Optimal Design of a 6.5GHz Low Noise and High Gain CMOS Low Noise Amplifier By Single Objective Firefly Algorithm

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ABSTRACT:
A high-gain, low-power, highly linear cascode low noise amplifier (LNA) is considered with the circuit of an inductive source degeneration for employing at 6.5 GHz frequency; it is optimized by a capable swarm-based optimizer named firefly algorithm (FA) as an evolutionary method. By optimization of the noise figure (NF) and gain, the FA is useful while verifying all the design restrictions, e.g., the input and output matching, inverse isolation, linearity and power dissipation. Two situation studies have been accomplished for minimization of NF and maximization of gain. These two parameters optimization have been carried out by considering all parameters, for instance, a single objective function. The FA-based optimal consider parameters are used to perform the circuit of the CMOS LNA in ADS software at the UMC 0.18 μm CMOS technology node with a 1.8 V supply voltage. The FA performance in optimizing the LNA parameters is also compared with the performance of other similar contemporary algorithms like particle swarm optimization (PSO), human behavior PSO (HB- PSO), backtracking search algorithm (BSA) and cuckoo search algorithm (CSA). The optimized LNA parameter value using the FA, and other algorithms which simulated in MATLAB environment is compared with the simulated result of the ADS software. Statistical analysis is also performed for each situation study, and the results are compared with the above-mentioned optimization algorithms. Simulation results, comparative study, and statistical analysis approve the FA advantage over the other methods in expressions of its computational efficiency and consistency.

KEYWORDS: Firefly Optimization; Low Noise Amplifier; particle swarm optimization; Single Objective Function

1. INTRODUCTION

The first gain stage of the receiver is Low noise amplifier (LNA). It must fulfill abundant qualifications at the same time, which makes its consider and arrangement challenging. The signals coming from the receiver antenna are very weak; therefore, signal amplification is needed previously feeding it in to the mixer. This process sets the necessity of a definite gain to the LNA. The received signals must have a certain Signal to Noise Ratio (SNR) to allow suitable detection. Subsequently, the noise which added through the circuit of LNA should be decreased as much as possible [1]. A huge interference signal or blocker can occur at the LNA input. The components should be correctly linear to have a logical signal reception. For mobile applications, moderate power dissipation is another restriction. Up till now, printed CMOS-based wideband amplifiers are implemented in several constructions [2]. The optimal LNA design is both complex and time-consuming work as the circuits parameters are to be optimized through required design specification [3]. Space restraint and budget aspects are the chief anxiety of the present technology, and from this time, to encounter these requirements, some functional experiments and analysis of designed circuits are accomplished through designers with using design software of the computer. Adjustment of tunable parameter manually is time-consuming, and it also requires highly trained employees. With the aim of avoiding these difficulties, in recent years, many researchers have tried to optimize numerous LNA parameters using different optimization methods. Now a days optimization acting an active part in the scientific research field and manufacturing requests. Numerous classical optimization methods, for example, gradient search methods, quadratic programming, linear programming [4], Newton's method, Nonlinear programming [5], etc., are employed to solve the composite engineering problems. These algorithms use gradient information to search solutions close primary point to have the

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higher propensity to setup into local optima. Additionally, these algorithms are capable of solving simply constant problems. An alternative algorithm based on the magnetic field [6] are regarded which sideways through forces of electrical, forces of magnetic is considered to make available valuable data for the optimization method. As far as the engineering problems are anxious, the most of them are highly non-smooth, non-convex, non-linear or discrete problems. Recent engineering optimization problems cannot be solved satisfactorily due to above mentioned confines of classical optimization methods. Consequently, as a substitute, researchers have on the go applying problems by meta-heuristic optimization methods. These algorithms are typically population-based and explore the feasible area to search for the global or near-global solution for the requisite objective function. They have no limitations on the objective function nature. The key features of these algorithms are that they do not need derivative of the objective functions and limitations associated with it. They are administered through some mathematical equations inspired via natural laws. These algorithms work on the randomization process and provide more accurate consequences than that of classical optimization methods. Local search [7], genetic algorithm [8], particle swarm optimization (PSO) [9], human behavior particle swarm optimization (HB-PSO) [10], cuckoo search algorithm (CSA) [11], simulated annealing (SA) [12], ant colony algorithm (ACA) [13], backtracking search optimization [14], bacterial foraging [15], gravitational search algorithm (GSA) [16] are some of the samples of commonly used meta-heuristic algorithms that are predominantly used to solve different engineering problems. In current years, researchers have tried to optimize LNA parameters through nature-inspired algorithms. To optimize various electrical parameters like S_{11} (Input reflection coefficient), S_{22} (Output reflection coefficient), S_{21} (Voltage gain), S_{12} (Reverse isolation coefficient), and NF (noise figure). Lately, several authors have also reported the optimized design LNA parameter via PSO [17-18]. In this paper, authors have tried to optimize the LNAs NF and gain as a single objective function. A universally accepted optimizer named firefly algorithm (FA) [19] is advanced to optimize the LNA parameters such as NF and gain. In the present work, NF is minimized, whereas the gain is maximized, incorporating entirely necessary design limitations. Former parameters like S_{11}, S_{12}, S_{22}, and linearity are also obtained for each case study. Parameters NF and gain are optimized as the single objective function. The collected works disclose that FA has not been utilized till date to optimize the above-mentioned LNA parameters. From now, the current work is the original attempt to optimize the LNA parameters through FA. The suggested work is simulated in MATLAB version 2014b, and ADS Spectre, UMC, 0.18 μm technologies. The remaining sections are prepared as follows: Section 2 defines the CMOS LNA design. Section 3 describes the firefly procedure. In Section 4, its execution in optimizing several LNA parameters are argued in feature. In Section 5, several results attained from designed LNA simulated at 6.5 GHz. In Sections 6 and 7, various optimization methods are argued, associations have been prepared. Conclusion of this paper and addressing association of the suggested method by supplementary printed CMOS UWB LNA works are provided in Section 8.

