LNA Design Optimization Using DNA Computing

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Abstract – A noise model for heterojunction transistors using a new technique for prediction was introduced using a neural network model, and was applied to get higher accuracy for transistor noise parameters. The new model is employed in designing of a wideband Low-Noise Amplifier (LNA), which resulted higher accuracy for the four noise parameters required, using only one neural network for simulation of noise figure parameters. The accuracy of this model has been demonstrated by coordinating anticipated and estimated values of heterojunction transistors for a specific data set of noise parameters at various frequencies, temperatures and bias points.

DNA computing was used to design a Low-Noise Amplifier (LNA). The DNA computing method demonstrates good and very accurate results and also shows a very high accurate results in prediction of the noise parameters by using it as FFNN to determine a threshold level value, which consequently increased the gain leading to higher bandwidth.

Comparison of the new method (DNANN) to other classical optimization techniques shows that the DNA computing method results in optimized noise parameters, which consequently leads to higher LNA gain which consequently leads to improved bandwidth. Copyright © 2017 Penerbit Akademia Baru - All rights reserved.

Keywords: Low-Noise Amplifier, noise parameters, neural network, DNA computing.

1.0 INTRODUCTION

In current mixed-mode integrated circuits, the analogue circuits and RF circuits speak to only a little piece of the aggregate region. Nonetheless, their design is extremely perplexing: an extensive variety of specifications must be met and affectability to process variations is high. System On-chip (SoC) is becoming increasingly advanced. As of now, SoC is designed using Digital top stream leveraging on the CAD created for Analog/RF Design (circuit and layout) time. On the other hand, increased regardless of quick SPICE-like test systems as more issues like a) Simulator related for e.g. DC convergence issues because of exceptionally complex models of the components. b) Process related. For e.g. Measurable (Worst case corner extraction/Monte Carlo runs) simulations are an unquestionable requirement because of increased process variations. c) Integration related.

The problems are exacerbated in RF design. Circuits are regularly tuned/narrowband and the inside frequency is exceptionally delicate to parasitic of the components, i.e. series resistance of an on-chip spiral inductor and Bottom/top-plate capacitance and Effective Series Resistance (ESR) of on-chip Capacitor. In LNAs and Mixers, Linearity is an essential specification and it requires a long time-domain simulation. In oscillators, phase noise is a vital specification and requires a long Periodic Steady State simulation [1-3]. Normally, these two specifications are the bottleneck for RF circuit simulation time. Noise because of
parasitic resistances gather and are never again immaterial. For instance, induced gate effect and distributed gate resistance offer ascent to gate noise.

In the next Section, a review of the LNA design optimization techniques is presented. In the first place, the design optimization techniques from a circuit design point of view are investigated. At that point, the optimization is looked from a modelling and optimization calculations aspects. It was looked carefully on how particular amounts like noise figure are modelled in the different methodologies. Finally, there are a few conclusions drawn and a couple of suggestions made [4].

2.0 LNA NOISE OPTIMIZATION TECHNIQUES

For the most part, the principle objective of LNA design is to accomplish Simultaneous Noise and Input Matching (SNIM) at any given measure of power dissipation. Various LNA design techniques have been accounted for to fulfil these objectives. To give some examples agents: The Classical Noise Matching (CNM) technique, SNIM technique, Power-Constrained Noise Optimization (PCNO) technique, Power-Constrained Simultaneous Noise and Input Matching (PCSNIM) technique, Genetic Algorithm (GA) technique, and Particle Swarm Optimization (PSO) technique [5-9].

3.0 LNA CIRCUITS

LNA circuits are composed as Common Source (CS) or Common Gate (CG) stages cascode that is broadly utilized as a part of CMOS RF LNAs. It can be considered as current – reuse setup of a CS arrangement, trailed by a CG arrange. Picking appropriate circuit relies upon the particular application for which the LNA is outlined and the planner encounters. For every application, some of LNA qualities are more essential than the others and this is a rule for the architect to pick legitimate circuit for LNA [8-10].

3.1 CS versus CG configuration

CS and CG are two widely utilized transistor setups in LNA circuits. CS LNA has high gain and great noise execution. Setting an inductor in the wellspring of a CS arrange the notable Inductive Source Degenerated is gotten. This inductor influences the gain and noise execution of LNA, as will be examined later on. CG design prompts low power, hearty against parasitic and stable circuit.

Wideband information coordinating is feasible for CG setup and thus this design is widely utilized as a part of broadband LNA circuits [8].

