Chalmers University of Technology

EME102: Active Microwave Circuits

Home Assignment

Transistor Modelling - Part I

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January 27, 2017

Contents

List of Figures

1 Abstract

To determine the parasitic resistances and inductances based on the forward bias method proposed in Dambrine[1] along with the parasitic capacitances using the forward pinch method proposed in Gao[2]. The setup used is illustrated in the following diagram:

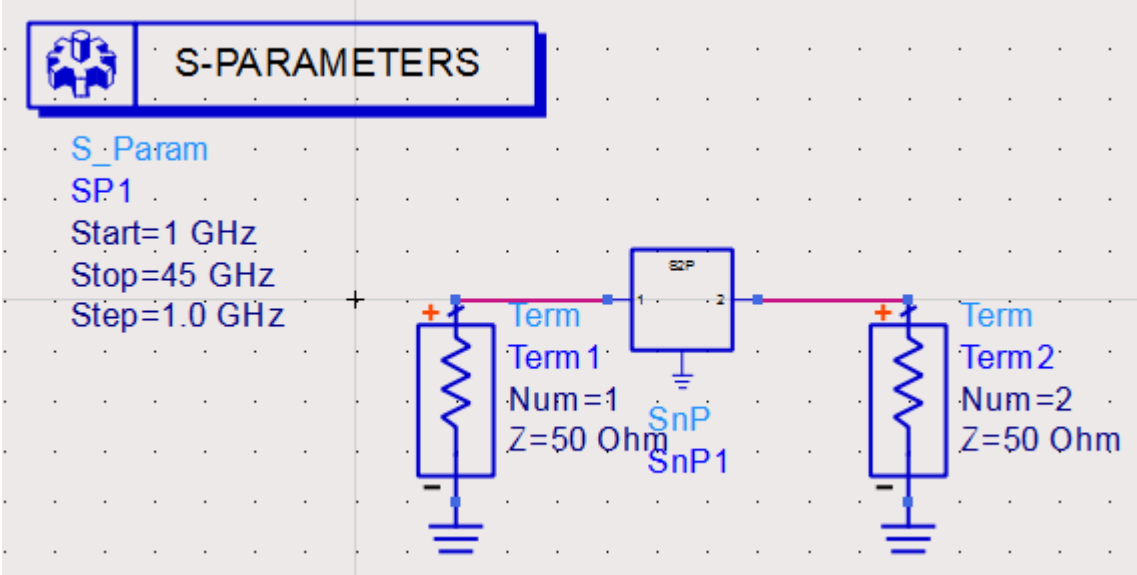


Figure 1: Experimental setup

The inductance and resistance values were determined from Dabrine's paper, particularly equations 15, 16 and 17. Since in equation 15 a term appears that depends on a few parameters, the following assumptions were made: $n = 2$ (ideality factor of 2, since it is assumed a non-ideal device, $T = 25$ degrees calculus (converted into Kelvin), $I_g = 0.1$ from the file "Cold_FET_forward_bias.s2p". R_c was given to be 0.35 Ω.

The capacitances were calculated from Gao's paper, equations 1-6 with width of 1mm.

2 Plots

Below is the diagram for Z parameters of the transistor in state "Cold FET forward bias".