2. CMOS LNA DESIGN

" Fig 1" is shown the circuit of LNA for optimization consideration which operating frequency is 6.5 GHz where L_g, L_s, and L_d are gate, source, and drain inductors, respectively. These inductors are entirely on-chip spiral inductors. They convention in the designed LNA is assumed as follows: 1. The importance of the input capacitance is regulated by L_g, 2. input matching is reached by implementing L_s. 3. L_d is working to have output resonance with output capacitance and, more significantly, to have a LNA taking great gain. M_1 and M_2 are the input and the cascoding devices, respectively [20]. M_2 is used to deliver isolation among regulated output and regulated input. Moreover, M_2 decreases the influence of C_{gd} of M_1, which can be an actual problem. The first phase in designing any LNA is to allocate the standards of M_1 and C_{gs}, by considering both noise into account and bias current [21-23]. The wanted input resistance can be developed by appropriately choosing the principles of L_g and L_s. M_3 and R_1 arrangement a bias circuit where MOSFET M_3 fundamentally arrangements a current mirror through M_1 [22], and its width is prepared nearby one-tenth of the M_1 width to decrease the bias circuit power dissipation. For blocking of DC, C_{in} and C_{out} are accustomed.

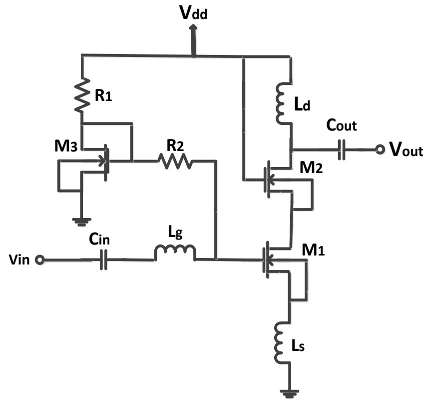

Fig 1. General schematic of the LNA

3. FIREFLY ALGORITHM PROCEDURE

In 2007 the firefly procedure was advanced by Xin-She Yang, which is based on the flashing behavior and the food searching manner throughout the night. After meticulous fireflies studies, Yang experiential that throughout the food searching manner, a fireflies collection straight themselves headed for the firefly which has extra bright. This process helps in shortening the distance among two fireflies. This was the main observation seen through Xin -She Yang, which helps him in developing the mathematical type of updating the firefly locations. The flashing light emitted by the use of the firefly is the means of relation among them. There are approximately two thousand firefly types accessible, and the pattern of flashes is different for the distinct species. They mostly release two kinds of light, one for representative the obtain ability of food source and other for the mating aim. FA has expanded much popularity due to its simple implementation manner and parameter plausibility. The real demonstration of the performance of any natural species into a mathematical typical is an onerous duty, therefore, for simplicity, Yang prototypes three primary directives for the FA development [19].

1. Every single firefly will appeal one another irrespective of their sexes regardless as they are unisexual.
2. Brightness and appeal are prepared straight relative. Therefore, minimum bright firefly will be fascinated to the brighter one. Similarly, distance and brightness are inversely proportional. Firefly will change accidentally if none of them found brighter.
3. A firefly brightness is the suitability of the objective function; consequently, for a maximization problem, the brightness may merely be proportional to the value of objective function and vice versa assessment. Exploiting the above-stated instructions, the degree of attractiveness β of the firefly algorithm can be stated as:

$$\beta = \beta' e^{-\gamma r^2} \quad (1)$$

where r denotes the distance among two fireflies, γ is the light preoccupation coefficient. At $r=0$, the degree of attractiveness is definite via β'. A brighter firefly virtually has more intensity (I) than the less bright firefly; from now for any maximum optimization problems [18], the brightness I of a firefly at a specific position x can be selected as $I(x) \alpha F(x)$. It can moreover be supposed that the degree of attractiveness acquires deviated through the absorption from its source, and by the side of the similar time, some light is absorbed by the media. In a simplified form, it can be definite that light intensity $I(r)$ varies as the inverse-square law and can be denoted such as:

$$I(r) = \frac{I'}{r^2} \quad (2)$$

Where I' signifies the intensity at the source. When a medium has a secure light absorption coefficient γ, then the intensity of light (I) deviates through distance (r) that is stated such as:

$$I = I'' e^{-\gamma r} \quad (3)$$

The distance among the two fireflies i and j through their locations X_i and X_j, respectively, can be signified such as [24]:

$$r_{ij} = |X_i - X_j| = \sqrt{\sum_{k=1}^{d} (X_{i,k} - X_{j,k})^2} \quad (4)$$

In this procedure, the brighter or more attractive firefly (j) has the power to attract the motion of another firefly (i) and is definite via [25]:

$$X_i = X_i + \beta' e^{-\gamma r_{ij}^2} (X_j - Xi) + \alpha \left(rand - \frac{1}{2} \right) \quad (5)$$

Where current value is indicated through X_i. The term $\beta' e^{-\gamma r_{ij}^2} (X_j - Xi)$ is for the reason of the attraction while the last term $\alpha \left(rand - \frac{1}{2} \right)$ happens as a result of the random choice of a sample from a population through α taken as randomization variable. Now, "rand" is random number generators that are uniformly distributed within $[0,1]$. Principally, in this execution, β' is occupied as 1 and $\alpha \in [0,1]$. An essential graphical a firefly procedure illustration is shown in "Fig 2".