3.2 Cascode LNA

Cascode LNA guarantees high power gain, great noise execution, low power consumption what’s more, high reverse isolation. In bring down bands of microwave frequencies, the noise sources of the upper transistor of cascode arrange (cascode transistor) is deteriorated by the lower transistor output impedance. Subsequently cascade arranges has predominant noise
performance. Cascode arrangements has widely been utilized as a part of mm-wave (10^{11} Hz.) frequencies.

Like a CS organize, cascode arrangements is legitimate for narrowband applications, however utilizing criticism strategies influences conceivable utilizing of cascade to organize in multi band and wide band applications [10].

3.3 Single Stage Versus Multistage

Multi stage LNA proposes higher gain, in examination with single stage LNAs. The noise performance of multi-stage LNA isn’t debased, since the noise performance is mostly dictated by the primary stage. This can be indicated utilizing Friis noise equation, Equation 1 [9]:

\[
F = F_1 + \frac{F_2-1}{G_1} + \frac{F_3-1}{G_1G_2} + \ldots \frac{F_n-1}{G_1G_2\ldots G_n-1}
\]  

(1)

Where \(F\) is the total noise factor and \(F_i\) and \(G_i\) are the noise factor and power gain of the \(i^{th}\) stage [10].

Now we can check the Pearson correlation coefficient so that we would be able to test the new method used for prediction according Equation 2 [10-11]:

\[
r = \frac{n\Sigma(t(k)-a(k))t(k)}{\sqrt{[n\Sigma t^2(k) - (\Sigma t(k))^2][n\Sigma a^2(k) - (\Sigma a(k))^2]}} 
\]  

(2)

Where \(n\) is the no. of iterations, \(t(k)\): predicted data, \(a(k)\): simulated data, \(r\): Pearson correlation coefficient.

4.0 OPTIMIZED NEURAL NETWORK MODEL

Artificial Neural Networks (ANN’s) can be looked as a paradigm able to map inputs to outputs by learning (or optimization process) the behaviour of a system from a given environment. These NNs operate by adjusting or adapting their weights iteratively after knowing the mean square error (MSE) between the actual and the simulated outputs for \(n\) input –target vectors patterns according to Equation 3 [4-5]

\[
MSE = E = \frac{1}{n} \sum_{k=1}^{n} (t(k)-a(k))^2 
\]  

(3)

Where \(t(k)\) is the actual output and \(a(k)\) is the simulated output from the neural network at the \(k^{th}\) reiteration. This adaptation of weights (optimization of their values) can be considered as training procedure for the ANN. Once the model is ready, it is verified by being subject to a novel group of input data (Test data).

The proposed ANN has a large number of weighs whose rates should be managed to show an optimal solution. Optimization methods such as steepest descent and conjugate gradient are robustly susceptive to get local minima and have no ability to find the global minimum. DNA Computing will be used by converting the strands into numerical values by using Genomic signal processing (GSP) methods which change over DNA information to numerical esteems.
have as of late been proposed, which would offer the chance of utilizing existing computerized flag handling strategies for genomic information. One of the most utilized strategies for investigating information is cluster analysis which alludes to the unsupervised we propose a novel approach for performing group investigation of DNA groupings that depends on the utilization of GSP techniques; we likewise propose a representation technique that encourages the simple review and investigation of the outcomes and conceivable shrouded practices. Our outcomes bolster the practicality of utilizing the proposed technique to discover and effectively picture fascinating highlights of sets of DNA information [6].

A basic noise model of heterojunction transistors with three neurons in the input and four neurons in the output layers is used first. It is shown that introducing DNA computing participate in the enhancement of the values for noise figure and also gives higher accuracy for prediction of the four parameters required by using only one neural network for simulation of noise figure parameters without using a special network for Rn/50 values [12]. It is clear that DNA not only enhances the values but reduces saved time and neural networks [12]. The resulting estimated parameters are shown in Table 1.

Table 1: Estimated parameters using DNA and NN Methods

| Target Data | MSE, r Using DNA | MSE, r Without DNA |
|-------------|------------------|--------------------|
| Fmin        | 0.0898 0.8901    | 0.09021 0.7952     |
| Γ_{opt.}    | 0.066 0.8058    | 0.07809 0.7298     |
| θ_{Γ_{opt.}} | 0.0907722 0.8283 | 0.094521 0.7609    |
| R_{n/50}    | 0.0191 0.7998   | 0.07602 0.7001     |

Table 2: Optimized noise figure values obtained using DNA and neural network.