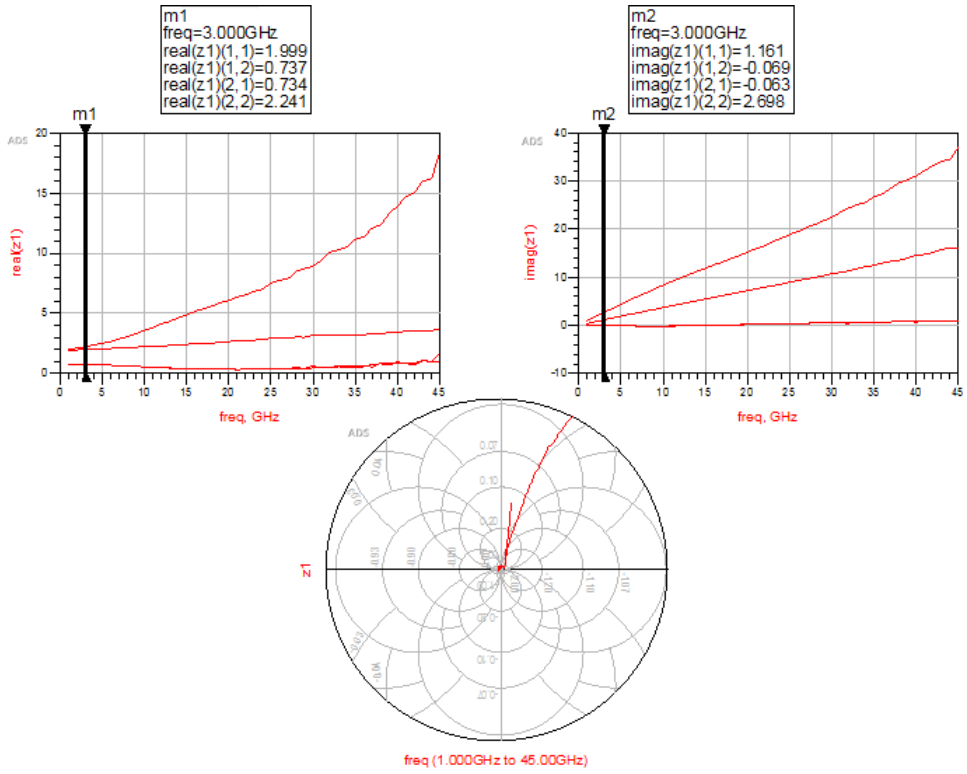


Figure 2: Z parameters - Cold FET forward bias

The diagram for the Y parameters used for determining the capacitances is as follows:

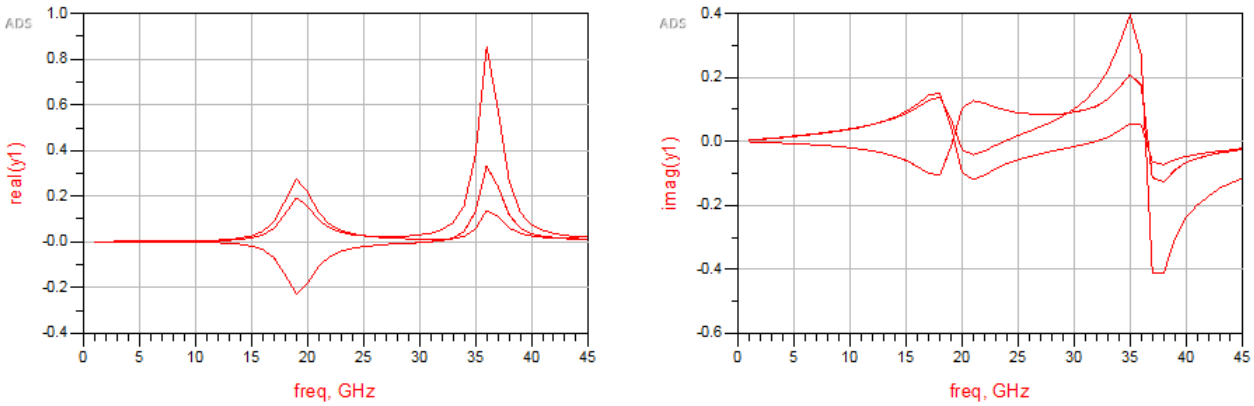
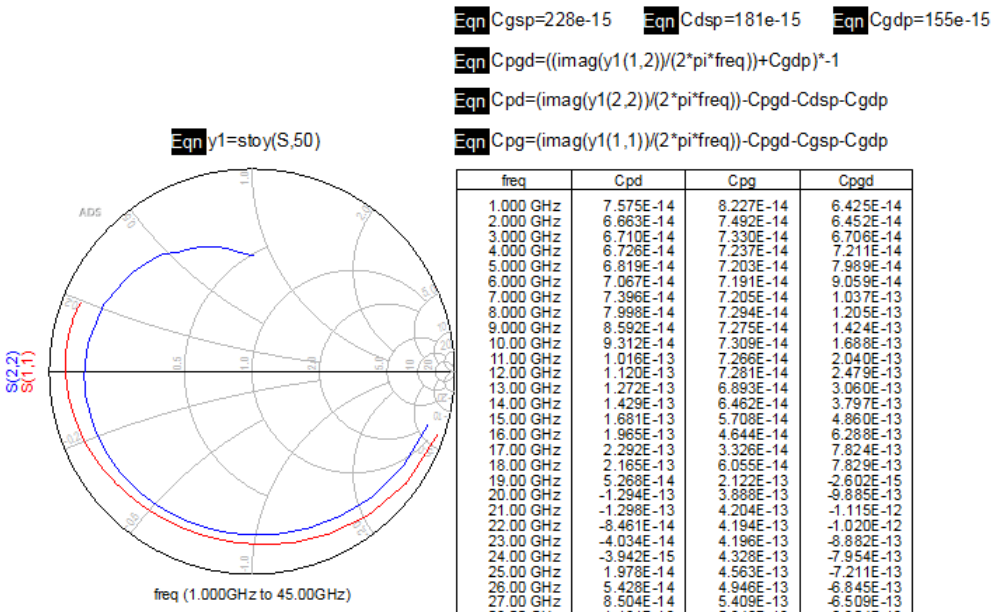