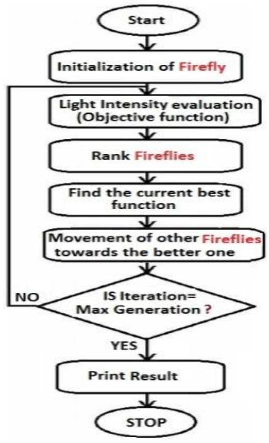

Fig2. FA Procedure Diagram

4. IMPLEMENTATION OF FA FOR LNA PARAMETER OPTIMIZATION

For the suggested optimization problem, the parameters should be supposed carefully, are the MOSFET width, gate, source and drain inductors, input and output capacitors. Entirely these parameters or regulator variables are continuous in nature. Exploration space comprise the place of fireflies that represents the control variable. The locations of each firefly represent design variables in the definite exploration space. Initialization of the fireflies location is completed over random production by equation said below:

$$x_i = x_i^L + rand\left(x_i^U - x_i^L\right) \quad (6)$$

where "rand" is the uniformly distributed random number among 0 and 1. x_i^U and x_i^L are the upper and lower ranges of control variables, respectively. After variables initialization, these are accustomed to compute the objective function assessment. In natural expressions, it is the fireflies' light intensity. In this suggestion, two design objectives are careful specifically NF and power gain. All fireflies are arranged and organized as stated by their light intensity. In this work, NF requirements to be minimized, therefore for this condition, organization is completed in ascending order, while gain requirements to be maximized, therefore the ability is organized in descending order. Firefly, which is at the top of the population can be considered as best individual for that iteration. Locations of fireflies are updated as (5). The value of the parameters of firefly accustomed in (5) is mentioned in "Table 1".

Table 1. Optimization factors settings during of designs

Factors	Alpha (α)	Beta (β)	Gama (γ)	Pop. Size	Max repetition
Value accustomed	0.8	0.2	1	50	500

After informing the fireflies location, it can be potential that the new location is outside their definite restrictions. Therefore, the restricted checking is practical after each updating procedure. This can be completed in subsequent approach:

If
$((V_i) > (V_{i-\max}))$
$(V_i) = (V_{i-\max})$
else
if
$((V_i) < (V_{i-\min}))$
$(V_i) = (V_{i-\min})$
else
$(V_i) = (V_i)$

where (V_i) is the ith control variable and $(V_{i-\max})$ is the ith control variable upper restrict. $(V_{i-\min})$ is the ith control variable lower restrict [25]. The best firefly's location is demonstrated equivalent to the optimized objective functions value. This is the complete procedure for the one specific weight. After getting the optimized all the objective functions value mentioned above, weight is altered and another optimized value is recorded. Compromised solution can be established by describing the precedence of the objective function.

5. RESULTS AND CONVERSATION

5.1. NF Analysis

NF is the extent of degradation of signal-to-noise ratio (SNR). Deprivation is chiefly due to the components available in the RF signal chain. In MOS transistor, noise is principally rules through the active device's inherent portion. Together M_1 and M_2 in LNA are reliable for generating noise, but the role of M_2 is very insignificant in association with M_1. If the NF value is high, the amplifier will face trouble in setting apart noise, and weak signal took via the antenna. This can lead to the loss of originality in the informative signal. From this time, for the recovering execution of an amplifier, NF ought to be as small as probable. Thus, it is significant for the LNA designers to optimize the value of NF gratification totally the restrictions for its consistent and proficient task. For RF, the noise is mostly as a result of its thermal noise component. Subsequently the NF mathematical appearance is too great; it is hard to denote trendy this work.

5.2. Restriction

Maximum power transmission from the antenna to LNA happens merely when LNA input and output are corresponding. So, with the purpose of attaining this, following equality restriction should be deliberated:

$$L_s = \frac{R_s C_{gs}}{g_m} \quad (7)$$

$$L_g = \frac{1}{\omega_0^2 C_{gs}} - L_s \quad (8)$$

Where g_m, ω_0 and C_{gs} are the MOS transistor M_1 transconductance, the frequency in radians and the gate to source capacitance, respectively. At this point $\omega_0 = 2\pi f_0$ where $f_0 = 6.5GHz$. The consequence factor way [21] is exploited to give the quality restriction stated in (7) and (8).

Table 2. Proposal variable and their acceptable ranges for NF and Gain

Parameter	*unit*	*Lower range*	*Upper range*
W_1	μm	100	300
W_2	μm	100	270
R_2	$k\Omega$	2	3.5
L_g	nH	2	5
L_S	nH	0.2	0.9
L_d	nH	1	3

6. CASE STUDY 1: NF MINIMIZATION

This case study exhibits the NF minimization. In "Fig 1"the circuit accustomed for optimization aim is shown. Results are associated with four distinctive algorithms like particle swarm optimization (PSO), human behavior PSO (HB-PSO), backtracking search algorithm (BSA) and cuckoo search algorithm (CSA). In "Table 2" the control variables ranges are shown. "Tables 3" and "4" signifies optimized designed parameters value got through distinctive algorithms containing FA and the objective function standards for distinctive algorithms, respectively. From " Table 4", it can be understood that the optimized value NF attained by FA is minimum, i.e., 1.4944 dB as associated with other algorithms. It can moreover be distinguished that FA provides 8.05%, 6.85%, 5.79% and 1.89% less NF when associated by PSO, HB-PSO, BSA and CSA, respectively. The convergence time of these algorithms is moreover shown in "Table 4" in which it can be understood that FA receipts minimum time to converge, although HB-PSO profits maximum time to achieve its universal optima. It can be thought that the calculative FA efficiency is much better than other recent algorithms existing for comparison. For the similar design parameter, a value attained for NF by ADS tool is moreover on the condition that in "Table 4". "Fig 3" represents the convergence scheme for NF attained through FA. The figure represents the convergence attained at, less than tenth iteration that displays the algorithm advantage in designate of its calculative time. In "Fig 4", the bar diagram depiction of the percent saving of NF through FA when associated through other algorithms is correspondingly obtainable. With the purpose of algorithm check the consistency, 50 trial runs are reserved for each algorithm, and it is established that the FA successes maximum time to the optimal value, which shows that the algorithm is significantly consistence and does not deviate much from its optimal value. The trial run chart for different algorithms are set in "Fig 5". "Table 5" displays the statistical analysis of different algorithms accustomed to improving NF.

