R.T.
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

HONEY BEE MATING OPTIMIZATION ALGORITHM APPLIED TO DESIGN LOW NOISE MICROSTRIP AMPLIFIER

PEYMAN MAHOUTI

MSc. THESIS
DEPARTMENT OF ELECTRONICS AND COMMUNICATIONS ENGINEERING
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ADVISOR
PROF. DR. FİLİZ GÜNEŞ

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A thesis submitted by Peyman MAHOUTI in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** is approved by the committee on 18.12.12 in Electronic and Communication Engineering Department, Communication Engineering Program.

Thesis Advisor

Prof. Dr. Filiz GÜNEŞ

Yıldız Technical University

Examining Committee Members

Prof. Dr. Filiz GÜNEŞ

Yıldız Technical University ______________________

Prof. Dr. Sedef KENT

Istanbul Technical University ______________________

Associate Prof. Dr. Ahmet KIZILAY

Yıldız Technical University ______________________

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LIST OF SYMBOL

B	Norse Bee
D	Drone Bee
dB	Decibel
Gen	Generation
GT	Total Gain
H	Hive
L	Larva
L	Lengths of microstrip lines
N_{Egg}	Total Egg number
NF	Noise figure
Q	Queen Bee
W	Widths of microstrip lines

LIST OF ABBREVIATIONS

HBMO	Honey Bee Mating Optimization
IMC	Input Matching Circuit
OMC	Output Matching Circuit
PSO	Particle Swarm Optimization

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ABSTRACT

HONEY BEE MATING OPTIMIZATION ALGORITHM APPLIED TO DESIGN LOW NOISE MICROSTRIP AMPLIFIER

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In recent years, evolutionary and meta-heuristic algorithms have been extensively used as search and optimization tools in various problem domains, including science, commerce, and engineering. Ease of use, broad applicability and global perspective may be considered as the primary reason for their success. The honey-bee mating process has been considered as a typical swarm-based approach to optimization, in which the search algorithm is inspired by the process of honey-bee mating in real life. In this work, the honey-bee mating (HBMO) algorithm is presented [1] as a new meta-heuristic optimization tool to determine design target space for a microwave amplifier subject to the potential performance of the employed transistor and design of the matching circuit for a wide-band(or ultra wide-band) Front End Low Noise Amplifier.

Key words: Honey Bee Mating, Low Noise Amplifier, Microstrip, Optimization, Feasible Design Space

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ÖZET

BAL ARISI ÇIFTLEŞME ALGORITMASI ILE DÜŞÜK GÜRÜLTÜLÜ MIKROŞERIT KUVVETLENDIRICI TASARIMI

Peyman MAHOUTI

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Son yıllarda evrimsel ve meta heuristic algoritmalar çok yaygın bir biçimde arama ve optimizasyon sistemleri olarak, fen bilimleri, finans ve mühendislik sistemlerinde ve daha bir çok farklı alanlarda kullanılmıştır. Kullanım kolaylığı, geniş uygulanabilirlik ve global bir bakış açısı onların başarısı için birincil nedeni olarak kabul edile bilinir. Bal arası çiftleşme optimizasyonu temelde bir sürü temelli bir yaklaşım ile optimizasyon gerçekleştiriyor. Bu algoritmada ise bal arılarının çiftleşmesinden esinlenilerek Bal Arısı Çiftleşme Optimizasyonu BAÇO, yeni bir meta heuristic optimizasyon yöntemi olarak sunulmuştur [1]. Bu çalışmada bir düşük gürültülü kuvvetlendirici için transistorun uygulanabilir Tasarım Uzayı analizi ve geniş banda sahip bir uydurma devre tasarımı gerçekleştirmek için Bal Arası Çiftleşme Optimizasyonu n gerçekleştirme çalışması sunulmuştur.

Anahtar kelimeler: Bal Arısı Çiftleşme Optimizasyonu, düşük Gürültülü Kuvvetlendirici, Mikro Şerit Hat, Optimizasyon, Uygulanabilir Tasarım Uzayı.

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CHAPTER 1

INTRODUCTION

1.1 Literature Review

During the last decade nature inspired intelligence has been extensively used as a direct search and optimization tools in various problem domains, including science, commerce and engineering. Thus, these methods use only the objective function and constraint values to guide the search strategy, whereas gradient-based methods exploit the first and/or second-order derivatives of the objective function and/or constraints to guide the search process. Since derivative information is not used, these search methods usually require many function evaluations for convergence; thereby they can also be applied to a variety of problems which may even be non-differentiable or discontinuous, non-convex, and highly nonlinear, without a major change in the algorithm. The success of these types of algorithms is partly due to their inherent capability of processing a population of potential solutions simultaneously, which allows them to perform an extensive exploration of the search space. Thus, these are the primary reasons for broad applicability. Among the most popular nature inspired approaches, when the task is optimization within complex domains of data or information, are those methods representing successful animal and micro-organism team behavior, such as swarm or flocking intelligence (birds flocks or fish schools inspired Particle Swarm Optimization), artificial immune systems (that mimic the biological one), ant /bee colonies (ants/bees foraging behaviors gave rise to Ant/Bee Colony Optimization). Most of these nature inspired intelligences are also utilized in the design optimizations of the microwave devices and antennas, with the typical works of [1], [2], [3], [4].

One of the recently proposed nature inspired intelligence algorithms that have shown great potential and good perspective for the solution of various difficult optimization problems is the honey bee mating optimization (HBMO) [5- 10]. The HBMO algorithm first proposed by Afshar et al. [5], has been used to solve a single reservoir optimization problem [5, 6], clustering [7], state estimation in distribution networks [8], multi-objective distribution feeder reconfiguration [9, 10].

1.2 Aim of the Thesis

In our work, HBMO is applied, to our knowledge as the first time, as a simple and efficient global search optimizer to a microwave circuit design problem that is to determine the feasible design target space and design of a matching circuit for a wide-band(or ultra wide-band) front – end amplifier.

1.3 Hypothesis

In the First stage, algorithm will make a search for the feasible design target space for a wide-band front – end amplifier. The feasible design target space will be resulted in the form of the compatible (Noise Figure F, Input VSWR Vin, Maximum G_{Tmax}) triplets and the corresponding source Z_{Smax} and load Z_{Lmax} impedances depending on the operation point (VDS, IDS, f) of the device without having need for any further complicated expertise knowledge.

In the second stage, the honey bee mating in nature and the algorithm of the Honey Bee Mating Optimization (HBMO) is briefly explained.

In the third stage, algorithm will make a search for a matching circuit design for a wide-band (or Ultra wide-band) front – end Low Noise Amplifier .The matching circuits will be design with microstrip lines. The type of these designs can be T, L or Pi junction .The matching circuit design will be resulted in the form of Widths (W) and Lengths (L) of the microstrip lines which depended on the corresponding source Z_{Smax} and load Z_{Lmax} impedances for the required operation point, compatible triplets of Noise Figure, input VSWR, required Gain (results from the first stage) and bandwidth of the wide-band (or Ultra wide-band) front – end low noise amplifier.

CHAPTER 2

FEASIBLE DESIGN SPACE

The first stage of the work is organized as follows: In the first section, the feasible design target is formulated as a constrained optimization problem then the implementation and the worked example take place in the second section.

