An MSSO based optimized low noise amplifier for biomedical application

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Abstract: A low-noise amplifier (LNA) can be observed in all receivers. The development of an LNA is critical for the biomedical (BM) applications wherein a huge dynamic range is needed. The design of LNA comprises of the trade-off between Noise Figure (NF) and gain while modeling at the essential stability, which is also a problematic task. Mostly, the LNA comprises a shift of frequency. To reimburse the shift frequency, several prevailing methods are available that use many evolutionary algorithms. However, their optimal solution is diminutive. To conquer the problems of the existing procedures, this paper proposed an MSSO based optimized LNA for BM application. Initially, the LNA model is defined. Secondly, the LNA parameters are tuned with the help of the MSSO algorithm. The parameters are linearity, Gain, NF, input as well as output matching. The proposed system's performance is weighed against the existing system in the experimental evaluation. The proposed system shows better performance than the prevailing practices.

Key words:*Modified Salp Swarm Optimization (MSSO), Low Noise Amplifier (LNA), Noise Figure (NF), linearity and gain.*

1. INTRODUCTION

BM signal processing fetches helpful information as of the BM-signals [1, 2]. Previously the main attention was only on processing the BM-signal to extract the actual signal and eliminate noise. As these BM signals basically consist of very weak amplitude in the order of few mV with almost equivalent noise signal levels, it is very difficult to detect these signals [3]. The BM detection system contains electrodes, an instrumentation amplifier, a low pass filter, a sample and hold circuit (S/H) and an analog-to-digital converter [4]. Medical applications are also involved, for example in [5] neural application, the design of neural recordings lies with wireless transmission abilities for the un-tethered measurement of brain functions [6] is raised in past years.

In any application, the LNA stands as the initial stage of any receiver. Although plenty of the research is focussed on the LNA design for high-frequency applications, it is widespread in low-frequency designs as well [7]. Though fully differential LNA can augment the robustness in opposition to process variations and lessen the even-order distortion, it is critical to maximize the receiver's sensitivity [8]. LNA topologies are (i) Resistive termination (ii) common gate (iii) resistive shunt feedback [9] (d) Inductive degenerated for narrow and wideband LNA topologies. For better performance parameters like less power, low noise, high gain, low voltage and to optimize LNA, an appropriate topology must be chosen [10]. Many optimization algorithms are used to tune the LNA.

The paper is set as Section 2 provides a survey of the associated work concerning the proposed technique. Section 3 gives a concise discussion concerning the proposed work. Section 4 analyses the investigational outcomes. Section 5 deduces the paper.

2. RELATED WORK

Ram Kumar *et al.* [11] designed an extremely linear 5.5GHz LNA with the help of post alteration linearization methods in 0.18m CMOS technology, which exploited the topology of source inductive degeneration. The method put forwarded which advances the IIP3 of LNA. Likewise, the pre-mentioned topology was active in LNA for optimizing the NF and S_{11} at a higher frequency. During the consumption process of 10.8 mW from a power supply of 1.8V, the LNA attained a replicated 3rd order input intercept (IIP3) of 9.20 dBm. It also showed a result of 11.34dB and 2.33 dB of NF.

MouradFakhfakh*et al.* [12] conferred the technique termed Particle Swarm Optimization for the optimization approach of analogue circuits. Two applications were stated as examples, the methods are as follows: increasing the energy gain of an LNA for increasing the current cut off frequency, computing a Pareto-front of the bio objective problem, and reducing the 2nd generation current conveyor's parasitic input resistance. The suitability of PSO to enhance critical circuit problems, with regards to the numbers of parameters and impulsions, was given.

Habib Rastegar and Ahmad Hakimi [13] put forward a thin band Complementary Metal-Oxide Semiconductor LNA that accomplished the high IIP3. The IIP3 exploited the non-linearity termination method at RF. In the MDS method, amongst two transistors, one transistor was biased in the hard reversal region, contrarily, another one transistor was biased in the moderate inversion region in place of feeble transposal region. The linear LNA was modeled and also simulated in a 0.13mm CMOS process. At 3.66GHz,14 dB was obtained the same as shown in figure (NF) remained 2 dB. An IIP3 of 10.5dBm, as well as a power intake of 2.4mW voltage, was attained.

Guy Merlin Ngounou and Martin Kom [14] put forwarded distinct essentials and Optimum noise for a composition amplifier for the amplification of very low signals. The method presented was actually an instrumentation amplifier that amplified the signals with a lower amplitude. By applying this method in such a case of electrocardiograph, the signals provided simulation results fully in line with forecasts.