Table 3. Optimized project variables

Parameter	*PSO Suggested value*	*HB-PSO Suggested value*	*BSA Suggested value*	*CSA Suggested value*	*FA Suggested value*
W_1 (μm)	207	216	213	211	217
W_2 (μm)	153	176	174	209	172

R₂ (kΩ)	2.7	2.49	2.43	2.6	2.5
L_g (nH)	4.28	3.93	4.25	4.18	3.45
L_S (nH)	0.45	0.44	0.48	0.45	0.41
L_d (nH)	2.35	2.28	2.2	2.18	2.41

Table 4. Values of PSO, HB-PSO, BSA, CSA and FA

Objective	*PSO*	*HB- PSO*	*BSA*	*CSA*	*FA*
NF	1.6253 dB	1.6043 dB	1.5863 dB	1.5233 dB	**1.4944 dB**
CPU time (s)	44.239	51.234	48.43	38.99	**30.95**
Associations of PSO, HB-PSO, BSA, CSA and FA in ADS tool					
NF	2.136 dB	1.956 dB	2.026 dB	1.836 dB	**1.776 dB**

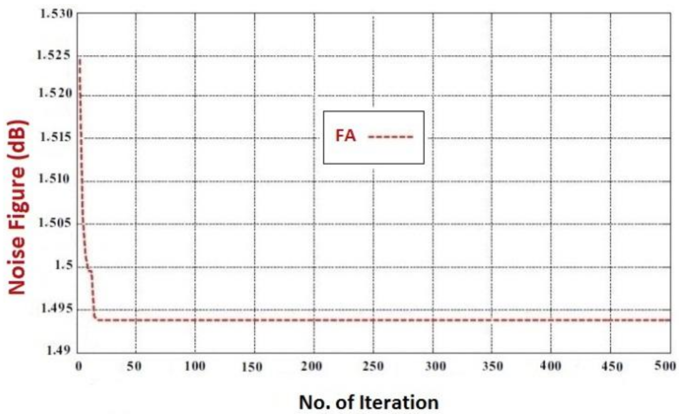

Fig 3. Convergence chart for NF achieved by FA

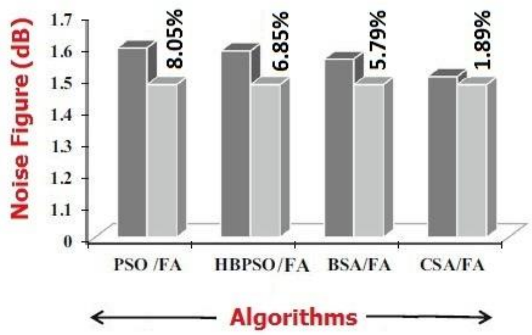

Fig 4. Comparative analysis of FA with other algorithm

It can be perceived from the table that FA has the standard deviation (SD) as 0.0665, which is less than entirely other approaches accepts PSO that has the SD of 0.0579. The SD of PSO is the best between entire methods, but the hits number to the optimal value is very high in the FA situation. Moreover, the worst, along with the mean FA value, is better than other methods. From the above results, it can be determined that the suggested method is robust and coherent in its performance.

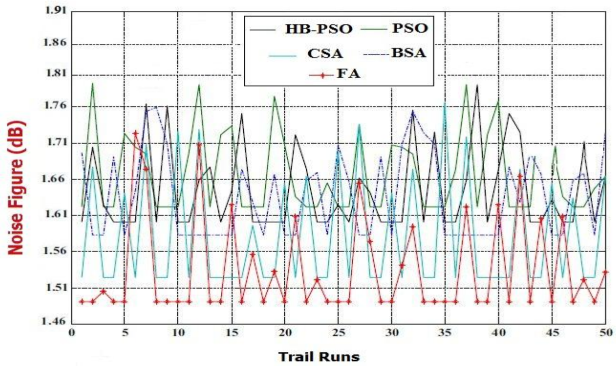

Fig 5. Trial run chart for NF achieved from five algorithms

Table 5. Statistical analysis NF for case 1

Approaches	*Worst*	*Best*	*Mean*	*Standard deviation*
PSO	1.792	1.6253	1.6697	**0.0579**
HB-PSO	1.791	1.6043	1.6459	0.0677
BSA	1.759	1.5863	1.6376	0.0672
CSA	1.766	1.5233	1.5822	0.0801
FA	1.723	1.4944	1.5362	**0.0665**

6.1. Simulated results acquired by ADS

In this part, simulation results for NF and other LNA parameters acquired via ADS have been exposed. NF is a quantity of the SNR reduction. For a good amplifier, it should be as small as probable. "Fig 6 "displays the NF of the FA founded optimized LNA. In this work, NF of 1.776dB is attained at 6.5GHz frequency. S_{11} is identified as input refection coefficient, which distinct how much event power is returned back to the source from the amplifier. "Fig7" displays the variant of S_{11} with admiration to the frequency. The value achieved for S_{11} is -10.3dB which expressions good input matching. "Fig 8" denotes the S_{21} value at distinctive frequencies. The attained S_{21} value consistent to minimum NF is establish to be 19.371dB. S_{22} is recognized as output refection coefficient. "Fig 9" demonstrations the S_{22} value at distinctive frequencies. From the simulation of the designed LNA, the S_{22} value is established to be -15.82dB that displays good output matching. In the same way, the S_{12} variation by the side of specific frequencies is shown in "Fig 10". The value achieved for S_{12} is -39.09dB. The acquired results displayed that the LNA is perfectly calculated to minimize NF, and the designed parameter conforms the restrictions by the side of the minimum NF value.

