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C band HBT Low Noise Amplifier for active functions at microwaves

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Abstract - *This paper discusses the use of differential structures for active functions at microwaves. Starting from the example of a single-ended LNA structure, we show the advantages of using a differential approach with the design examples of a LNA structure. The LNA was designed in the BiCMOS HBT process. ADS2010 was simulated to obtain the preliminary results.*

I. INTRODUCTION

Using Silicon technology has been restricted to low frequency digital and analogue applications during the last three decades. Particularly within the last decade, Silicon-based ICs have resulted in an increasing of importance for RF applications [1], because of the great advances Silicon, and Silicon-Germanium technologies own. The amount of articles reporting the use of SiGe technology in RFIC designing has shown a significant. Si/SiGe technology, as compared to GaAs, is noticeably advantageous, owing to its capability to reach more compact and cost-effective circuits. Despite these advantages however, designers need to be aware of some new constraints surrounding microwaves. The first major problem occurs when working with CAD tools. Because silicon technology is classically used in digital and analogue applications at low frequencies, component libraries are mostly developed in the field of CAD software using the same approach, as a natural trend. The philosophy behind designing these circuits is very different from the one behind designing classical microwave analogue circuits. Consequently, some components such as inductors are not accessible, for they were not classically used at low frequencies. For some processes the same is also true for varactor diodes. Currently, some component models are still not parameterized, hence making any optimization hard. Due to technological reasons, the ground plane of a circuit on silicon is placed on the top of the substrate. Therefore, considering microstrip lines as a serious option is not possible, even though recent studies have revealed the feasibility of transmission lines in polymers such as BCB, enabling performances close to those achieved with GaAs [1], [2]. Regarding the design, another problem may emerge from the specific conductivity of the doped Silicon (SiGe) substrate and its bad isolation, which results in a significant increase in the number of parasitic capacitances.

These capacitances are not able to be neglected, concerning the other capacitances of the circuits. The leakage currents also need to be paid a particular attention, due to the specific conductivity of the substrate. In order for this problem to be solved, many manufacturers employ guard rings. These rings are buried layers which surround the component, totally or in part, so that it is protected by acting as PN junction biased in inverse. All these protection processes obviously allow a more compact implementation, as compared to GaAs, which can be regarded as a positive point. It should be mentioned that, in designing circuits using bipolar transistors, the designer needs to be familiar with particular biasing methods and topologies, and this complicates the design procedure obviously. The SiGe BiCMOS HBT is a promising solution for designing active function at microwaves, from among all the other Si/SiGe processes. BiCMOS HBT is the title assigned to heterojunction bipolar transistor, for which the base is doped with Germanium. The designed chips work much faster by applying this reliable and stable process. Moreover, this technology enjoys the integration capability of CMOS process, which again, results in more compactness [4]-[7].

II. LNA SINGLE-STAGE DESIGN

Designing equations are the same as for the single stage LNA design which are summarized as:

$$R_{in}=R_g+\frac{L_s\cdot g_m}{C_{gs}}+j\left(\omega L_s-\frac{1}{\omega C_{gs}}\right) \qquad (1)$$

Can be restated as

$$R_{in}=R_g+R_a+j[X_{Ls}-X_{Cgs}] \qquad (2)$$

Where

$$R_a=\frac{L_s\cdot g_m}{C_{gs}} \qquad (3)$$

Hence, the impedance of the MOSFET without feedback

$$R_{in}=R_g - jX_{Cgs} \rightarrow R_{in}=-jX_{Cgs} \qquad (4)$$

Adding series feedback integrates the following term into the original input impedance:

$$R_a + jX_{Ls} \qquad (5)$$

Moreover, another inductor is added in series with the gate Lg that is chosen to resonate with the Cgs Capacitor.

We are trying to achieve is the following:

$Ra = \frac{L_s . g_m}{C_{gs}}$ Where R_{in} may be say 50 ohms.

Lg is designed so that it cancels out Cgs at the resonant frequency i.e.

$$j\left(\omega L_S - \frac{1}{\omega C_{gs}}\right) = 0 \qquad (6)$$

In most LNA designs the value of Ls is chosen and the values of gm and C_{gs} are calculated to give the required R_{in}.