In the first stage, algorithm will make a search for the feasible design target space for a wide-band front – end amplifier. The feasible design target space will be resulted in the form of the compatible (Noise Figure F, Input VSWR Vin, Maximum G_{Tmax}) triplets and the corresponding source Z_{Smax} and load Z_{Lmax} impedances depending on the operation point (VDS, IDS, f) of the device without having need for any further complicated expertise knowledge.

As explained in the accompanied paper [11], a transistor used for a small – signal amplification can be characterized by a linear two – port terminated by the source Z_S and load ZL impedances, at the input and output ports, respectively. In the Feasible Design Target Space (FDTS), this $\{Z_S, Z_L\}$ termination couple guarantees a compatible performance (Noise Figure F, Input VSWR V_{in}, $G_{Tmin} \leq G_T \leq G_{Tmax}$) triplet. In other words, it is a simultaneous solution of the following highly nonlinear performance equations under the physical realization conditions:

$$F = F(Z_S) = F_{\min} + \frac{R_n \left| Z_S - Z_{opt} \right|^2}{\left| Z_{opt} \right|^2 R_S} \tag{1}$$

$$G_T = G_T(Z_S, Z_L) = \frac{4 R_S R_L \left| z_{21} \right|^2}{\left| (z_{11} + Z_S)(z_{22} + Z_L) - z_{12} z_{21} \right|^2} \tag{2}$$

$$V_{in} = V_{in}(Z_S, Z_L) = \frac{1 + \rho_{in}}{1 - \rho_{in}}, \; where \;\; \rho_{in} = \left| \frac{Z_{in} - Z_S^*}{Z_{in} + Z_S} \right|^2 \le 1 \tag{3}$$

The physical realization conditions can be given as

$$\Re e\left\{ Z_{in} \right\} = \Re e\left\{ z_{11} - \frac{z_{12} z_{21}}{z_{22} + Z_L} \right\} > 0, \tag{4}$$

$$\Re e\left\{ Z_{out} \right\} = \Re e\left\{ z_{22} - \frac{z_{12} z_{21}}{z_{11} + Z_S} \right\} > 0, \tag{5}$$

$$F \ge F_{\min}, V_i \ge 1, \; G_{T\min} < G_T \le G_{T\max} \tag{6}$$

Where the conditions given by (4) and (5) ensure the stable operation of the active device, while the inequalities in (6) guaranties the performance ingredients to remain within the physical limitations of the device.

Here, to determine the design target space for a low-noise front-end amplifier, the problem can be considered into two parts as follows: In the first part, upper limitation of the gain G_{Tmax} should be Determined with its passive Z_{Smax}, Z_{Lmax} termination pair. This problem can be described as a mathematically constrained maximization to find out the maximum value of G_T (R_S, X_S, R_L, X_L) Given by Eq. (2) for the passive Z_S and Z_L terminations satisfying the physical realization conditions given by Eqs. (4-6) subject to the constraints of the following:

$$\Phi_1 = F_{req} - F(R_S, X_S) = 0,$$
$$\Phi_2 = V_{inreq} - V_{in}(R_S, X_S, R_L, X_L) \tag{7}$$

Where F (R_S, X_S) and V_{in} (R_S, X_S, R_L, X_L) are given *by* equations (1) and (3); F_{req} and V_{inreq} are the required noise figure and input VSWR values, respectively.

Thus, the corresponding fitness function using Eqs. (1-3) for the HBMO algorithm is expressed in terms of the cost (error) of the objective in our work:

$$fitness = f(R_S, X_S, R_L, X_L) = e^{-a\,G_T} + b\left|F - F_{req}\right| + c\left|V_{in} - V_{inreq}\right| \tag{8}$$

In (8), a, b and c are the weighting coefficients which are chosen during the process by trial, and the Eqs.(4-6) are used as constraints of the optimization Thus, the fitness decreases as the cost defined by (8) decreases.

CHAPTER 3

HONEY BEE MATING OPTIMIZATION

3.1 Honey Bee Colonies Structures and Honey Bees Mating in Nature

A honey-bee colony typically consists of a single egg laying long-lived queen, anywhere from zero to several thousand drones (depending on the season) and usually 10,000 to 60,000 workers (Moritz and Southwick, 1992). The colony can be founded in two different ways (Dietz, 1986). In "independent founding" the colony starts with one or more reproductive females that construct the nest, lay the eggs, and feed the larvas. The first group of broods is reared alone until they take over the work of the colony. Subsequently, division of labor takes place and the queen specializes in egg laying and the workers in brood care (Dietz, 1986). Another founding method is called "swarming" in which a new colony is founded by a single queen or more, along with a group of workers from the original colony.

A colony of bees is a large family of bees living in one bee-hive. A bee hive is like a big city with many "sections of the town". The queen is the most important member of the hive because she is the one that keeps the hive going by producing new queen and worker bees. With the help of approximately 18 males (drones), the queen bee will mate with multiple drones one time in her life over several days. The sperm from each drone is planted inside a pouch in her body. She uses the stored sperms to fertilize the eggs. Whether a honeybee will become a queen, a drone, or a worker, depends on whether the queen fertilizes an egg. Since she is the only Bee in the colony that has fully developed ovaries, the queen is the only bee that can fertilize the egg. Queens and workers come from fertilized eggs and drones from unfertilized eggs.

Queens represent the main reproductive individuals which are specialized in eggs laying [11]. Drones are the fathers of the colony. They are haploid and act to amplify their mothers' genome without altering their genetic composition, except through mutation.

The mating process occurs during mating-flights far from the nest. A mating flight starts with a dance where the drones follow the queen and mate with her in the air. In a typical mating-flight, queen mates with seven to twenty drones. In each mating, sperm reaches the Spermatheca and accumulates there to form the genetic pool of the colony. Each time a queen lays fertilized eggs, she retrieves at random a mixture of the sperms accumulated in the Spermatheca to fertilize the egg [12]. Insemination ends with the eventual death of the drone, and the queen receiving the "mating sign." The queen mates multiple times but the drone inevitably only once. These features make bees-mating the most spectacular mating among insects.

Only the queen bee is fed "royal jelly," which is a milky-white colored jelly-like substance. "Nurse Bees" secrete this nourishing food from their glands, and feed it to their queen. The diet of royal jelly makes the queen bee bigger than any other bees in the hive. A queen bee may live up to 5 or 6 years, whereas worker bees and drones never live more than 6 months. There are usually several hundred drones that

Live with the queen and worker bees. Mother Nature has given the drones' just one task which is to give the queen some sperm. After the mating process, the drones die. As the nights turn colder and winter knocks the door, the drones still in the hive are forced out of the hive by worker bees. It is a sad thing, but the hive will not have enough food if the drones stay.

Queens represent the main reproductive individuals which are specialized in eggs laying [15]. Drones are the fathers of the colony. They are haploid and act to amplify their mothers' genome without altering their genetic composition, except through mutation. Workers are specialized in brood care and sometimes lay eggs. Broods arise either from fertilized or unfertilized eggs. The former

Represent potential queens or workers, whereas the latter represent prospective drones. The mating process occurs during mating-flights far from the nest. A mating flight starts with a dance where the drones follow the queen and mate with her in the air. In a typical mating-flight, each queen mates with seven to twenty drones.

In each mating, sperm reaches the Spermatheca and accumulates there to form the genetic pool of the colony. Each time a queen lays fertilized eggs, she retrieves at random a mixture of the sperms accumulated in the Spermatheca to fertilize the egg. Insemination ends with the eventual death of the drone, and the queen receiving the "mating sign." The queen mates multiple times but the drone inevitably only once. These features make bees-mating the most spectacular mating among insects.