Figure 3: Y parameters - Cold FET pinchoff bias

The following figure shows the values of capacitances for a frequency sweep along with the equations:



freq	Cpd	Cpg	Cpgd
1.000 GHz	7.575E-14	8.227E-14	6.425E-14
2.000 GHz	6.663E-14	7.492E-14	6.452E-14
3.000 GHz	6.710E-14	7.330E-14	6.706E-14
4.000 GHz	6.726E-14	7.237E-14	7.211E-14
5.000 GHz	6.819E-14	7.203E-14	7.989E-14
6.000 GHz	7.067E-14	7.191E-14	9.059E-14
7.000 GHz	7.396E-14	7.205E-14	1.037E-13
8.000 GHz	7.998E-14	7.294E-14	1.205E-13
9.000 GHz	8.592E-14	7.275E-14	1.424E-13
10.00 GHz	9.312E-14	7.309E-14	1.688E-13
11.00 GHz	1.016E-13	7.266E-14	2.040E-13
12.00 GHz	1.120E-13	7.281E-14	2.479E-13
13.00 GHz	1.272E-13	6.893E-14	3.060E-13
14.00 GHz	1.429E-13	6.462E-14	3.797E-13
15.00 GHz	1.681E-13	5.708E-14	4.860E-13
16.00 GHz	1.965E-13	4.644E-14	6.288E-13
17.00 GHz	2.292E-13	3.326E-14	7.824E-13
18.00 GHz	2.165E-13	6.055E-14	7.829E-13
19.00 GHz	5.268E-14	2.122E-13	-2.602E-15
20.00 GHz	-1.294E-13	3.888E-13	-9.885E-13
21.00 GHz	-1.298E-13	4.204E-13	-1.115E-12
22.00 GHz	-8.461E-14	4.194E-13	-1.020E-12
23.00 GHz	-4.034E-14	4.196E-13	-8.882E-13
24.00 GHz	-3.942E-15	4.328E-13	-7.954E-13
25.00 GHz	1.978E-14	4.563E-13	-7.211E-13
26.00 GHz	5.428E-14	4.946E-13	-6.845E-13
27.00 GHz	8.504E-14	5.409E-13	-6.509E-13
28.00 GHz	1.181E-13	5.946E-13	-6.324E-13
29.00 GHz	1.599E-13	6.787E-13	-6.275E-13
30.00 GHz	2.202E-13	7.916E-13	-6.425E-13

Figure 4: Capacitances at different frequencies

3 Discrepancies

When we were deriving the expressions for the inductances, we found one of the inductors to be negative. This implies that, at that frequency the inductor is acting as a capacitor. Possible deviation from the expected model might arise from the S_{12} parameter. As the authors of the article state on bottom of page 8 (in the PDF) the biggest difference from the measured S parameters and the modelled S parameters occurred in S_{12}.

4 Extrinsic Parameters

The extrinsic parameters at 3 GHz are as follows:

freq	Ld	Lg	Ls	Rd	Rg	Rs
3.000 GHz	1.468E-10	6.525E-11	-3.654E-12	1.329	0.806	0.562

Figure 5: Table of parasitic inductances and resistances at 3 GHz

freq	Cpd	Cpg	Cpgd
3.000 GHz	6.710E-14	7.330E-14	6.706E-14

Figure 6: Table of parasitic capacitances at 3 GHz

5 References

[1] Dambrine, Gilles, et al. "A new method for determining the FET small-signal equivalent circuit." IEEE Transactions on microwave theory and techniques 36.7 (1988): 1151-1159.

[2] Gao, Jianjun, et al. "A new method for determination of parasitic capacitances for PHEMTs." Semiconductor science and technology 20.6 (2005): 586.