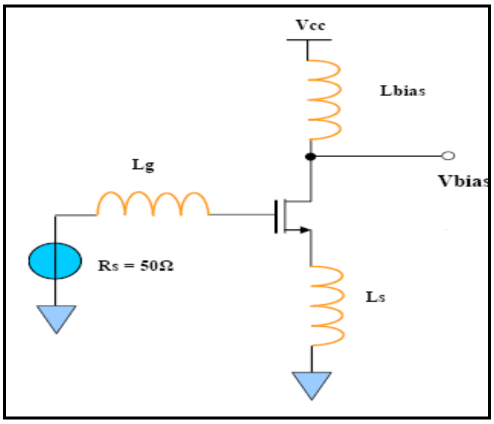

Figure 1. Initial single-stage LNA schematic

III. DIFFERENTIAL LNA DESIGN

Figure 1 represents the differential LNA basic circuit. Each of the halves of the differential amplifier are actually a single LNA which were designed earlier in this paper (ie with a 50ohm input impedance set by making gm = 20mS), with the degenerating inductors (Ls) connected together at the 'virtual earth', as shown in the picture. At this time, the source of the current is attached to the negative supply which is set to provide twice the current which is flowing down one of the sections of the LNA. Figure 2 represents ADS schematic showing the differential LNA. Bear in mind that a differential signal should be supplied to each LNA input. An 'ideal' Balun (balanced to unbalanced) transformer has been applied here (also two AC sources could be applied each set to 0.5V and opposite polarity). Another balun is used on the amplifier output too, in order to re-combine the signal to let the voltage gain to be simulated.

Applying differential structure was restricted to the low frequency applications for several years. As compared to single-ended topologies, differential structures are of the following advantages :

- Insensitivity to noise and interference coupled through supply lines and substrate.
- The potential for using many linearization methods used for Tran conductance stages for low noise amplifiers using this approach.
- Smaller even-order distortion.

The schematic of differential LNA structure is shown in Fig 2, and the result which includes S-parameter (Gain, impedance matching) and noise figure is shown in Figures 3 to 8. Gain between 2.1-3.7 GHz above 10 dB and noise figure 2-3.5 GHz below 2.