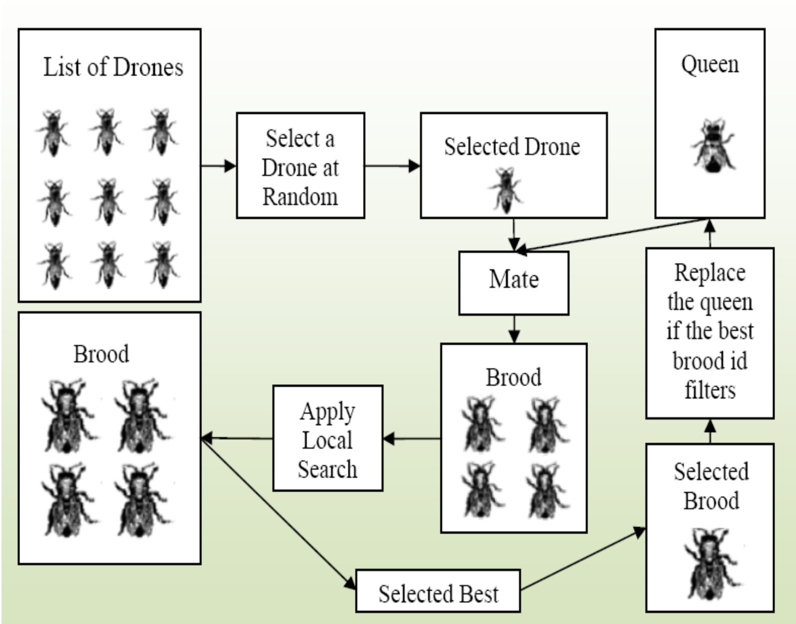

Figure 3.1 Schematic of Honey Be Mating

3.2 Honey Bee Mating Algorithm

Honey-bees Mating algorithm used to determine the feasible design space can be described as in the following steps

3.2.1 Define Input Data

Input data consists of the two parts: The first part is the input data of the problem which are the scattering and noise parameters of the selected transistor; the second part input data includes the user parameters of the algorithm.

The first part:

- Scattering parameters of the selected transistor and

-Noise parameters of the selected transistor

The second part:

-The maximum energy of the Queen at the start of a mating flight E_{max}

-The minimum energy of the Queen at the end of the mating flights E_{min}

-The energy decaying schema $\alpha(t) = Rand(.)$

-The number of the Drone bees N_{Drone}

-The total number of the Eggs produced N_{Egg}

-Set the numbers of the Generation (N_{Gen}), Hive (N_{Hive}), Brood (N_{Brood}), Larva (N_{Larva}), Fertilization ($N_{fertilization}$) are equal to each other and all of them to $(N_{egg})^{1/5}$.

3.2.2 Parameters of HBMO

-Fitness of the FDTS problem is given by Eq. (8)
-Inequality constraints are given by in eq. (4-5-6)

3.2.3 Queen Q and Drone's Population D with their Genetic Inheritances

$$Q\_population = \begin{bmatrix} Q_1 \\ Q_2 \\ \\ Q_{N_{Hive}} \end{bmatrix} \quad D\_Population = \begin{bmatrix} D_1 \\ D_2 \\ \\ D_{N_{Dr}} \end{bmatrix} \tag{9.a}$$

Queen's genetic inheritance

$$Q_i = [R_L, R_S, X_L, X_S] \tag{9.b}$$

Where each Drone has a unique genetic inheritance for its own:

$$D_i = [R_L, R_S, X_L, X_S] \quad i = 1, 2, 3, ..., N_{Dr} \qquad \begin{matrix} R_L = [r_{Li}]_{mx1} & R_S = [r_{Si}]_{mx1} \\ X_L = [x_{Li}]_{mx1} & X_S = [x_{Si}]_{mx1} \end{matrix} \tag{10}$$

where $m = 5000$ *for Queens and* $m = 100$ *for the Drones*

Q_i, D_i given by (Eq.9- 10) represent genetic inheritances of the honey bees which will be passed down to the next generations' via the successful mating flights being collected into the Queen Bee's Genetic pool (sphermatecha). Each variable in the Genetic Pool (Eq. 9-10) is created via a random generator within the constraints with the initialization given in the next section with the Eqs. (11-12-13-14).

3.2.4 Initialization and Generation of the Genetic Inheritances

-Set the elements of all the Q's to zero excluding the first one: $Q\_population = 0 : i \neq 1$

-Randomly initialize fitness values of the Queen and the Drones between 0-0.1.

-Generate all the genetic inheritances of the Queen and Drone Bees within their boundary conditions as follows:

$$r_L = C_1 rand(.) \tag{11}$$

$$r_S = C_2 rand(.) \tag{12}$$

$$x_L = C_3 rand(.) - C_4 rand(.) \tag{13}$$

$$x_S = C_5 rand(.) - C_6 rand(.) \tag{14}$$

Where C_i, i=1,2,3,5 are the upper and C_i, i=4,6 lower practical boundaries.

3.2.5 Generating of the Queen's Spermatheca (Mating Flight)

-At the start of the process Queen will flies with her maximum energy E_{max}.

- A drone is randomly selected from population D.

-The mating probability is calculated based on the fitness values of the Queen and Drone bee.

$$\mathrm{Prob}(Q, D) = e^{\left(-\frac{\Delta f}{E(t)}\right)} \tag{15}$$

-A number between 0 and 1 is randomly generated and will be compared with Prob(Q,D) of the mating flight, if it's less than the calculated probability the mating will be a successful attempt and Drone's sperms will be added to the Genetic Pool.

$$\mathrm{Prob}(Q, D) \geq Rand(.)$$

-Reduce Queen’s Energy Level and if it’s less than E_{min} stop mating flights and queen will return to hive to give births.

$$E(t+1) = E(t) x \alpha(t) \tag{16}$$

$if\ E(t) > E_{min}$ continue, otherwise stop Mating Flight

3.2.6 Generating of the Genetic Pool (GP)

If a mating flight is successful, the master Queen Bee will accept all sperms of the partner drone into her Spermatheca to generate the genetic pool with her genetic inheritance, from which the new generations of the entire colony will have their genetic identities. In our work this genetic pool will be represented with our optimization variables (R_L, X_L, R_S and X_S). Size of the genetic pool will be increased with the number of the successfully performed mating flights, and each variable will be generated randomly as the size of the genetic pool (GP Eq.17):

$$GP = [R_{LGP}, R_{SGP}, X_{LGP}, X_{SGP}]_{1X\,4} \tag{17}$$

$$R_{LGP} = [r_L]_{mx1} \quad R_{SGP} = [r_S]_{mx1}$$
$$X_{LGP} = [x_L]_{mx1} \quad X_{SGP} = [x_S]_{mx1}$$

where m=5000+N_{Drs}x100 and N_{Drs}: Number of the drone bees that had a successful mating flight with the Queen bee

As we mention before, in a classical HBMO process, drone bees act like an amplifier for their Queen’s Genetic inheritance, however in our algorithm Drones genetic inheritance will amplify the master Queen’s genetic inheritance by increasing diversity in genetic pool. Genetic Pool can be described as superpose of the Queens and Drone bees genetic inheritance.