DeepanshDubey and Anu Gupta [15] presented a low power and noise operational amplifier for implantable BM methods. The amplifier was planned with the intention of diminishing the input-referred noise and power consumption. For decreasing the input thermal noise, this approach of the EKV Model was used to fix the transistors' bias currents. PMOS input transistors having huge gate areas as well as operating in reduce inversion were handled for reducing the flicker noise. At all the process corners such as TT, FF, SS, SF, and FS, the concert of the circuit were acutely observed. The simulations are done at 36.9"C.

3. PROPOSED METHODOLOGY

LNA is the key constituent of RF transceiver, which is utilized to amplify a weak, low power signal devoid of demeaning its signal-to-noise ratio. LNA that is utilized in the radio communication system as well as ISM band application can handle the extensive dynamic gamut of input signal devoid of getting overloaded and also undertaking saturation. The LNA is the main part of the BM applications such as neural, biosensors, Electrocardiogram (ECG), along with Electroencephalogram (EEG) applications. But, in the LNA, the shift frequency is the problem. So to overcome the shift frequency, the proposed methodology uses the Modified Salp Swarm Optimization (MSSO) algorithm aimed at BM applications. The LNA design and the parameters optimization using MSSO is elucidated in the subsection. The diagram for the bio-signal processing system is exhibited in Figure 1,

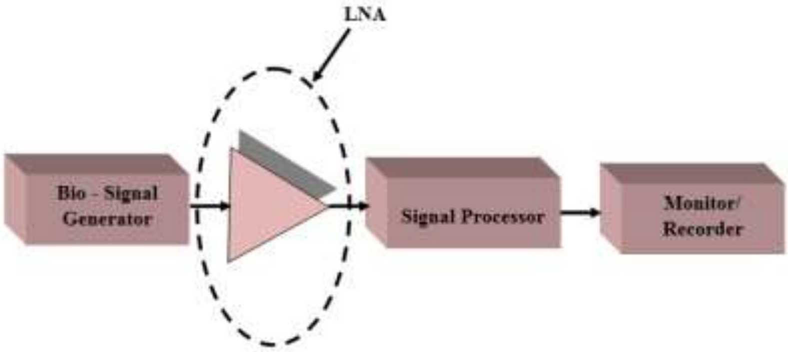


Figure 1: Block diagram of Bio-signal processing system

3.1 LNA Design

This paper considers the LNA by taking BM applications. LNA is also called as neural amplifiers and biopotential amplifiers that are only preferred for amplifying the very low frequency as well as amplitude signals. The shift of frequency is the problem in the LNA. In the proposed work, the shift of frequency is compensated centred on the optimized various parameters like linearity, Gain, NF, input and output matching. The proposed method concentrates the shift frequency at 5.5 GHz whose simplified circuit is displayed in Figure 2. The design has three inductors namely, gate inductor Z_g, source inductor Z_s, and drain inductor Z_d. Roles contributed by the above-mentioned inductors in the designed LNA are (i) Z_g helps in turning out the effect of the input capacitance (ii) performance of Z_s help in achieving the input matching and (iii) gain of the LNA is enhanced with the use of Z_d and also it is implemented to get output resonance with output capacitance. $W1$ and $W2$ are the input and Cascading devices, respectively. The main role of a Cascading device is to offer isolation between tuned output and tuned input. The biasing circuit $W3$ and R1 are employed where they form the current mirror Ellinger.

