Design and optimization of a new LNA

Kamran Delfan Hemmati[1], Mojtaba Behzad Fallahpour[2] , Abbas Golmakani[3]
1- Pouyandegan e danesh Institute of Higher Education, Chalus, Iran.
Email: kamran_delfanhemmati@yahoo.com
2- Malek e Ashtar University of Technology, Tehran, Iran.
Email: m_behzad_fp@yahoo.com
3-Sadjad Institute of Higher Education, Mashhad, Iran
Email: golmakani@sadjad.ac.ir

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ABSTRACT:
In this paper a new LNA with image rejection filter is presented. Furthermore, after determining topology, a proposed CAD (Computer Aided Design) with a proposed multi objective genetic algorithm will be used to optimize the LNA. By performing the algorithm, several results will be obtained as they have no priority to each other, so the designer can select each of them according to his need. Simulation results show that the proposed plan weakens the image considerably; it also increases LNA gain without changing the noise figure (NF), output matching and input matching. The proposed multi objective genetic algorithm program is written by MATLAB and the circuit simulated by HspiceRF with 0.18µ technology.

KEYWORDS: LNA, Image rejection filter, Multi objective genetic algorithm, non dominated answers.

1. INTRODUCTION

Low noise amplifiers (LNA) are one of the key building blocks for RF receivers. Using a LNA, the effect of noise from subsequent stages of the receive chain is reduced by the gain of the LNA, while the noise of the LNA itself is injected directly into the received signal. Thus, it is necessary for a LNA to boost the desired signal power while adding as little noise and distortion as possible [1,2].

But there are complicated relations to design LNA circuits. Designing with these relations is difficult and time-consuming, because the relations are approximate. Therefore, a designer must rely on his own knowledge and "tries and errors" methods to obtain desirable results. Here the importance and necessity of using CAD plays an important role, but computer aided analysis and synthesis tools for RF ICs are still in their infancy which it is forcing the designers to rely on experience, intuition, or inefficient simulation techniques to predict the performance[3,4].

In this paper a LNA with image rejection filter is presented, but after determining the circuit structure, finding the appropriate amounts of constituent elements, is high significance although the size of elements can be obtained by using analytical equations but desirable results cannot obtained after simulating the circuit with this initial amounts; mostly due to the approximate nature of relationship and failure to consider non-linear effects in designing.

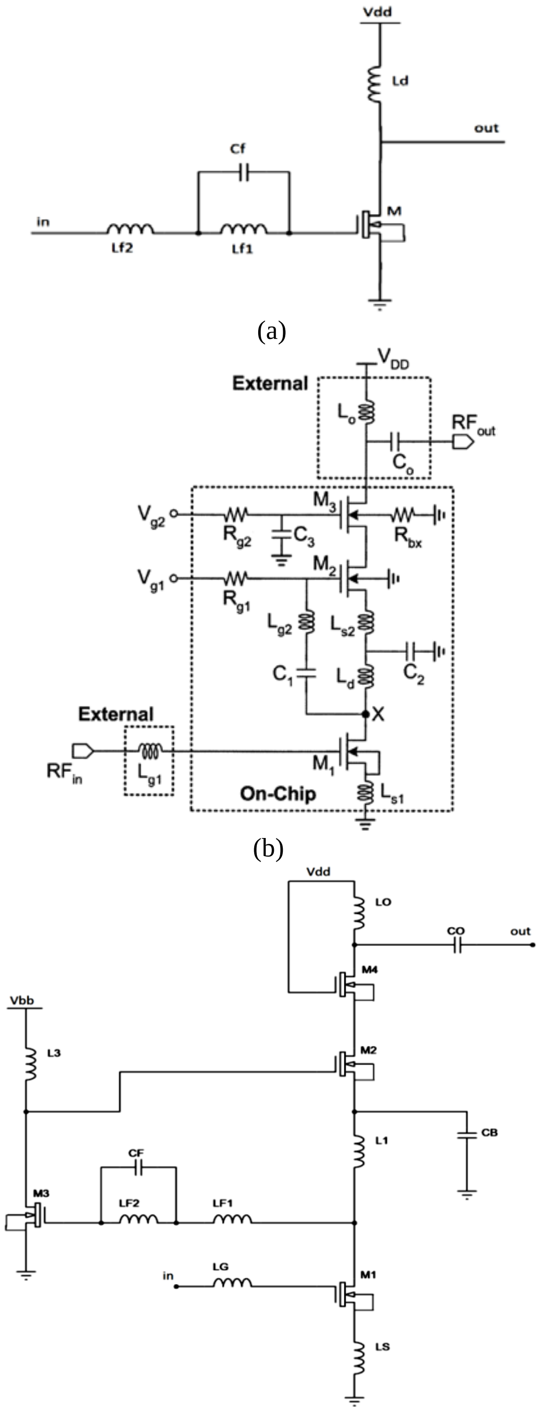
For solving this problem, a proposed CAD with a proposed multi objective genetic algorithm is presented in this paper. In this CAD, any other calculation is not needed and designer just determines the allowed range of parameter changes to increase the algorithm convergence.