3.2.7 Perform Breeding process and searches for the new Master Queen Bee

Algorithm will start to randomly fertilize eggs as the number of the N_{Egg}. During this phase all new members of the hives will be pass from five categories which their size had been set in first step.1-Fertilization (SPE), 2-Egg/Larva (EGG), 3-Brood (B), 4-Hive (H), 5-Generation (Gen).

In this algorithm each bee will be created with 4 variables (R_L, X_L, R_S and X_S). For creating a fertilized egg, algorithm will randomly take variables from GP (Eq.12) and put them in $f_{fertilized\ Egg}$ (Eq.18).

$$f_{Fertilized\ Egg} = [R_L, R_S, X_L, X_s]_{1X4} \tag{18}$$

$$f_{Fert\ Egg} = [GP(K_1,1), GP(K_2,2), GP(K_3,3), GP(K_4,4)]_{1X4} \tag{19}$$

where $K_1 = r_L(K_5,1), K_2 = r_S(K_6,1), K_3 = x_L(K_7,1), K_4 = x_S(K_8,1)$ and K_5, K_6, K_7, K_8, are randomly generated integers within the constraints of $(1\sim5000+100Dr_S)$

Example: for N_{Drs}=5 we have m=5500, it means that we have 5500 different values for each of variables (RL, RS, XL, XS). In equation 19 we randomly choose variables values from 5500 different values which mean we have 45500 different possibilities. We choose N_{Egg} number from these possibilities.

After creating the fertilized egg, algorithm will calculate G_T, F and V_{in} by using impedance values from Eq.18 and scatter parameters from the data sheets of the desired transistor. And for each fertilized egg there will be a fitness value (Eq. (7), (8), (20)).

$$f_{Fert\ Egg} = \{G_{T\ egg}, F_{egg}, V_{IN\ egg}\}$$

With this random process we can make a randomly global search for our optimization.

An example for HBMO with $N_{Egg}=15^5$, N_{Gen}=15.

Since $N_{Feritilization}$, N_{Larva}, N_{Brood}, N_{Hive}, N_{Gen} are equal to each other's, for each SPE cycle, algorithm will fertilize 15 Eggs and calculate their fitness values then a nurse bee will scan these Fertilized eggs and nurse bee will add the best fertilized egg to the Egg/Larva category and the rest will be discarded. This process can be seen as an example of the survival of the fittest, and then the same process will be done in each other categories. In the end Total Egg number will be equal to $N_{EGG}=Gen^5$.

3.3 Categorization of New Born Bees

3.3.1 Fertilization ($N_{Fertilization}$):

$N_{Fertilization}$ represents success rate of the fertilization of the EGGs. Only the best fertilized egg with the lowest error value from $N_{Fertilization}$ number of fertilized eggs will survive and will be added to Larva Category. In each cycle only the best fertilized EGG will be give birth by the queen. This step can be considered as an example for the survival of the fittest in nature.

3.3.2 Larva (N_{Larva}):

This category is created by gathering best results from previous step (Fertilization) and the best unit from Larva will be taken as a Brood.

3.3.3 Brood (N_{Brood}):

The best units from Larva phase will be gathered as Brood bees. The best brood from this section will be chosen as the Queen of the hive.

3.3.4 Hive (N_{Hive}):

The chosen Queen of each Hive from the previous step will be compared with each other and if the best of them is better than the previous master Queen, she will be the new master Queen of the colony and the rest of the current Queen and drone population and all the other populations from the previous steps will be discarded.

3.3.5 Generations (N_{Gen}):

N_{Gen} represents the number of generations of the bee colony. New Master Queen which had been found from previous step will take the throne and it will take new mating flights with new randomly chosen drone among the randomly created Drones population. All the steps up to here will be repeated until the end of the generations (N_{Gen}).in the end the last master Queen of the colony will be our best solution for our problem.

3.4 Worked Example

In the worked example, HBMO is applied to gain maximization subject to $F_{min}(f)$ and V_{ireq} with respect to the input and output terminations for the transistor NE3512S02) in an operation frequency band of 2-18GHz .

Minimum noise figure profile of NE3512S02 is given in Fig. 3.2. In the Fig. 3.3, the resulted maximized gain variations with frequency are shown as compared with the ones obtained from the performance characterization theory [13] at the bias condition

(2V, 5mA). Furthermore the maximum gain variations are depicted in Fig. 3.4 together with the target values of the V_{in} =1.5 at the various bias conditions. These results had been simulated with HBMO while iteration/N_{Gen} is equal to 15 in a system with Intel (R) core ™ 2 duo 2.2 GHz, 2GB Ram (Lenovo 3000 V200) with operation system of windows XP SP3 and MATLAB R2009.

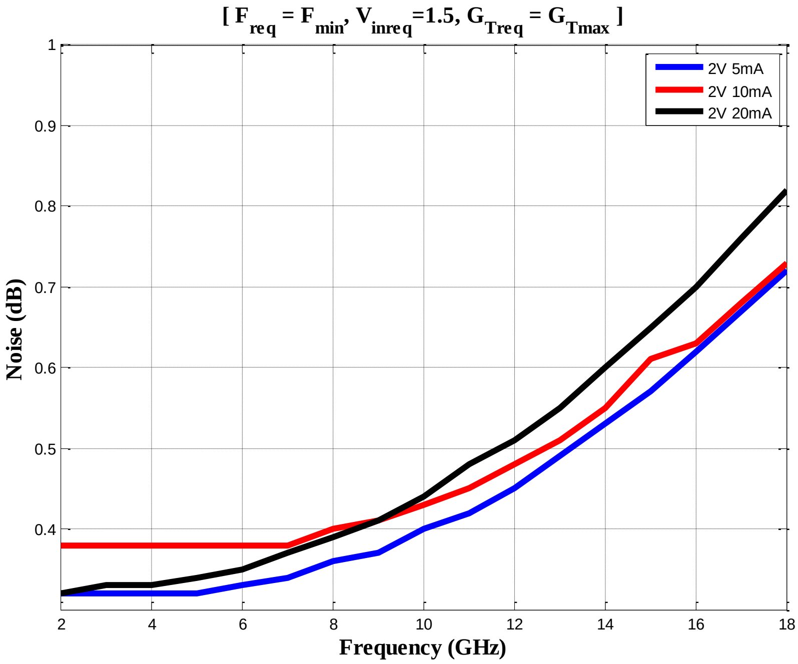

Figure 3.2 Noise Figure Profile of NE3512SE02 for V_{in}=1.5, G_{Treq}=G_{TMax} at different Bias conditions