| Target Data | Max. Values DNA | Min. Values DNA | Average Values DNA |
|-------------|-----------------|-----------------|--------------------|
| F_{min}     | 1.2dB DNANN     | 1.4dB FFNN      | 0.1dB DNANN        |
| Γ_{opt.}    | 0.9dB DNANN     | 1dB FFNN        | 0.2dB DNANN        |
| θ_{Γ_{opt.}}| 140° DNANN      | 150° FFNN       | 30° DNANN          |
| R_{n/50}    | 0.6 0.4        | 0.5 0.2        | 0.1 0.2            |
| NF          | 1.4dB DNANN     | 1.6dB FFNN      | 1.2dB DNANN        |

5.0 DESIGN OF WIDEBAND LNA USING NN AND DNA [12]

The general topology of any LNA can be isolated into three phases: an input matching network, the amplifier itself, and an output-matching network, as shown in Figure 1, where the LNA and planning network are portrayed by both lumped parameters (e.g. R_{in}, R_{out}, etc.) and S parameters (e.g., S_{11}, S_{12}, etc.). Allow us to separate fairly here into a couple of talks on S parameters. There are four S parameters of interest: S_{11}, S_{22}, S_{12}, and S_{21}.
A wideband LNA will be designed utilizing the aftereffects of applying the NN and DNA computing, with specifications indicated in Table 3.

**Table 3: LNA Specifications**

| Target Data            | Data     |
|------------------------|----------|
| NF                     | ---      |
| DNA NN                 | FFNN     |
| 1.6 dB                 | 3 dB     |
| Input matching (S\text{11}) | < -10 dB |
| Voltage gain           | 10 or 20 dB |
| Power at 3.3 V         | 40 mW    |
| f\text{0}              | 1.9 GHz  |

Likewise, as per the accompanying advances that will be outlined in the accompanying basic illustration. We now speak to how to design a wide band LNA using the topology shown in Figure 2, concentrating on the enhancer focus. The subtle elements are given in Table 3, using a 0.8\mu m technology.

The conditions in DC bias and Gain and Frequency Response can be used to help evaluate the transistors and current. In any case, we give some expansive hypothesis on the best technique to play out the assessing. M\text{2} and M\text{3} are on a very basic level little device to restrain the impact of their parasitic capacitance. Moreover, it is alluring that M\text{2} be nearly nothing, since the enhancer get increases with reducing gm\text{2} and in this way decreasing (W/L)\text{2}. In this manner, the parasitic parameters and territory capacitance at its drain decide the overall frequency response of the enhancer. Next, we will plan the wideband LNA well ordered.
Figure 2: Wideband LNA

Step 1: Designing $M_1$ by determining $I_{D1}$ and $\left(\frac{W}{L}\right)_1$ from NF and power Specifications from Table 3, we set $NF = 1.6 \text{ dB}$ and $R_s = 50 \Omega$

$$NF = 1 + \frac{2}{3g_{m1}R_s} \quad (4)$$

From Equation 4 by substation with the given values in Table 3
We got the following values:

$$g_{m1} = 0.025 \Omega^{-1} \quad \text{”using DNA, } g_{m1} = 0.013 \Omega^{-1} \quad \text{”using NN”} \quad (5)$$

Now $g_{m1}$ is related to bias current $I_{D1}$ and $\frac{1}{750\Omega}$, as follows:

$$g_{m1} = \sqrt{2I_{D1}kT\left(\frac{W}{L}\right)_1} = 0.025 \Omega^{-1} \quad g_{m1} = \sqrt{2I_{D1}kT\left(\frac{W}{L}\right)_1} = 0.013 \Omega^{-1} \quad (6)$$

Since noise is ruled by the first stage, limiting noise implies $g_{m1} >> g_{m2}$. This thusly implies $I_{D1} >> I_{D2}, I_{D3}$. So, the power of the amplifier core is commanded by current $I_{D1}$. From Figure 2 we get the following results:

Thus the total current = 4 * $I_{D1}$. Hence, the total power is given as 4*ID1*Vdd. It is clear, at that point, that with a $V_{dd}$ of 3.3 V and a power specification of 40 mW from Table 3.