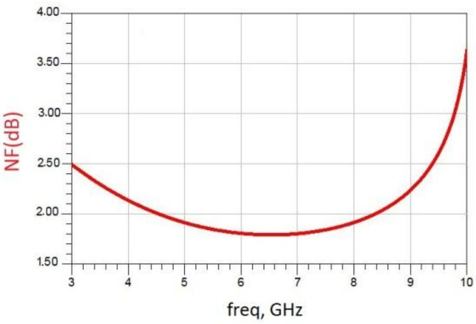

Fig 6. Simulation result of NF

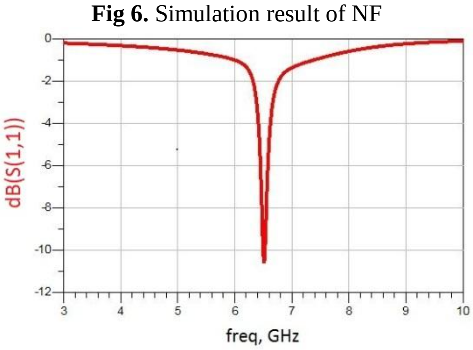

Fig 7. Simulation result of S_{11}

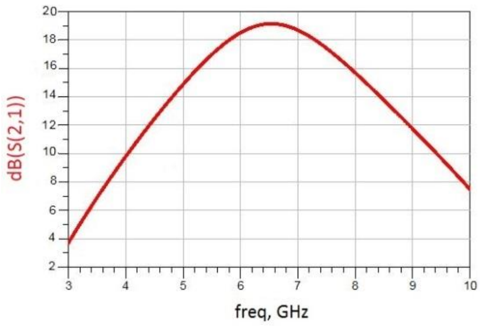

Fig 8. Simulation result of S_{21}

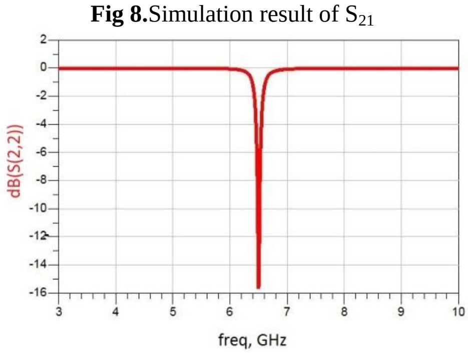

Fig 9. Simulation result of S_{22}

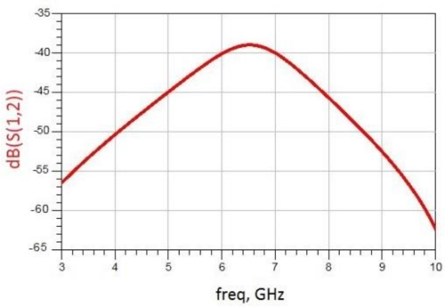

Fig 10. Simulation result of S_{12}

The execution of the designed LNA is moreover explored under procedure variations and incompatibility by Monte Carlo (MC) exploration over 250 samples in "Figs 11 and 12". "Table 6" lists the worst, best, mean of the execution parameters attained from the MC simulations. The MC simulations prove that the designed LNA execution parameters do not require alteration considerably under incompatibility or procedure variations. To confirm the designed LNAs schematics act and its ability for employment, the comprehensive layout of the suggested LNA is executed that is showed in Fig. 13. It occupies 295.73 µm×375.24µm silicon die areas. As established in Fig. 14, simulation and post-layout results of the NF are established in this figure. The post-layout results of the NF are 2.12dB. Fig.14 demonstrates the good matching among simulation and post-layout results.

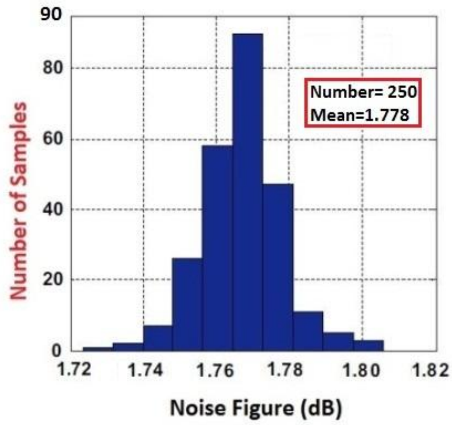

Fig 11. The histograms of NF in the MC simulations

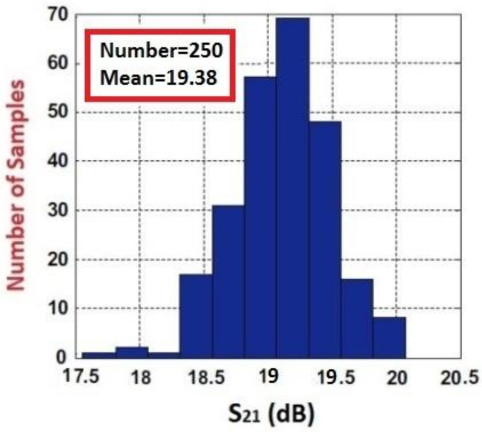

Fig 12. The histograms of S_{21} in the MC Simulations

Table 6: The Monte Carlo exploration over 250 samples

Approaches	*Worst*	*Best*	*Mean*
NF	1.806dB	1.728dB	1.778dB
S_{21}	17.63 dB	20.38dB	19.38dB