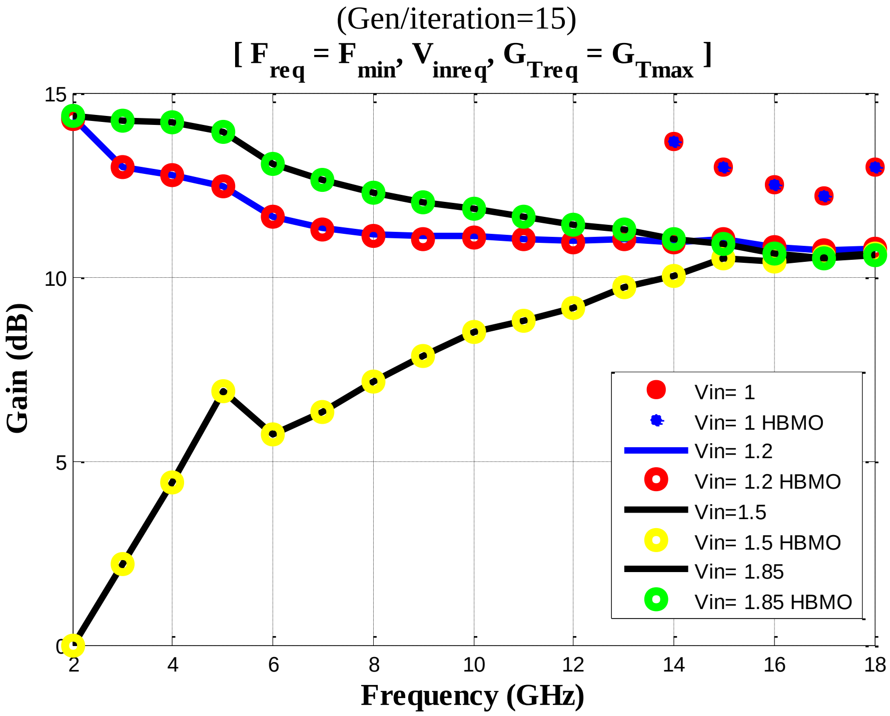

Figure 3.3 Gain Variations for NE3512SE02 at different V_{in} values for Bias condition 2V 5mA (Gen/iteration=15)

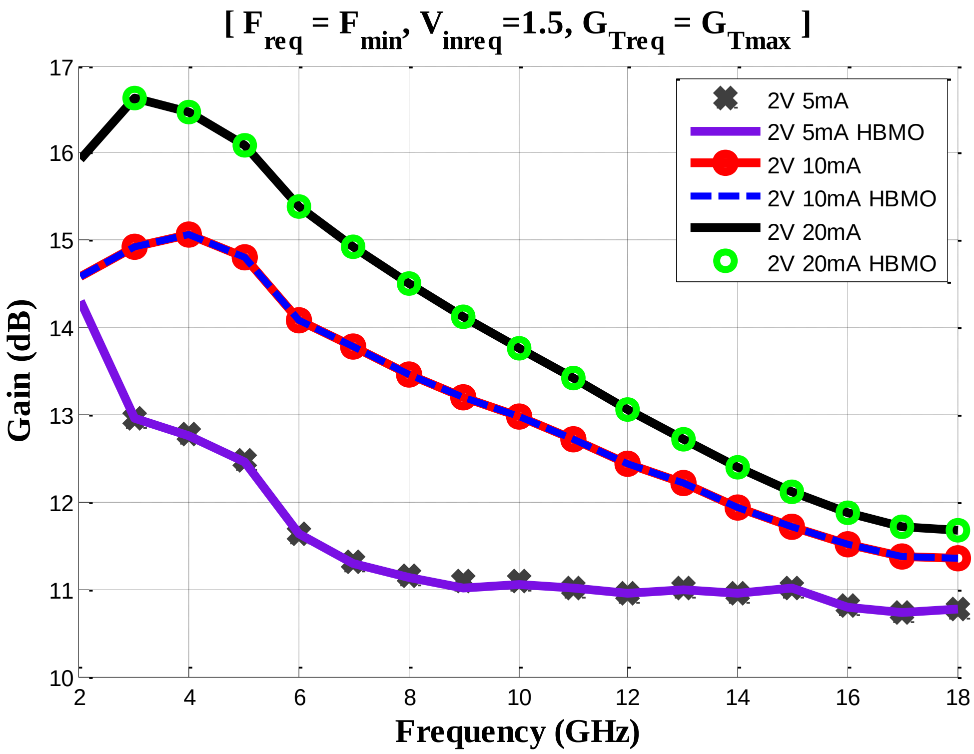

Figure 3.4 Gain Variations of NE3512SE02 for V_{inreq}=1.5, F_{req}=F_{min} for different Bias conditions (Gen/iteration=15)

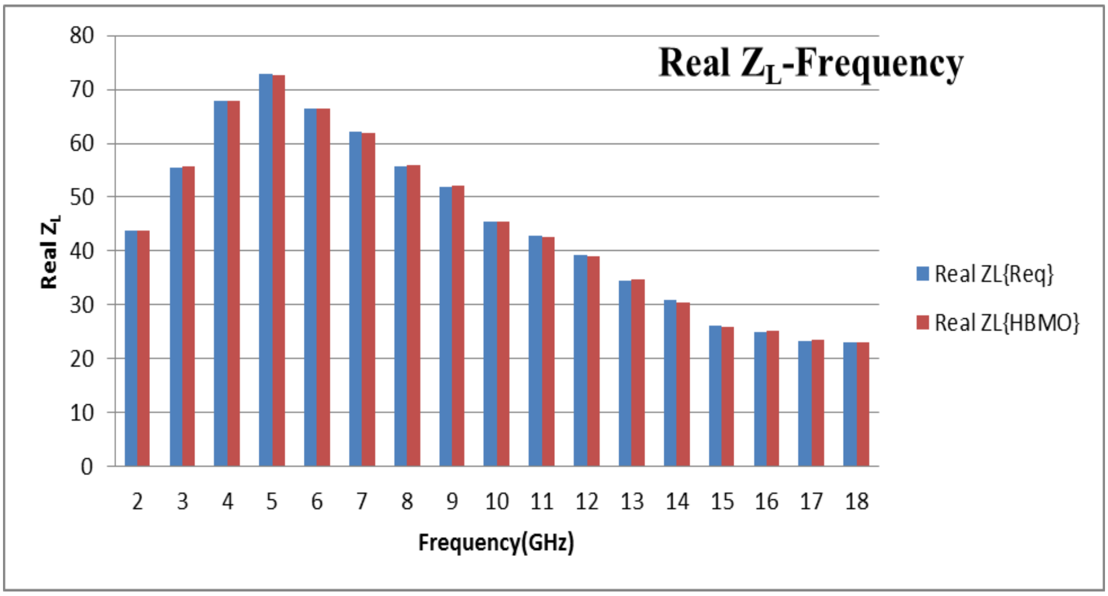

Figure 3.5 Real part of the load impedance of NE3512SE02 for triplets of V_{in}=1.5, F_{req}=F_{min}, G_{Treq}=G_{TMax} while Bias condition is 2V 5mA (Gen/iteration=15)

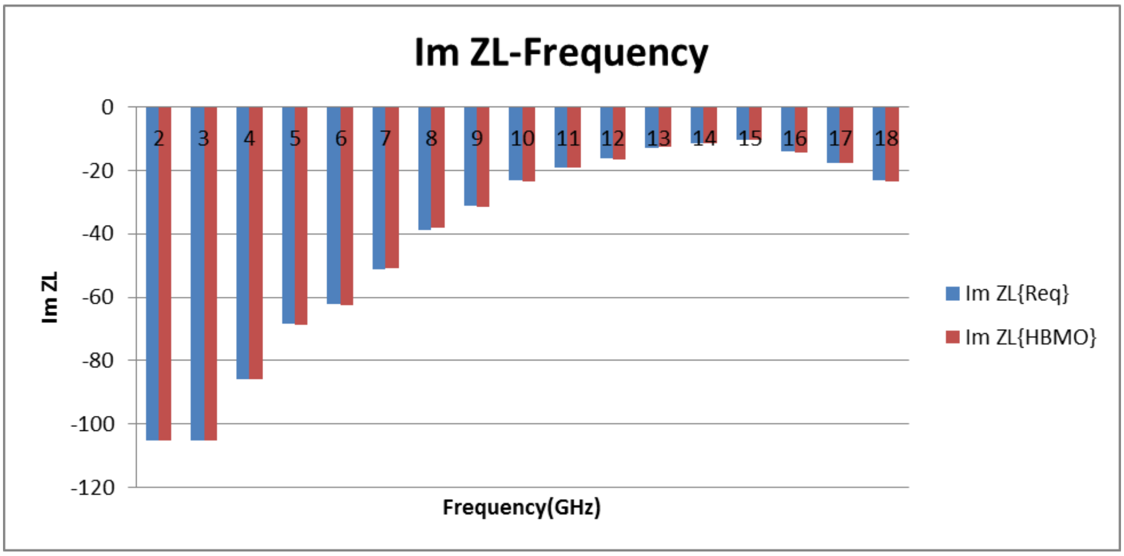

Figure 3.6 Imaginary part of the load impedance of NE3512SE02 for triplets of V_{in}=1.5, F_{req}=F_{min}, G_{Treq}=G_{TMax} while Bias condition is 2V 5mA (Gen/iteration=15)