This paper is organized as follow: Presenting a LNA with image rejection filter is given in section II. In section III, optimizing multi objective algorithm is presented. Implementing of suggested multi objective genetic algorithm is given in section IV and finally you can see simulation and results in section V.

2. PRESENTING A LNA WITH IMAGE REJECTION FILTER

The usual architecture for RF receivers is heterodyne architecture, which gives us high efficiency and stability. Filtering the image frequency of these receivers is essential; this is usually done by an external SAW (Surface Acoustic Wave) filter. These kinds of filters are big and expensive and incompatible with integration. To overcome this problem, many researches have done. Filtering the image frequency may be done in LNA or before mixer in one or two stages. If we use both of them the image frequency, will be weak. According to "IEEE 802.11a" standard, the amount of the image deletion must be at least 30dB [5-8].

In this proposed plan, the circuit in Fig.1-a is added cascadely to path of the RF signal of a low noise amplifier with a current repeating structure (Fig.1-b),



(a) (b) (c)

Fig. 1. a) Proposed amplifier and filter. b) Low noise amplifier with a current repeating structure [9]. c) Proposed LNA circuit with image rejection filter

this circuit is made up of a common source and a filter (which allows RF frequency to pass and is open circuit in image frequency). Furthermore the path of DC current for bias gate of the transistor must be established. RF frequency and image frequency of the filter will be obtained from following equations:

$$f_{image} = \frac{1}{2\pi.\sqrt{l_{f1}.c_f}} \quad (1)$$

$$f_{RF} = \frac{1}{2\pi.\sqrt{\frac{l_{f1}\, l_{f2}}{l_{f1}+ l_{f2}}.c_f}} \quad (2)$$

The main LNA circuit is obtained by adding Fig.1-a cacadely in path of M1’s drain to M2’s gate (Fig.1-c). This proposed plan weakens the image considerably, furthermore, increases LNA gain without changing the noise figure (NF), output matching and input matching, according to simulation results from section 4. Until now, we have designed the LNA with perfect advantages but we will design and optimize the mentioned plans with a proposed multi objective genetic algorithm. At first, we present a background of this proposed algorithm as follows:

3. OPTIMIZING MULTI OBJECTIVE ALGORITHMS

Most of actual optimizing questions are naturally multi objective. It means that several objects must estimate at the same time. There are two views for solving multi objective optimizing questions. In the first method, we combine objects together, and then give weight to them to change the question to a single objective one. In this condition a certain weight will be given to each objective and objectives with higher priority will be assigned more weight to them. But the problem is that, in actual optimizing questions, objectives have no specific priority to each other. So it is not clear what weight should be allocated to each objective [10, 11]. Another method is using of ″non-dominated″. In this method, each objective is optimized separately, so that we obtain a bunch of non-dominated answers called ″pareto optimal answers ″.None of these answers have any priority to each other, according to all goal functions. So the designer can select each of them on the basis of his need. Multi objective genetic algorithm uses such a technique to optimize multi objective problems .In many of optimizing questions, objectives are in opposition to each other. So the improvement in one may destroy the others. Increasing numbers of ″pareto front ″after a few repeat causes the problem. The result of this increasing is disorder in performance of program. To solve this problem, many algorithms have suggested in recent years. In ″SPEA″ algorithm, that presented by ″ Zitzler ″, the numbers of pareto front preserve in an external archive there will use of a classification algorithm to reduce numbers of pareto front if the numbers of pareto front cross from distinct border[12,13].

The classification is done in this way: the crowding distance between remained non-dominated numbers should be preserved. In fact, those numbers that their similar or close answers are available will be deleted from the cycle. Also ″Deb″ and his colleague introduced a method called ″non-dominated sorting genetic algorithm″ (NSGA2) .this method uses non-dominated ranking for ″elitism″ and implementing of ″population distance″ for preservation of answers crowding[14,15].

4. IMPLEMENTING OF SUGGESTED MULTI OBJECTIVE GENETIC ALGORITHM

In this paper we have used two combined algorithms, SPEA and NSGA2, in following way:
First, we form a random primal N sized population. By using usual operators of genetic algorithm another N members are made. Then all members will be gathered in a new collection with 2N size. Here, a non - dominated classification, similar to NSGA2 should be done. In NSGA2, if the first rank numbers be more than N, the numbers that don't have a good crowding possibility, will be removed until make balance with N. But in this condition we act like SPEA .We keep these numbers into external archives and avoid of pruning them (This act increases the speed of algorithm convergence because most of the time proper answers that have been achieved after several repetitions may be eliminated by pruning). Among the archive members who have more crowding distance, have possibility to make next generation.