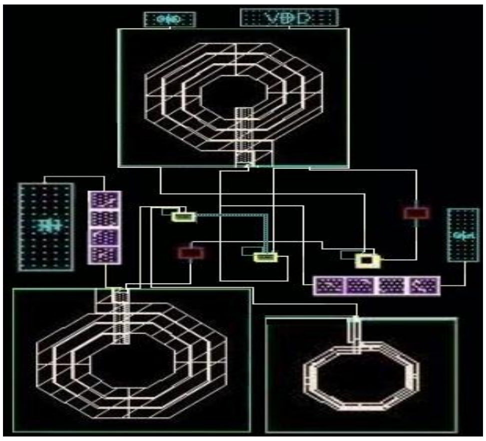

Fig 13. The Layout of the suggested LNA

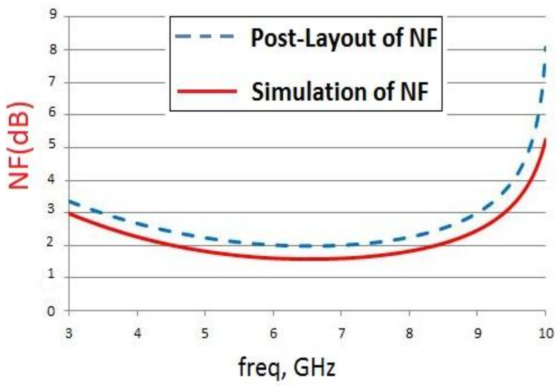

Fig. 14. Simulation and Post-layout of NF

7. CASE STUDY 2: GAIN MAXIMIZATION

Gain is commonly defined as the ratio of the amplitude of the output signal to that of the input signal. Mainly, it is the quantity of an amplifier's capability to grow up the amplitude of a signal. Mostly, the signal power received through the antenna is feeble and causes unhealthy transfer. From this time, it is the greatest significance for the design engineers to maximize the amplifier gain for the operative and consistent transfer. If an amplifier gain is high, the power of the feeble signal conventional through the antenna will rise, which subsequently leads to the healthy transfer. Furthermore, the LNA high gain causes a decrease in the receiver NF that is alternative most significant cause of the gain maximization. The gain's appearance is not given due to its large number of terms. This case study exhibits the gain maximization through substantial the restriction is specified in (7) and (8). The circuit accustomed for optimization aim is shown in "Fig 1". FA is accustomed to optimize the objective function. Outcomes are compared via four different algorithms as PSO, HB-PSO, BSA and CSA. The ranges of control variables are shown in "Table 5". In this case, besides, the penalty-based way is accustomed to treat the specified equivalence restrictions. "Tables 7" and "8" denote optimized considered parameters values attained through different algorithms excluding FA and the objective function standards for different algorithms, respectively. From "Table 8", it can be understood that the optimized value gain attained through FA is maximum as associated with other algorithms. From this Table, it can be understood that the time reserved by FA is much less than the other algorithms. For the comparable design parameter, a value attained for gain gotten with ADS tool is similarly providing in "Table 8". Time reserved through different algorithms in optimizing the parameters is similarly shown in this table. It can be perceived that the FA takes less time for convergence than any other state-of-the-art algorithm accustomed to optimize the identical objective. The FA convergence chart is shown is "Fig 15". Fifty trial runs are taken for each algorithm to report the best solution. The variations in gain with admire to trail runs are calculated in "Fig 16". To check the algorithm robustness in optimizing gain, statistical analysis is moreover executed and obtainable in "Table 9". It can perceive that though the standard deviation, the FA is somewhat greater than that of the PSO, but it is less than the other algorithms.

Table 7: Optimized variables for case-2

Parameter	*PSO Suggested value*	*HB-PSO Suggested value*	*BSA Suggested value*	*CSA Suggested value*	*FA Suggested value*
$W_1\,(\mu m)$	223	231	227	237	230
$W_2\,(\mu m)$	160	165	162	172	180
$R_2\,(k\Omega)$	2.22	2.15	2.51	2.19	2.31
$L_g\,(nH)$	3.89	3.66	4	3.59	3.81
$L_S\,(nH)$	0.52	0.52	0.53	0.49	0.48
$L_d\,(nH)$	2.42	2.45	2.22	2.51	2.61

Table 8: Value of the PSO, HB-PSO, BSA, CSA and FA

Objective	*PSO*	*HB-PSO*	*BSA*	*CSA*	*FA*
Gain	20.02 dB	20.27dB	20.35dB	20.4 dB	**20.509 dB**
CPU time (s)	18.07	22.46	17.21	15.43	**10.22**
Comparisons of PSO, HB-PSO, BSA, CSA and FA in ADS tool					
Gain	18.42 dB	18.77 dB	19.07 dB	19.3 dB	**19.84 dB**

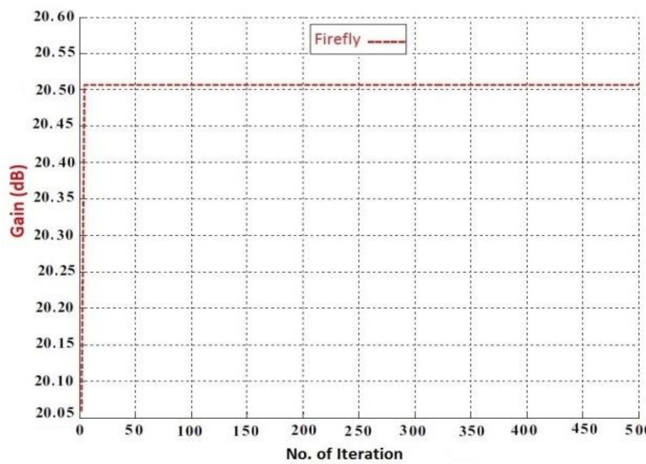

Fig 15. Convergence chart for Gain achieved by FA

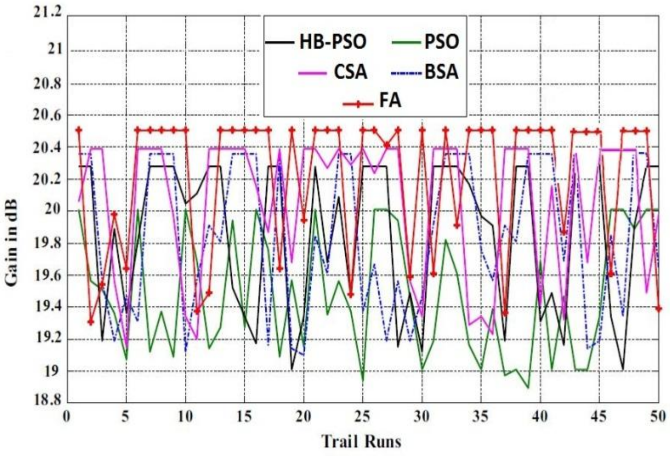

Fig 16. Trial run chart for Gain achieved from different algorithms

Table 9: Statistical analysis Gain for case -2

Procedures	*Worst*	*Best*	*Mean*	*Standard deviation*
PSO	18.88 dB	20.02 dB	19.48 dB	**0.399**
HB-PSO	19.02 dB	20.27 dB	19.87 dB	0.465
BSA	19.14 dB	20.35 dB	19.83 dB	0.475
CSA	19.20 dB	20.4 dB	20.05 dB	0.442
FA	19.31dB	20.509 dB	20.21 dB	**0.437**