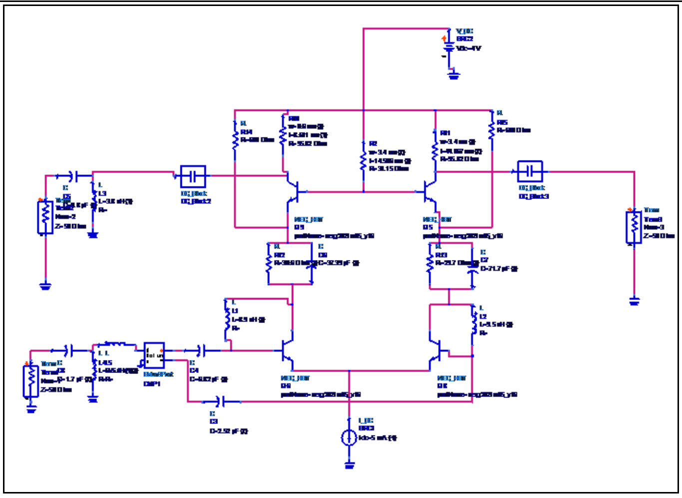

Figure 2. Shamanic of Differential LNA

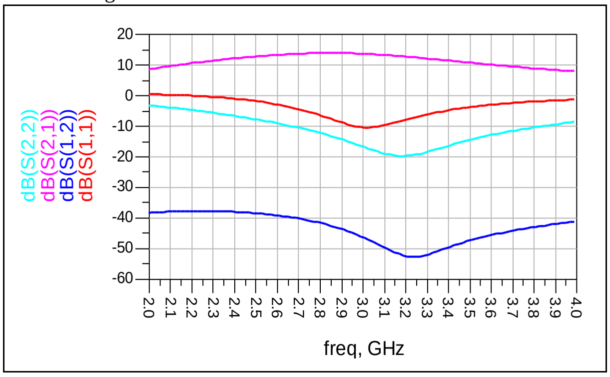

Figure 3. S-Parameteri of Differential LNA vs frequency

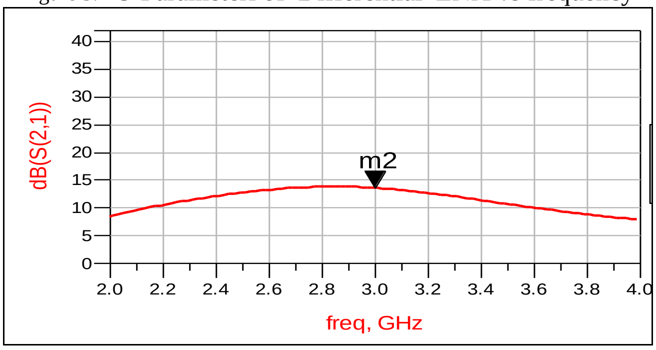

Figure 4. S21 of Differential LNA vs frequency

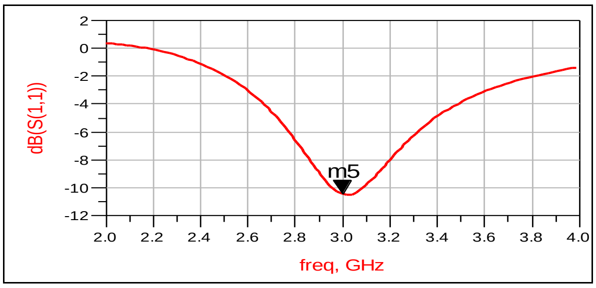

Figure 5. input impedance matching of Differential LNA vs frequency

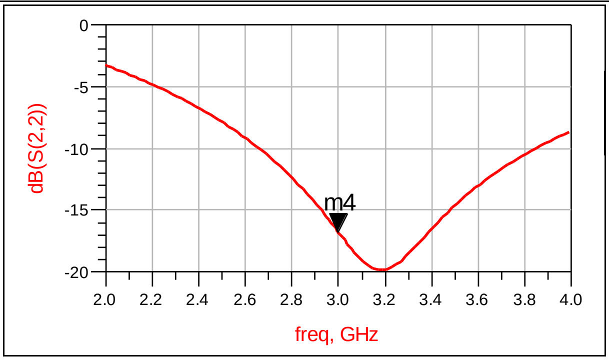

Figure 6. Output impedance matching of Differential LNA vs frequency

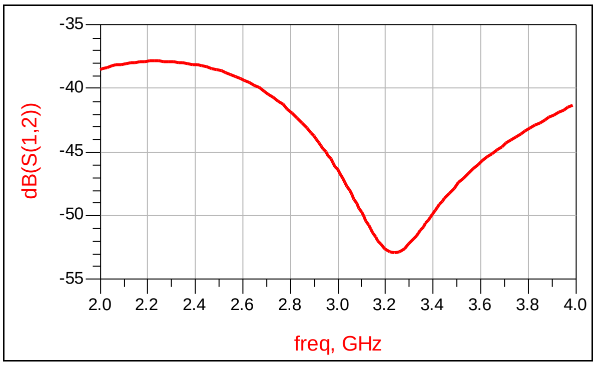

Figure 7. S12 of Differential LNA vs frequency

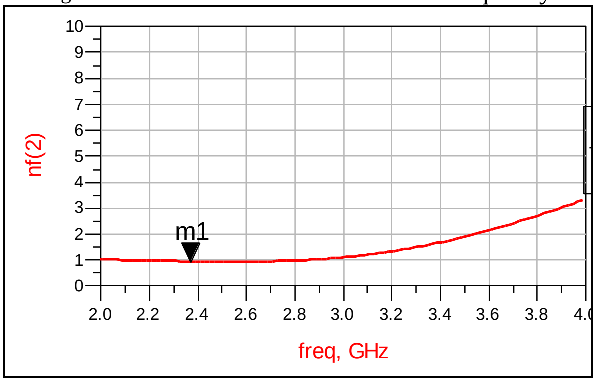

Figure 8. Noise Figure of Differential LNA vs frequency

TABLE I. COMMPARE BETWEEN THIS PAPER AND REF [8]

Frequency(GHz)	1-3	2.6-3.4
S21(dB)	9	11
S22(dB)	-12	-10
S11(dB)	-8	-10
Noise Figure(dB)	1.7	1-1.9
Power (mW)	46	35
Ref	**[8]**	**This work**

IV. CONCLUSION

This paper gave the design of differential LNA by using advanced design system (ADS 2010). A design LNA was given, with the associated step-by-step design process to meet a given specification. ADS simulations have been given to predict the various circuit parameters of gain, noise figure and power consumption, all summarized in Table 1.

REFERENCE

[1] B. A. Kopp, M. Borkowski, and G. Jerinic, “Transmit/receive modules,” *IEEE Trans. Microw. Theory Tech.*, vol. 50, no. 3, pp. 827–834, Mar. 2002.

[2] J.D. Cressler, "A new contender for Si-based RF and microwave circuit applications", *IEEE Trans. on MTT, Invited Paper*, vol. 46, no.5, pp. 572-589, May 1998.

[3] D. Li, Y.Tsividis, "Active LC filters on silicon", *IEE Proc.-Circuits Devices Syst.*, vol. 147, no. 1, February 2000.

[4] W.B. Khun, "Design of integrated, low power, radio receivers in BiCMOS technology", *Dissertation presented to the faculty of the Virginia Polytechnic Institute and State University*, 1995.

[5] T.H Lee, “The Design of CMOS Radio Frequency Integrated Circuits”, *Cambridge University Press*, ISBN 0 521 63922 0, Chapter 2.

[6] C.S Kim, M Park, C-H Kim, Y C Hyeon, H K Yu, K Lee, K S Nam, “A fully integrated 1.9GHz CMOS Low-noise amplifier” *in IEE Microwave and guided wave letters*, Vol 8, No 8 August 1998.

[7] T Soorapanth, T.H Lee, “RF Linearity of Short- Channel MOSFETs”, *IEEE Journal of Solid State Circuits*, vol. 32, no. 5, May 1997

[8] H. Bazzi, S. Bosse, L. Delage, B. Barelaud, L. Billonnet, B. Jarry, *‘Using HBT BiCMOS Differential Structures at Microwavesin SiGe Technologies’* I.R.C.O.M.- UMR CNRS n 6615 – 87060 LIMOGES