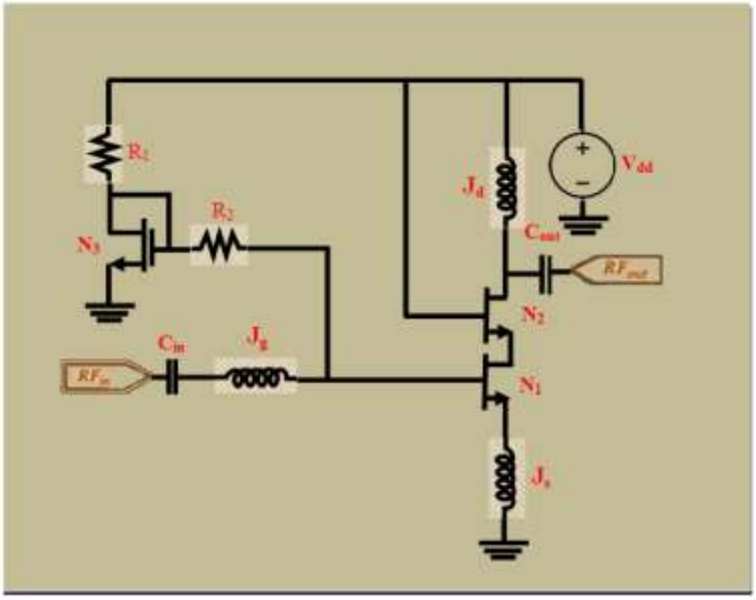


Figure 2: LNA design

Various parameter optimization using MSSO for tuning the LNA is explained as in the below section.

3.3 Modified Salp Swarm Optimization (MSSO) algorithm

By using the MSSO algorithm, several parameters of the LNA get optimized. Slap has a translucent barrel-shaped body and its tissues are similar to that of jellyfishes. They live in deep oceans and move by means of water forces in order to find their provisions. The group of salps is called salp chains.

In the mathematical representation of salp chains, there are '2' terms of classifications: i) leader and ii) followers. The leader is the one that is at the front of the chain, while the remaining salps are considered as followers. Utilizing the equations (1) and (2), the leader salp's position is updated. In that equation, if the random number a_3 is above or equivalent to 0, then the salp position is updated based on the equation (1) or if the a_3 is below 0, then the salp position is updated centred on the equation (2),

$$K_j^1 = \eta Q_j + a_1\left(\left(u_j - l_j\right)a_2 + l_j\right) \tag{1}$$

$$K_j^1 = \eta Q_j - a_1\left(\left(u_j - l_j\right)a_2 + l_j\right) \tag{2}$$

Where, K_j^1 signifies the first slap's position (i.e. leader) in the j^{th} dimension, Q_j implies the food source's position in the j^{th} dimension, u_j implies the upper bound of j^{th} dimension, l_j indicates the lower bound of j^{th} dimension, a_1, a_2 and a_3 are random values. In the proposed methodology, the food source's position is multiplied with the inertia weight,

η which is denoted as the MSSO. The inertia weight $\eta \in [0,1]$, the new parameter in the MSSO algorithm hastens the convergence speed amid the search. It as well makes a balance between exploration and exploitations capabilities to initially flee a huge number of local solutions in feature selection tasks and attain an accurate appreciation of the optimum solution.

From equation (1) and (2), it can well be understood that the leader only updates its position concerning the food source. The coefficient a_1 stands as the most imperative parameter in MSSO since it balances exploration along with exploitation as defined below:

$$a_1 = 2e^{-\left(\frac{4e_i}{I_x}\right)^2} \tag{3}$$

Where, e_i is the current iteration and I_x implies the maximum number of iterations. In fact, they dictate if the next position in j^{th} dimension should be towards positive infinity or negative infinity and also the step size.

To update the followers' position, the following equations is employed (Newton's law of motion):

$$K_j^i = \frac{1}{2}\omega t^2 + \alpha_0 t \tag{4}$$

Wherein, $i \geq 2$, K_j^i signifies the i^{th} follower salp's position in j^{th} dimension, t signifies time, as well as α_0 implies the initial speed. ω is calculated as:

$$\omega = \frac{\alpha_{final}}{\alpha_0} \text{ Where } \omega = \frac{K - K_0}{t} \tag{5}$$

As the time in optimization is iterated, the discrepancy amid iterations is equivalent to 1. By regarding $\alpha_0 = 0$, this equation is expressed as:

$$K_j^i = \frac{1}{2}\left(K_j^i + \eta K_j^{i-1}\right) \tag{6}$$

Wherein $i \geq 2$ and K_j^i implies the i^{th} follower salp's position in j^{th} dimension. The inertia weight value is also multiplied in the follower position updation procedure. Based on this way, the parameters are optimized and then compensate the shift of frequency. Pseudocode for the MSSO is exhibited in Figure 3,

Input: Various parameters of the LNA
Output: Compensate shift frequency

Begin
  Initialize the salp population $x_i (i = 1,2,....n)$ and maximum iteration Max
  Set $s = 1$
  While $(s \leq Max)$
    Calculate the fitness of each search agent
      for each salp x_i
        if $(i == 1)$
          Update the position of the leading salp by eq. (1) & (2)
        else
          Update the position of the follower salp using,