7.1. Simulated results acquired by ADS

In this section, design resolution achieved through FA is employed to obtain the LNA parameters such as S_{21}, NF, S_{11}, S_{22}, and S_{12}. Their variations are shown in "Figs 17, 18, 19, 20 and 21", respectively. From "Fig 17", it can be understood that the S_{21} value, is 19.84dB that is maximum at 6.5GHz frequency. Correspondingly, the NF value relates to the same solution is attained as 1.886dB. The chart attained from the ADS for NF is displayed in "Fig18". The other parameters variations as S_{11}, S_{22}, and S_{12} are correspondingly exist in "Figs 19, 20, and 21", respectively. Their consistent values are attained as -25 dB, -17.5dB, and -40.1dB, respectively.

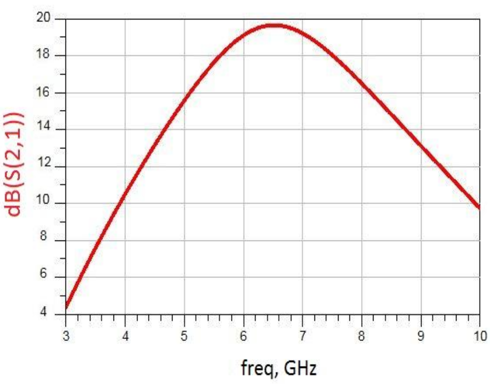

Fig17. Simulation result of S_{21} (case-2)

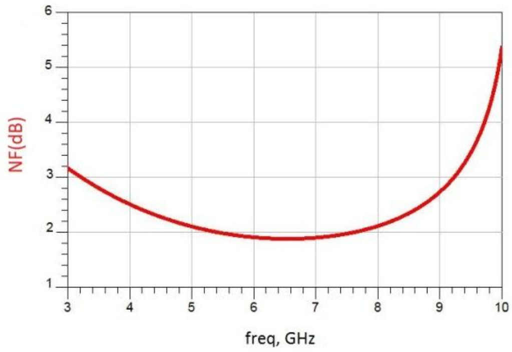

Fig18. Simulation result of NF (case-2)

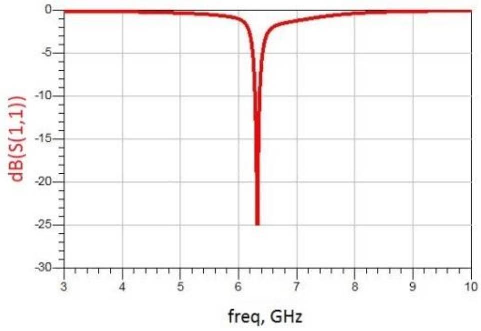

Fig19. Simulation result of S_{11} (case-2)

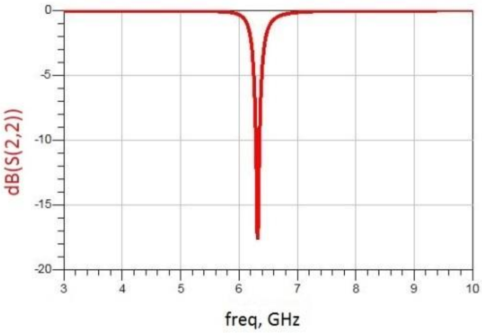

Fig 20. Simulation result of S_{22} (case-2)

Fig21. Simulation result of S_{12} (case-2)

The other LNA parameters similar power consumption (PC), and linearity are furthermore correspondingly significant as far as an amplifier project is anxious. These parameters involve variation through the variation in both NF and gain. The value of PC and linearity, attained from ADS software match up to minimum NF, and Maximum gain is shown in "Table 10". The designed LNA execution is correspondingly explored under procedure variations and incompatibility utilizing Monte Carlo (MC) exploration over 250 samples in "Figs 22" and "23". Table 11" lists the worst, best, mean of the execution parameters attained from the MC simulations. The MC simulations exhibit that the designed LNAexecution parameters do not require alteration considerably under incompatibility or procedure variations. To confirm the schematics act of the considered LNAs and their ability for employment, the comprehensive suggested LNA layout is executed that is showed in Fig. 24. It occupies 240.23 µm×327.24 µm silicon die areas. As established in Fig. 25, the post-layout results of the peak gain is 18.12dB. Fig.25 demonstrates the good matching among simulation and post-layout results.Table 12, sum up the act of recently printed CMOS UWB LNAs.