As there are complicated and approximate relations to design LNA circuits; designing with these relations is difficult and time-consuming. Therefore, the designer must rely on his own knowledge and tries and errors methods to obtain desirable results. So in this situation for designing and optimizing proposed LNA, we use from a proposed CAD. In this CAD, MATLAB and Hspice RF are linked in order to optimize the LNA Fig.2. Hspice RF simulation is used for evaluating of the fitness of the circuit specifications per every iteration of the GA.

In fact the proposed multi objective genetic Algorithm program is written by MATLAB and the circuit simulated by Hspice RF in this proposed CAD.

5. SIMULATION RESULTS

In this method the parasitic elements are considered according to their layout so the circuit will optimize according to it. Designing parameters in a circuit optimization are: number of turns (loops) and width of circuit inductors, the number of the fingers of the transistors, sizes of capacitors and bias voltages.
The range in which sizes of the elements change is shown in table I, to determine the range of searching of optimization algorithm. The number of bits for coding each parameter is 8.

Table 1. The range in which sizes of the elements

Parameter	Min.	Max.
2R-inductor	40µm	120µ
N-inductor	.25	5
L=W- capacitor	5µm	100µ
NoF(Number of Finger)-transistor	1	64

Here the circuit in Fig.1-a is optimized with two intentions: amplifying the RF frequency and weakening the optimized image frequency. The results of optimizing are shown in Fig.3-a. Each place in Fig.3-a represents an answer; also the contrast between two intentions can be seen in the Fig.3-a. One of these answers and its S21 is presented in Fig.3-b.

The optimizing parameters in suggested LNA (Fig.1-d) are:
Number of turns (loops) and width in the coil of seven inductors, the number of the fingers of 4 transistors with W/L= 8µm/ 0.18µm, width and length of one capacitor, amount of Vdd voltages and the input bias voltages (v bias).

In heterodyne receivers, frequency is normally reduced with 2/3 and 1/3 of fRF in two stages. The operating LNA frequency for WLAN is supposed 5.7 GHz. So in first stage, LO frequency must be 3.8 GHz, and as a result image frequency will be 1.9 GHz. [1]

The goals of designing are: maximizing the amount of gain in operating frequency and minimizing the amount of gain in image frequency; also minimizing the amount of output and input non matching (S11, S22), noise figure, and power consumption.

Operating LNA frequency is 5.7 GHz and image frequency is 1.9GHz. Table II includes the designing results of 4 selected answers of pareto front. The results of Ans.1 in Table II of crowding parameters (S) and NF are shown in Fig.4.Also the compare of this work and previous works is presented in table III.

CONCLUSION

In this paper, we present a new LNA with image rejection filter. Furthermore, after determining topology, we used a suggested multi objective genetic algorithm to optimize structure. So any other calculation is not needed. The answers have not any priority to each other, and designer can select each of them according to his need. Simulation results confirm that; suggested structure weakens the image considerably; it also increases LNA gain without changing the noise figure (NF), output matching and input matching.

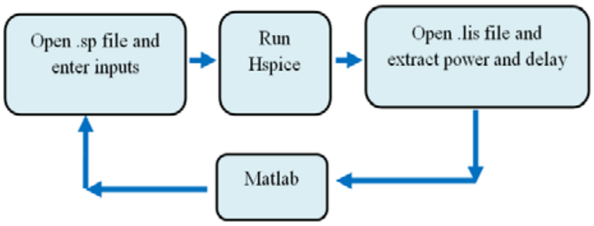
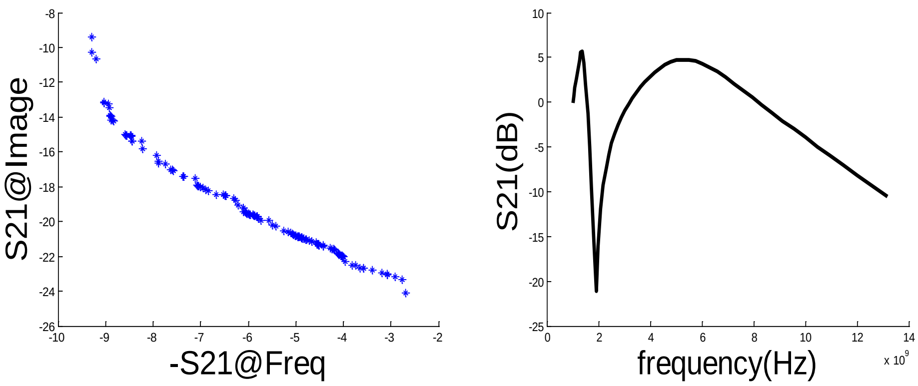
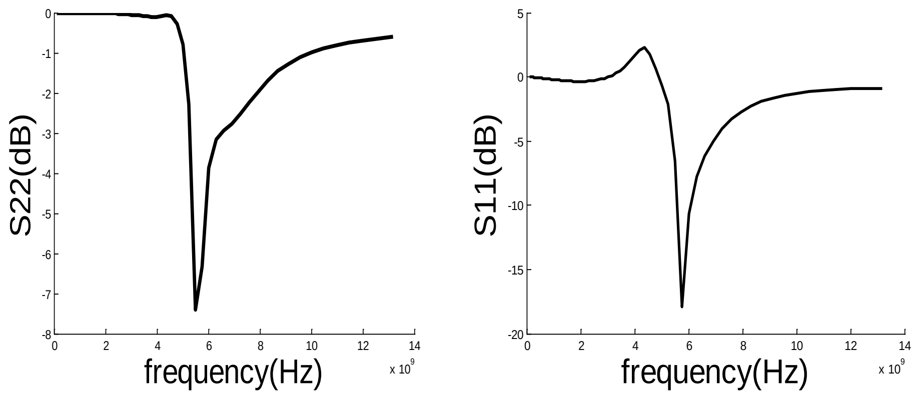