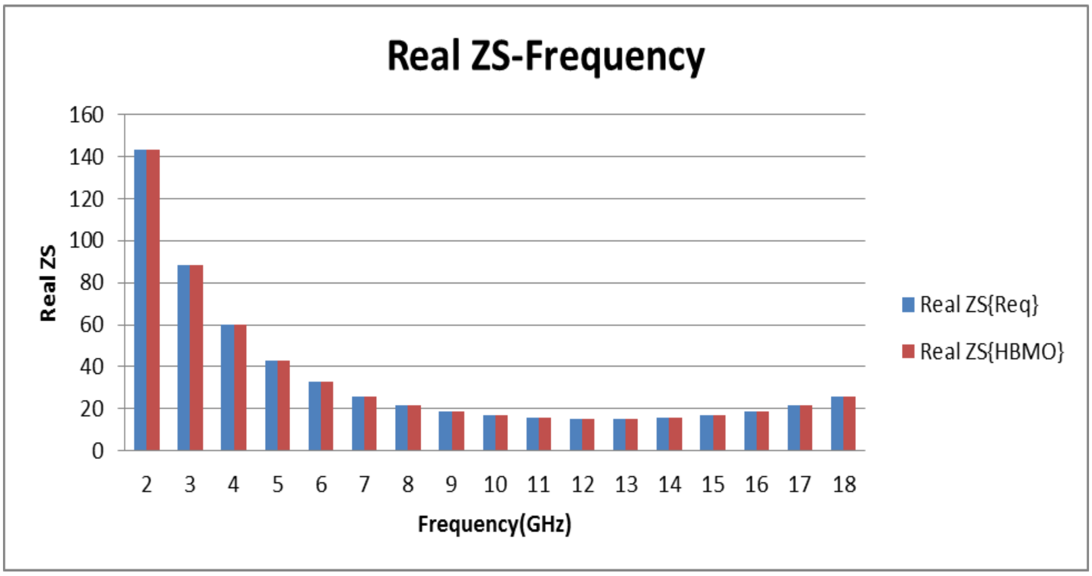

Figure 3.7 Real part of the source impedance of NE3512SE02 for triplets of V_{in}=1.5, F_{req}=F_{min}, GT_{req}=GT_{Max} while Bias condition is 2V 5mA (Gen/iteration=15)

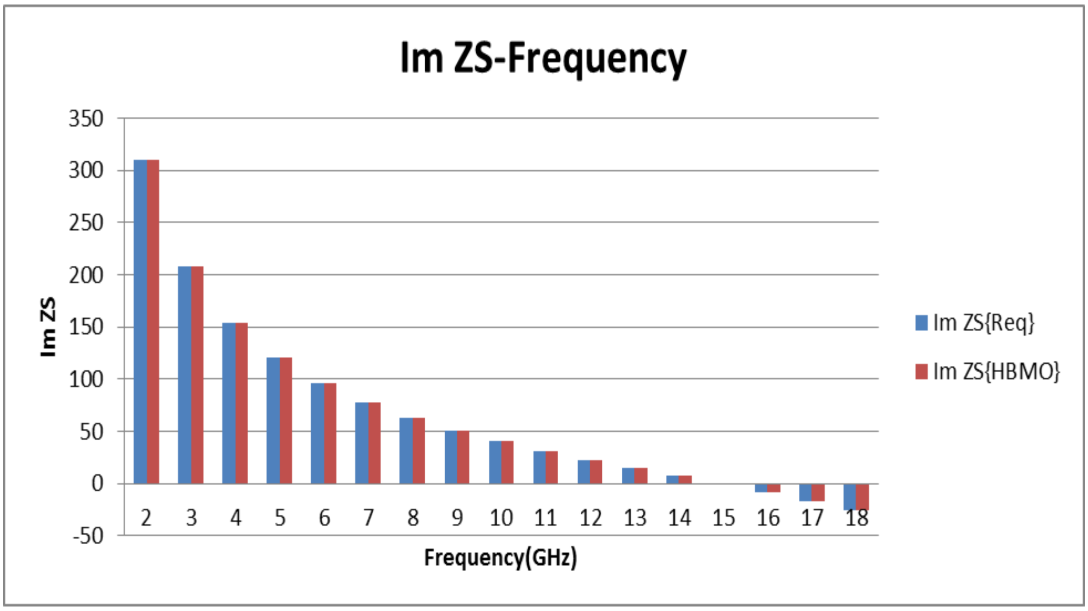

Figure 3.8 Imagınary part of the load impedance of NE3512SE02 for triplets of V_{in}=1.5, F_{req}=F_{min}, G_{Treq}=G_{TMax} while Bias condition is 2V 5mA (Gen/iteration=15)

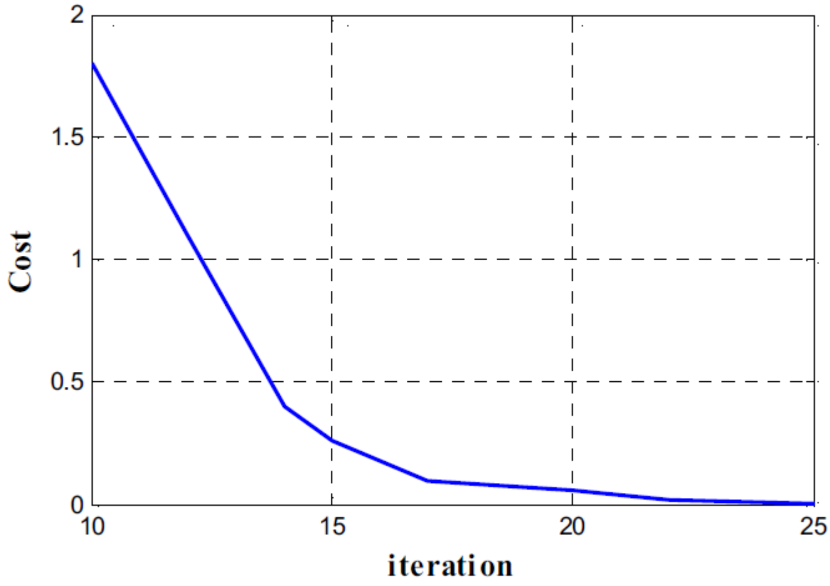

Figure 3.9 Cost-Iteration variations of the algorithm for V_{in}=1.5 & F_{req}=F_{min}