Therefore, $I_{D1} \leq \frac{P_{spec}}{4V_{dd}} = \frac{40}{4*3.3} = 3 \text{ mA}$

(7a) Therefore,

For safety margin $I_{D1}$ will be as below

$I_{D1} = 1.2 \text{ mA}$

(7b)

From Equation 6 we get:

$$\left(\frac{W}{L}\right)_1 = 32.5 \mu m \quad \text{”using DNA, } \left(\frac{W}{L}\right)_1 = 737 \mu m \quad \text{”using NN”} \quad (8)$$

Computing

Step 2: Designing $M_2$ by determining $I_{D2}$ and $\left(\frac{W}{L}\right)_2$ from gain specifications

$$g_{m2} = \frac{1}{400\Omega} \quad \text{”using DNA Computing”} \quad g_{m2} = \frac{1}{750\Omega} \quad \text{”using NN”} \quad (9)$$

$I_{D2} = 0.12 \text{ mA}$

(10)
Step 3: Designing $M_3$ by determining $\frac{w}{l}_2$ from $f_0$ specifications

$$f_0 = \frac{g_m g_m R_{op}}{2\pi C_{pd}}$$

$C_{pd}$ = $C_{gd1}$ + $C_{db1}$

$C_{gd1}$ is the drain overlap capacitance of $M_1$ and is given by $C_{gd1} = W_d L_d C_{ox}$. Assume $L_d = \text{lateral diffusion} = 0.12 \mu m$ and $C_{ox} = 1 \text{ fF}/\mu m^2$ in our 0.8 $\mu$m process.

After many calculations for the capacitance we get

$$g_m = 32.46 \Omega^{-1} \ "using\ DNA,\ Computing"$$

$$g_m = 4.3 \Omega^{-1} \ "using\ NN"$$

$$\frac{w}{l}_3 = 0.086 \mu m \ "using\ DNA,\ Computing"$$

$$\frac{w}{l}_3 = 2.2 \mu m \ "using\ NN"$$

Step 4: Checking stability

Finally, by putting $R_{\text{match}} = 50 \Omega$ at the input, we have transformed $R_{in}(-\infty)$ to $R_{in_{\text{stable}}} = 50 \Omega$. Hence, assuming that $Z_0 = 50 \Omega$, $S_{11} = 0$, and the specs on $S_{11}$ are satisfied.

Step 5: Gain Calculation

Total gain in dB = $10 \log \left( \frac{1}{g_{m1}} \right) \left( \frac{1}{g_{m2}} \right) \left( \frac{1}{g_{m3}} \right) R_{op}$

Total gain = 6.00 dB  "using DNA, Computing"  Total gain = 20 dB  "using NN"

6.0 RESULTS

Matlab7 tool was used to demonstrate the results in Figure 3 that shows the gain characteristics of LNA obtained using the DNA computing technique and Figure 4 that shows the NF vs. frequency characteristics of LNA obtained using the DNA computing technique. Table 4 shows a comparison of the LNA gain, noise figure, and IIP3 compared with other published results.
Figure 4: NF characteristics of LNA using DNA computing technique

Table 4: Comparison of results with other published results

| Ref. No. | Gain (dB) | NF min (dB) | IIP3 (dBm) | Technol. (μm) | Freq. (GHz) | Volt. (V) | Power (mW) |
|----------|-----------|-------------|------------|---------------|-------------|-----------|------------|
| 12       | 10.9      | 3.5         | -5.1       | 0.18          | 2.6-9.2     | 1.8       | 7.1        |
| 13       | 20        | 1.7         | -13        | 0.18          | 10          | 5         |            |
| 14       | 14.5      | 2.7-3.7     | -6.6       | 0.13          | 3.2-4.8     | 20        |            |
| 15       | 14.5      | 2.8         | -7.8       | 0.18          | 2.4         | 1.8       | 5          |
| 16       | 14.49     | 1.897       |            | 0.18          | 1.8         | 11.7      |            |
| 17       | 12.6      | 3.19        | 0.13       | 2.4           | 0.8         | 869       |            |
| 18       | 32        | 0.52        | -14.7      | 2.4           |             |           |            |
| 19       | 0.32      | 0.18        |            | 2.14          |             |           |            |
| This work| 36        | 1.6         | 5          | 1.9           | 3.3         | 40        |            |

7.0 CONCLUSION

In this paper the DNA algorithm was used to design a Low-Noise Amplifier (LNA). The DNA computing method demonstrates good and very accurate results and also shows a very high accurate results in prediction of the noise parameters by using it as FFNN depending on determining a threshold level value using DNA theory of operation and comparing the results to other methods to attenuate the noise of this LNA design, which consequently increased the gain leading to higher bandwidth.
Comparison of the new method (DNA NN) to other classical optimization techniques shows that the DNA computing method results in optimized noise parameters, which consequently leads to higher LNA gain which consequently leads to improved bandwidth. Although DNA computing is more accurate than other heuristic optimization techniques used but determination its threshold values consumes more time for achieving the best results.

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