Some LNA Basics

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***Abstract*—A brief discussion of some basic LNA properties as pertaining to a 200-MHz MRI receiver under consideration.**

I. Introduction

In this paper we are guided by the LNA summary presented in [1] to make some general conclusions about LNAs for pMRI applications.

II. Minimum Noise Figure

In [1], assuming negligible C_{gd} and $\omega << \omega_T$ (the unity current gain frequency) Yee shows that the minimum noise factor for four different LNA topologies (accounting only for drain current noise and induced gate current noise) (i.) common source (CS), ii.) common-gate (CG), iii.) CS with inductive degeneration (CSID), iv.) local shunt feedback (SSF)) is simply

$$F_{min} = 1 + 2\sqrt{\frac{\delta\gamma}{5}(1-|c|^2)}\frac{\omega}{\omega_T} \tag{1}$$

where the gate noise coefficient, δ, is an indicator of how the MOSFET channel shape influences the induced gate current noise (it is 4/3 for long channel devices), γ, is an indicator of how the MOSFET channel shape influences the drain current noise (it is 2/3 for long channel devices), and c is the correlation coefficient between the drain and induced gate currents (it is $j0.395$ for long channel devices).

The conductance and susceptance of the source at which this optimal noise admittance is observed varies depending on the configuration. For CS and CG they are given by

$$G_{CSG} = \sqrt{\frac{\alpha^2\delta(1-|c|^2)\omega^2 C_{gs}^2}{5\gamma}} \tag{2}$$

and

$$B_{CSG} = -\omega C_{gs}\left[1 + \alpha|c|\sqrt{\frac{\delta}{5\gamma}}\right] \tag{3}$$

where $\alpha = g_m/g_{d0}$ (g_m is the device transconductance and g_{d0} is the MOSFET channel conductance with drain-source bias set to 0 V) and C_{gs} is the LNA's gate-source capacitance.

For the CSID we have

$$G_{CSID} = \sqrt{\frac{5\gamma}{\delta}\frac{(1-|c|^2)\omega^2 C_{gs}^2}{\alpha^2}} \tag{4}$$

and

$$B_{CSID} = \omega C_{gs}\left[1 + \frac{|c|}{\alpha}\sqrt{\frac{5\gamma}{\delta}}\right]. \tag{5}$$

Many thanks to the friends of FishLab

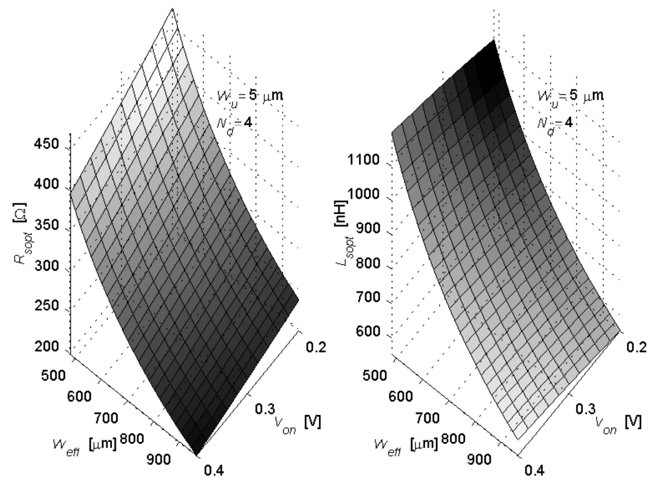

Fig. 1. Series-equivalent source impedance components needed to achieve minimum noise figure for a common-gate MOS amplifier.

And for SSH we have

$$G_{SSH} = \sqrt{\frac{\alpha g_m}{\gamma R_f} + \frac{\alpha^2\delta(1-|c|^2)\omega^2 C_{gs}^2}{5\gamma}} \tag{6}$$

and

$$B_{SSH} = -\omega C_{gs}\alpha|c|\sqrt{\frac{\delta}{5\gamma}} \tag{7}$$

where R_f is the shunt-shunt feedback resistance.

At an operating frequency of 200-MHz the minimum noise figure achievable for the topologies under consideration assuming long channel values of $\delta = 4/3$ and $\gamma = 2/3$ comes to $NF_{min} = 0.006$ dB. An impressive value, but we have not yet considered the circumstances under which it is realized. We cover this in the following section.

III. Common-Gate LNA

The optimum series-equivalent source impedance elements (resistance and inductance) needed to obtain a minimum noise figure in a 0.18-μm n-channel MOS LNA are shown in Fig. 1. The source properties are considered as a function of the LNA net width which consists of four devices in parallel ($N_d = 4$) of varying finger count where the unit width, W_u, of each finger is 5 μm. The results are obtained for a device with $\delta = 4/3$ and $\omega = 2/3$.

Clearly, the results are rather incommensurate with the source properties under consideration at the moment (a 4.7-T pick-up coil with series resistance of 1.7-Ω and series inductance of 56-nH). Part of the problem is that we are operating

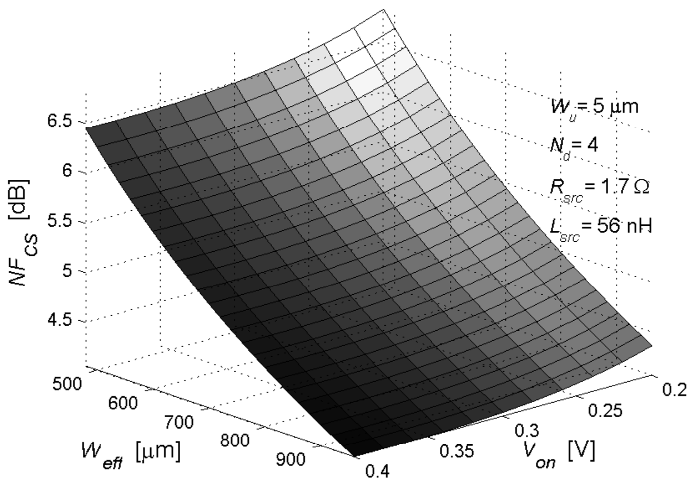

Fig. 2. Noise figure of CS-LNA with device dimensions specified in the plot driven by a series equivalent source impedance consisting of 1.7-Ω and 56-nH.

at only 200-MHz. At higher frequencies of operation, the optimum (again, for noise performance) source resistance and inductance drop. If we increase the net device width, a drop in the necessary source elements is also observed, but the width increase would have to be substantial. For 16 devices placed in parallel with a net width around 3-mm the optimum source resistance drops to around 100 Ω, lower but still far removed from the 1.7-Ω characteristics of the source currently under consideration.

A plot of the noise figure obtainable from a CS-LNA when driven by a 1.7-Ω, 56-nH series source impedance is shown in Fig.

References

[1] D. G.-W. Yee, *A Design Methodology for Highly-Integrated Low-Power Receivers for Wireless Communications*, Ph.d. dissertation, University of California, Berkeley, Spring 2001.