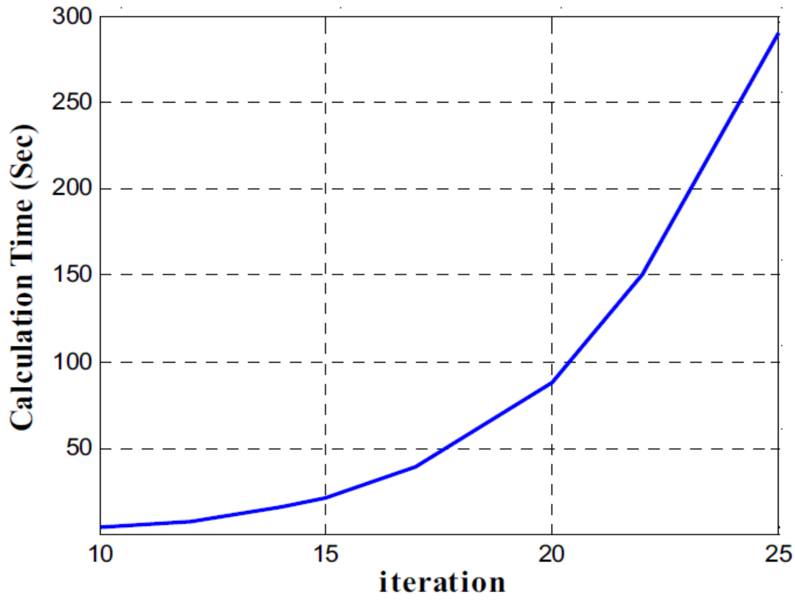

Figure 3.10 Calculation Time (second)-Iteration variations of the algorithm for V_{in}=1.5 & F_{req}=F_{min}

As it shown in Figures above The HBMO algorithm is applied to determine the feasible design target space for a wide-band front-end low noise microstrip amplifier and found both computationally efficient and fast convergent to the target within the high accuracy.

CHAPTER 4

DESIGN OF MATCHING CIRCUIT

4.1 Matching Circuits

In electronics, impedance matching is the practice of designing the input impedance of an electrical load (or the output impedance of its corresponding signal source) to maximize the power transfer or minimize reflections from the load.

In the case of a complex source impedance Z_S and load impedance Z_L, maximum power transfer is obtained when

$$Z_{\mathrm{S}} = Z_{\mathrm{L}}^{*}$$

Where * indicates the complex conjugate. Minimum reflection is obtained when

$$Z_{\mathrm{S}} = Z_{\mathrm{L}}$$

The concept of impedance matching was originally developed for electrical engineering, but can be applied to any other field where a form of energy (not necessarily electrical) is transferred between a source and a load. An alternative to impedance matching is impedance bridging, where the load impedance is chosen to be much larger than the source impedance and maximizing voltage transfer (rather than power) is the goal.

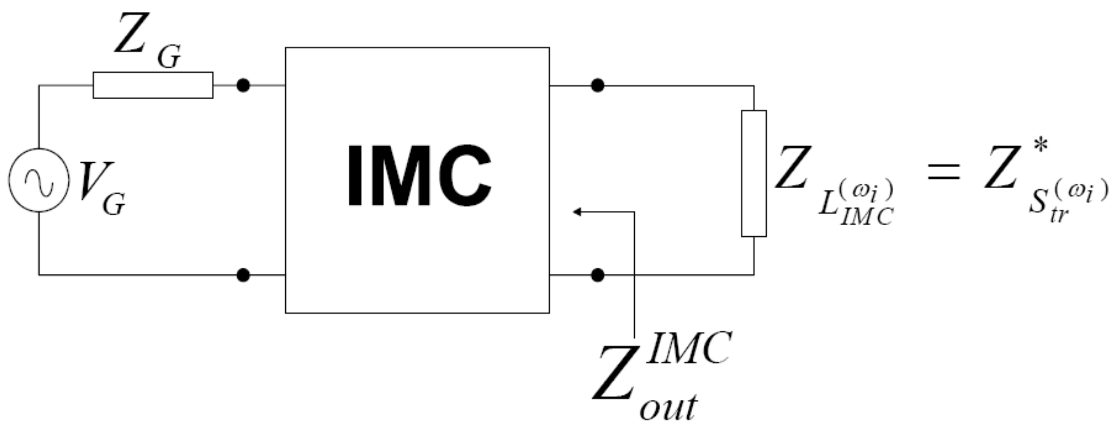

Figure 4.11 Input Matching Circuit

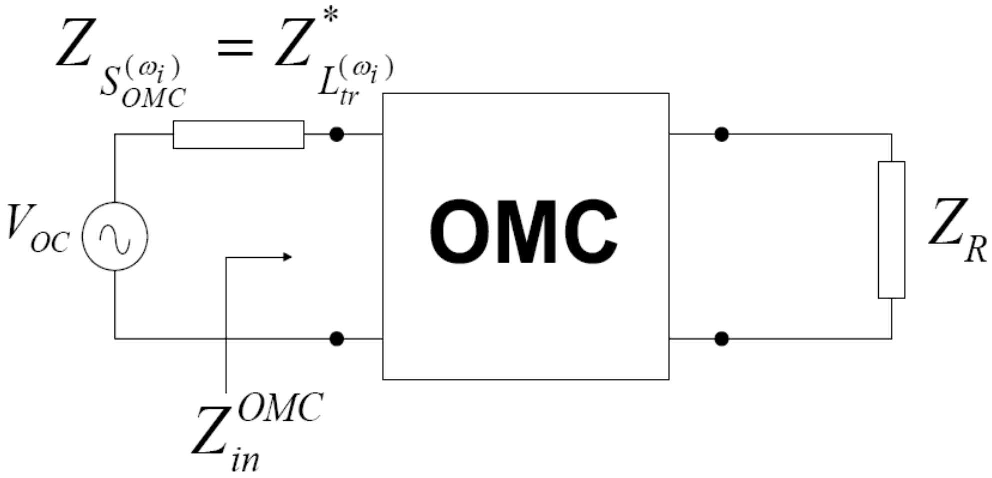

Figure 4.12 Output Matching Circuit

4.2 HBMO Algorithm for Matching Circuit Design

In the third stage, algorithm will make a search for a matching circuit design for a wide-band (or Ultra wide-band) front – end low noise microstrip amplifier .the matching circuits will be designs with microstrip lines. The type of these designs can be T, L or Pi junction .The matching circuit design will be resulted in the form of Widths (W) and Lengths (L) of the microstrip lines which depended on the corresponding source Z_{Smax} and load Z_{Lmax} impedances for the required operation point, compatible triplets of Noise Figure, input VSWR, desired Gain (results from the first stage) and bandwidth of the wide-band (or Ultra wide-band) front – end low noise amplifier.

In Fig. 4.3 a simple microwave Low Noise Microstrip Amplifier schematic has been shown. In this design T type microstrip junction has been used for matching circuit design.