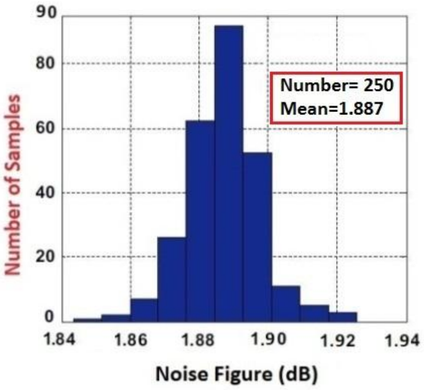

Fig 22. The histograms of NF in the Monte Carlo Simulations (case-2)

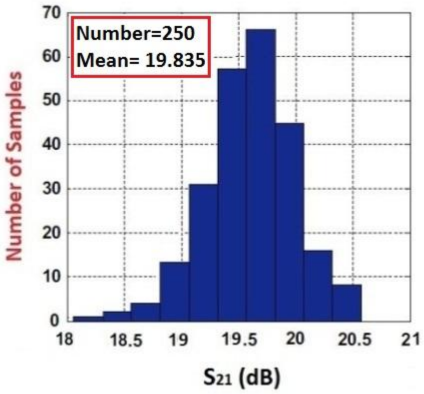

Fig23. The histograms of S_{21} in the Monte Carlo Simulations (case-2)

Table 10: Assessments of consumption IIP_3, VDD and Power

Parameters	*Technology (µm)*	*IIP_3 (dB_m)*	*VDD (V)*	*P_{diss}(mW)*
Case-1	0.18	-8	1.8	10
Case-2	0.18	-7.6	1.8	10

Table 11: The monte carlo exploration over 250 samples (case-2)

Procedures	*Worst*	*Best*	*Mean*
NF	1.928dB	1.848dB	1.887dB
S_{21}	18.15dB	20.7dB	19.835dB

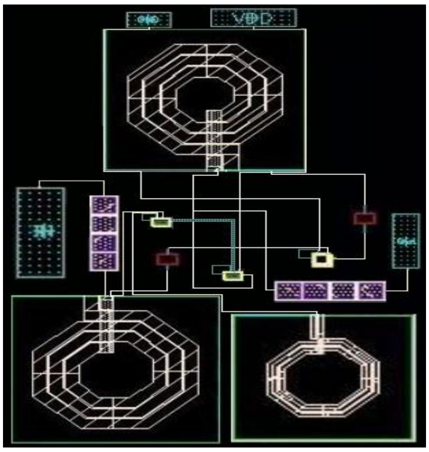

Fig 24. The Layout of the suggested LNA (case-2)

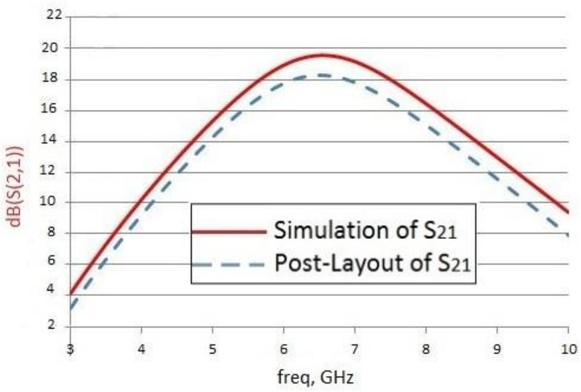

Fig. 25. Simulation and Post-layout of S_{21} (case-2)

8. CONCLUSION

In this paper, the exceedingly efficient algorithm from the swarm family called firefly is accustomed to optimize the two LNA parameters (NF and gain). The optimized LNA has a NF of 1.4944dB at frequency of 6.5GHz frequency that is attained from FA. When simulation result utilizing by the ADS software, the values of NF, S_{21}, and S_{11} are originate to be 1.776dB, 19.371dB, -10.3dB, respectively. The simulated results attained accustomed MATLAB with the PSO, HB-PSO, BSA and CSA are associated with that of the FA and observed that results obtained from FA are found to be better than the above-stated algorithm. The optimization of LNA with FA has a gain of 20.509dB at 6.5GHz frequency. When simulated with ADS software, the values of S_{21}, NF, S_{11}, and S_{22} are institute to be 19.84dB, 1.886dB, -25dB and -17.5dB, respectively. The simulated results attained from FA are associated with PSO, HB-PSO, BSA and CSA. Results attained from FA are established to be better than the other procedures in terms of consistency and search capability. Statistical analysis approves the FA robustness in resolving this kind of restrictions optimization difficulty. From the execution analysis, it can be thought that FA can be practical in the future to solve numerous such engineering optimization problems.

Table 12: Association of the suggested method by other printed CMOS UWB LNA

Ref.	[24][a]	[24][b]	[25][c]	[26]	[27]	[28]	[29][d]	[30][d]	**This Work**[a]	**This Work**[b]
Technology	0.18µm	0.18µm	0.18µm	0.09µm	0.18µm	0.18µm	0.13µm	0.18µm	**0.18µm**	**0.18µm**
Freq. (GHz)	5.5	5.5	5.5	2.4	5.5	2.4	2.4	4.4	**6.5**	**6.5**
S_{11}(dB)	-12.75	-26.35	-36.65	-18.7	-26.10	-14.63	-	-37	**-10.3**	**-25**
S_{22}(dB)	-23.46	-12	-22.62	-15.2	-23.31	-11.55	-	-42	**-15.82**	**-17.5**
S_{21}(dB)	22.37	22.84	22.15	27.6	17.19	32	12.6	12.52	**19.371**	**19.84**
S_{12}(dB)	-34.09	-34.82	-	-	-	-58.44	-	-	**-39.09**	**-40.1**
NF(dB)	0.76	0.87	1.16	1.07	1.24	0.518	3.2	1.8	**1.776**	**1.886**
P_{diss}(mW)	10.8	10.8	10.8	9.12	10.8	6.82	0.869	-	**10**	**10**
IIP_3(dB_m)	-7.2	-6.9	-2.6	-10.1	-	-14.7	-9.1	-	**-8**	**-7.6**
Consequences	Simulated	Simulated	Simulated	Simulated	Simulated	Simulated	Simulated	Simulated	**Simulated**	**Simulated**

[a] Case 1: Minimization of NF in Single- Objective FA Algorithm
[b] Case 2: Maximization of Gain in Single- Objective FA Algorithm
[c] Multi-Objective FA Algorithm
[d] Particle Swarm Optimization Algorithm

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