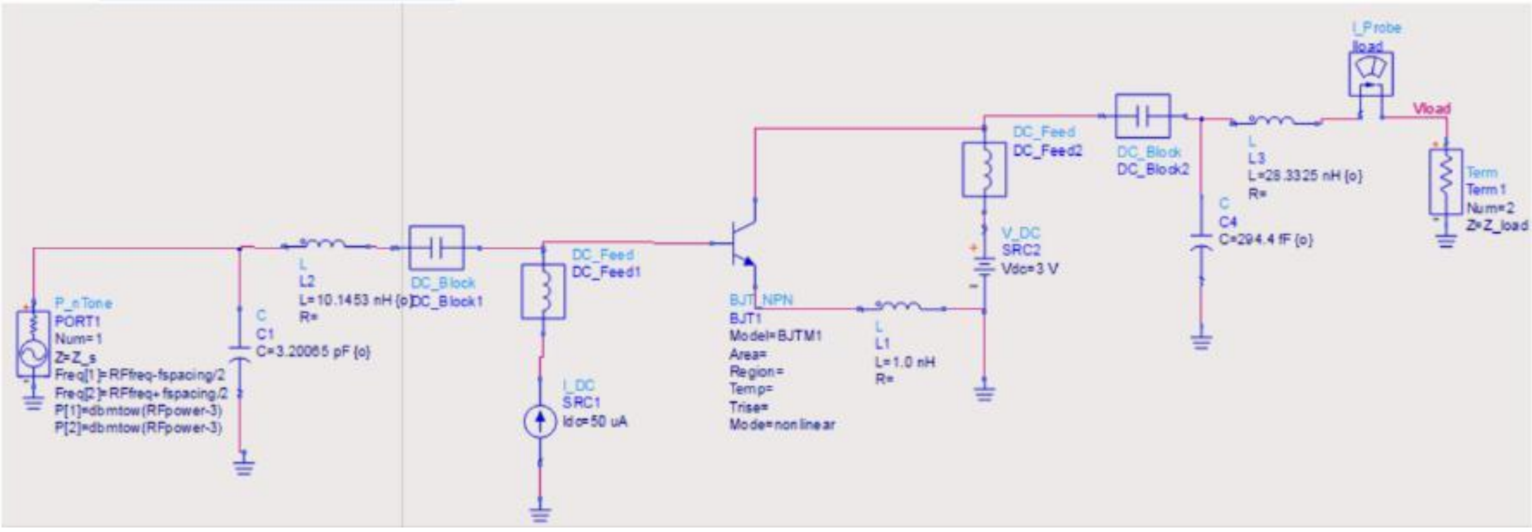


I conclude that the compression point at 1dB is -12dBm.

Two-tone study

Another way to qualify the linearity of an amplifier is to measure its third order intercept point. I chose to apply an input power of -20dBm and two100 kHz spaced tones with an average of 1 GHz. The diagram and simulation are as follows.

ADS Project



The simulation shows -1.57dBm in IIP3.

Conclusion

This project has helped me to better understand the course concepts. The ADS software experience during the TDs was very helpful in helping me to complete this project. I also think it is a skill that can be good to promote in the labour market.