Fig.2. Block Diagram of proposed CAD

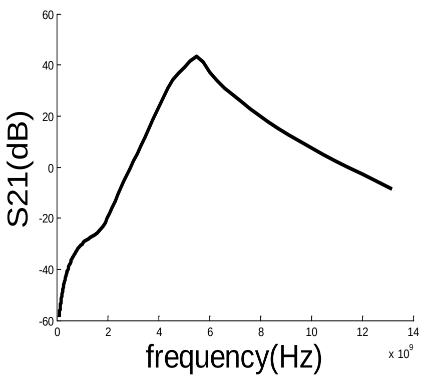


(a) (b)

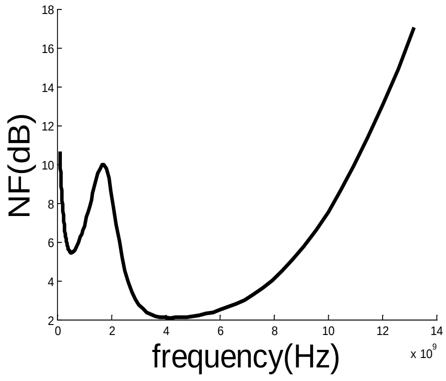
Fig.3. a) The result of Fig.1-a optimization. b) One of the answers (point) of Fig.3-a.



(a) (b)



(c)



(d)

Fig.4. Diagrams of Ans.1 in Table II of (S) and NF .a) S22 b) S11 c) S21d) NF

Table 2. The results of suggested LNA

	Ans. 1	Ans. 2	Ans. 3	Ans. 4
NF-M۱	17	21	22	23
NF-M۲	25	25	61	25
NF-M۳	23	22	22	23
NF-M4	25	47	45	12
N-Lg	3.75	3	3.75	3.75
N-Ls	.25	1	0.25	.25
N-L1	2.25	3.75	2.25	2.5
N-L3	2.5	4.25	2.5	2.75
N-L0	2	2	2	2.5
N-Lf1	2.25	1.5	2.25	.25
N-Lf2	0.25	1	2.25	2.25
N-Ls3	1.25	.25	.25	.75
R-Lg	45	30	30	90
R-Ls	45	45	45	45
R-L1	90	90	90	90
R-L3	45	45	45	45
R-L0	105	90	90	90
R-Lf1	30	30	30	75
R-Lf2	90	30	15	15
R-Ls3	60	60	90	105
LCf (μm)	10	18	21	27
WCf (μm)	25	9	8	7
Vbb	1.18	1.18	1.18	1.11
Vbias	.7	.64	.7	.6
S21 (dB) @Freq	41.47	30.39	32.96	34.1
S21 (dB) @Image	-21.87	-6.53	-9.28	20.83
S11 (dB)	-15.53	-16.49	-1.42	-16.01
S22 (dB)	-6.5	-13.06	-8.97	-17.59
NF (dB)	2.37	2.03	1.95	2.15
Power (mW)	13.46	10.97	18.44	7.69

Table 3. compare with previous work

Reference	Ans.1 of This work	Ans.1 of Cascade LNA with IR[1]	Ans.1 of Differential cascade LNA with IR[1]
S21 (dB) @Freq	41.47	14.1	13.8
S21 (dB) @Image	21.87	-3.44	-11.2
S11 (dB)	15.53	-16.4	-11.2
S22 (dB)	-6.5	-11.7	-15.3
NF (dB)	2.37	2.19	3.07
Power (mW)	13.46	13.8	14

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