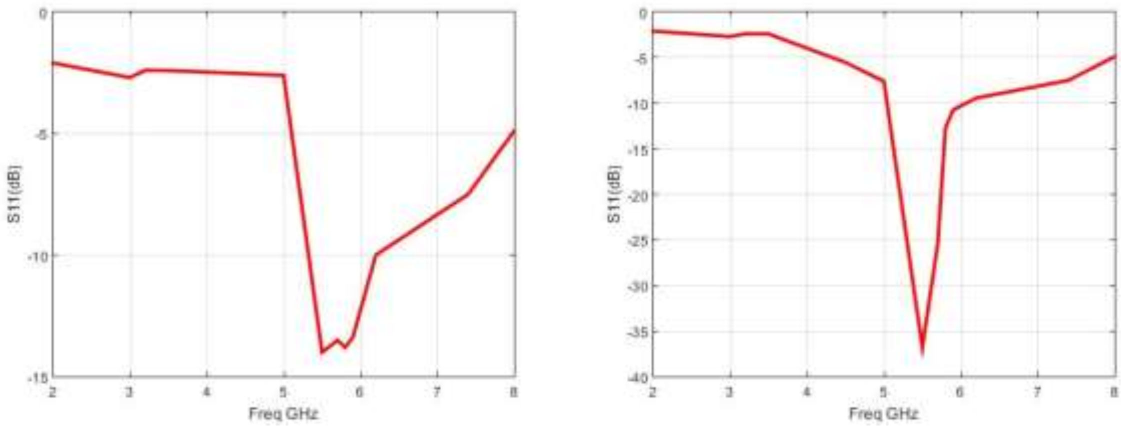
$$K_j^i = \frac{1}{2}\left(K_j^i + \eta K_j^{i-1}\right)$$

        end if
      end for
      Amend the salps based on the upper and lower bounds of variables
      Set $s = s + 1$
  end while
  Return optimal parameters
End

Figure 3: Pseudo code for the proposed MSSO algorithm

4. RESULT AND DISCUSSION

Here, the proposed system's performance is analyzed. An MSSO based optimized LNA for BM application is functioned in the working platform of MATLAB/Simulink. In the proposed work, the parameters of LNA are optimized concurrently by means of changing them into a single objective function. Outcomes are also contrasted with the existing FA along with PSO algorithms.



(a) **(b)**

Figure 4: $S_{11}(dB)$ in the present of parameter variations (a) without applying MSSO and (b) with applying MSSO

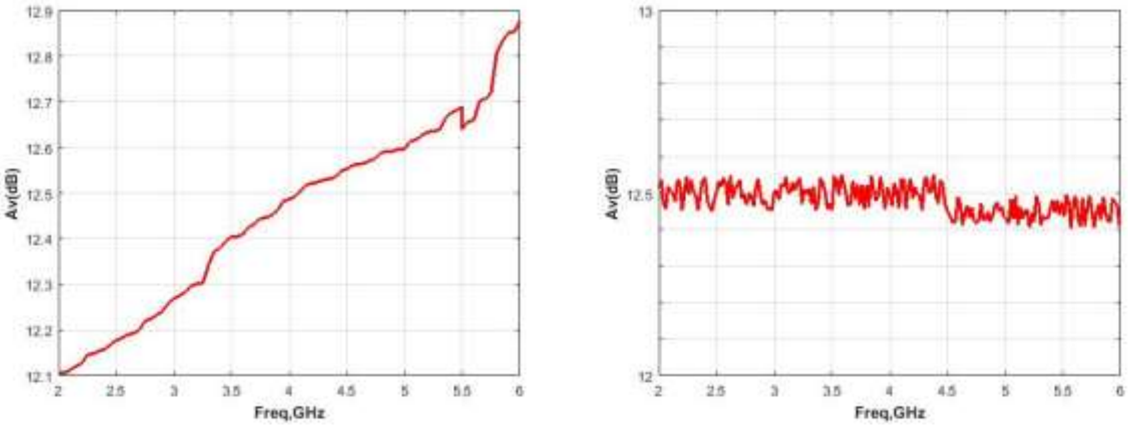


Figure 5: $A_v(dB)$ in the present of parameter variations (a) without applying MSSO and (b) with applying MSSO

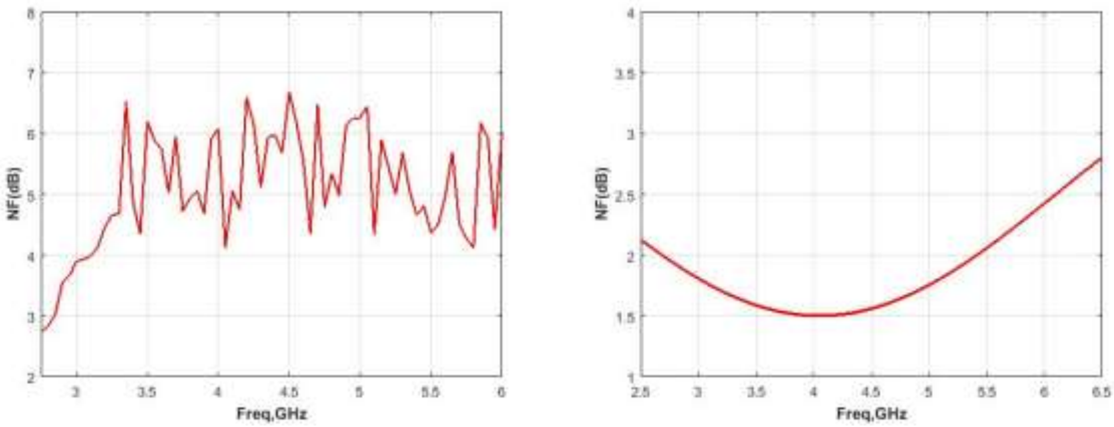


Figure 6: NF(dB) in the present of parameter variation (a) without applying MSSO and (b) with applying MSSO

Figure 4 depicts the input return loss (S_{11}) with parameter variations. Figure 4 (a) shows that the output is not optimum at the desired frequency of 5.5 GHz. Figure 4(b) exhibits that it is optimum at the desired frequency of 5.5 GHz by using the proposed MSSO. Figure 5(a) shows the voltage gain (V_g) of the proposed LNA with parameter variations. Figure 5(b) illustrates the voltage gain by using the MSSO algorithm. Figure 6 (a) shows the parameter variation without applying the MSSO algorithm and Figure 6 (b) shows the proposed LNA with applying proposed MSSO.

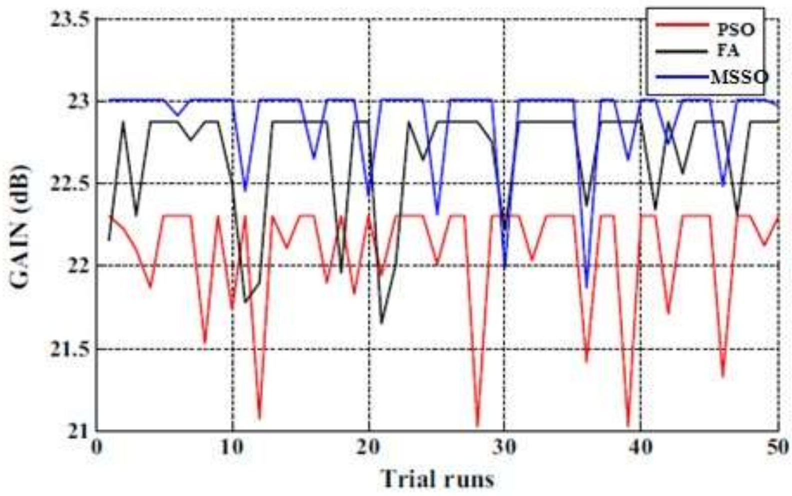


Figure 7: Demonstrate the trial run plot for gain

Figure 7 shows the trial run plot for different algorithms such as proposed MSSO, existing FA and existing PSO algorithm. The trial run starts from 0 and ends with the 50 trial. It concluded that the proposed system has better performance.

5. CONCLUSION

The augmenting demand for implantable BM systems has stimulated the development of low cost, low weight and highly integrated radio frequency transceiver that is utilized in wireless system networks for medical as well as health care applications like remotely controlling the drug delivery of patients or monitoring of patient's physiological parameters. So, maintaining the BM instrument process is important. In BM signals, the LNA has shift frequency, which is a major issue of LNA. This paper proposed an MSSO based optimized LNA for BM-applications. Here, various parameters of the LNA are tuned using the MSSO algorithm. The proposed system's performance is shown and the proposed system is weighed against the existing algorithms namely, PSO and FA the proposed system have better performance compared to the existent methodologies.

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