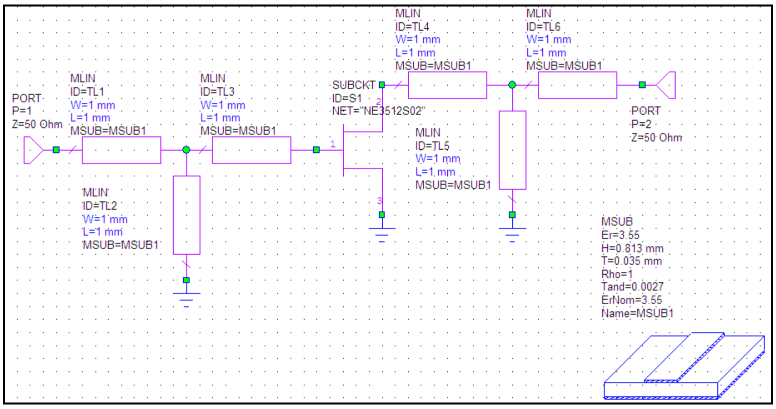

Figure 4.13 Schematic of a Microstrip LNA designed with T junction matching circuit

In this stage of the work, HBMO algorithm will try to search for the best values of W (Widths) and L (Lengths) of the microstrip lines which can transfers input signal from port to the transistors input with a very low level of loss for the desired bandwidths.

Algorithm will take W and L values from the Genetic pool that have been created just like described in the second stage, the only difference, this time instead of impedance values, gens of the honey Bees will be described with lengths and widths of the microstrip lines.

Algorithm will use impedance values, which have been found on second stage as our feasible design target space results, to calculate G_T for each frequency within our desired bandwidth. For each frequency, algorithm will calculate the objective function for each bee and in the end algorithm will sum up all errors in the frequency range for each bee individually to find the best bee gens which can be used to design a matching circuit for a wide-band (or Ultra-wide-band) Low Noise amplifier.

The objective function is described as:

$$e = (1 - G_{THBMO})^2 \tag{21}$$

Where: G_{THBMO} is depended on gens (W and L) of new born bees and it is a different value for each bee

Just like in the second stage objective function of all new born bees will be calculated and then the best of them will be the new Queen of the Colonies and the gens of the chosen Queen will be the W and L of the microstrip lines of the matching circuit.

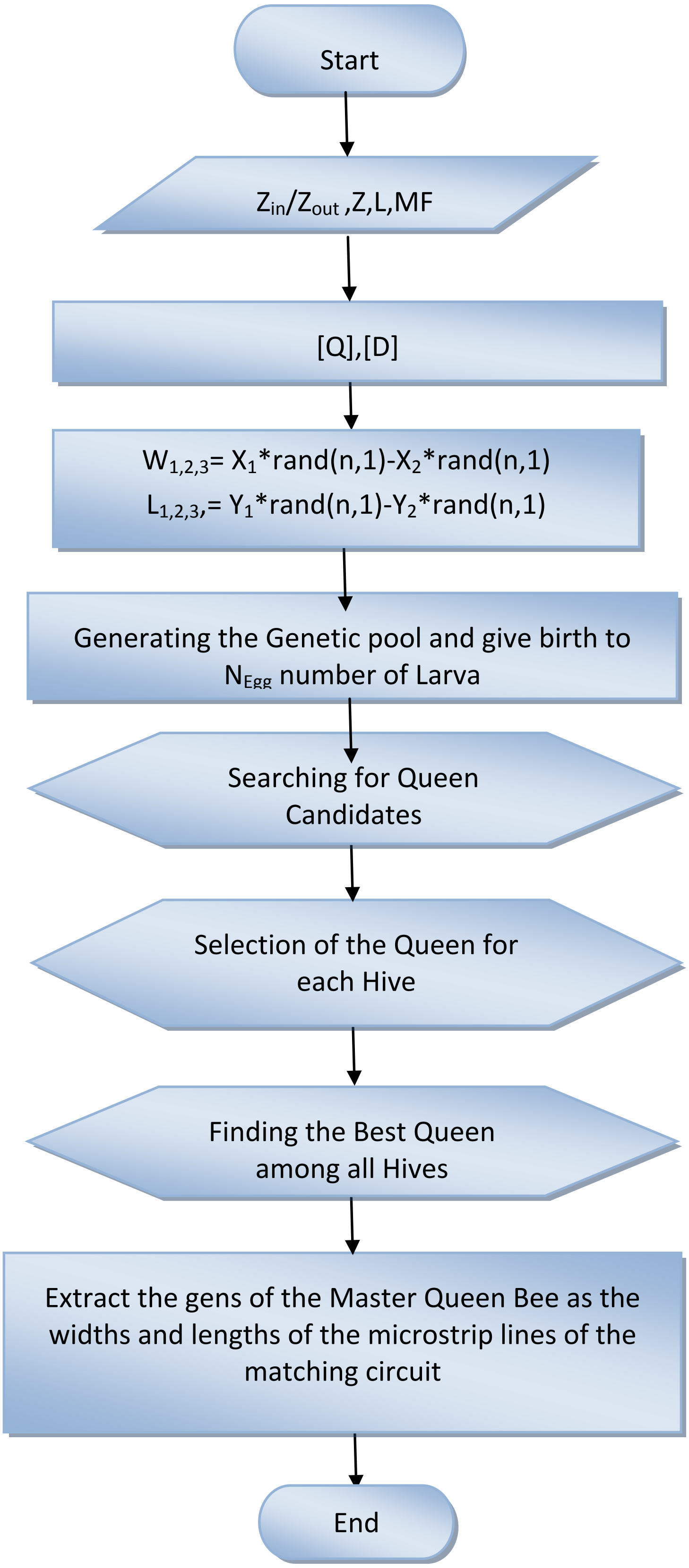

Figure 4.14 Flow chart of HBMO for Matching Circuit Design

4.3 Worked Example

By giving the results of Chapter 3 for NE3512S02 2V 5mA to the algorithm, it will try to design T type Junction matching circuit for a low noise microstrip amplifier with the linear gain of 10 db and the bandwidth of 3-7 GHz (the reason for choosing this bandwidth is because this bandwidth is within the recommended working bandwidth of the NE3512S02).

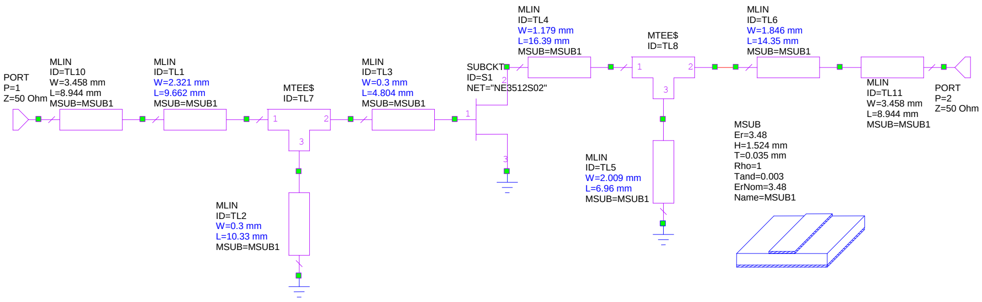

Figure 4.15 Schematic of LNA

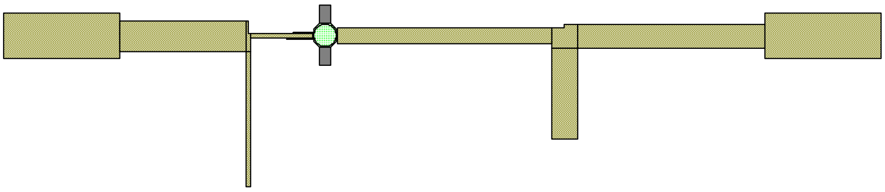

Figure 4.16 Lay Out of LNA

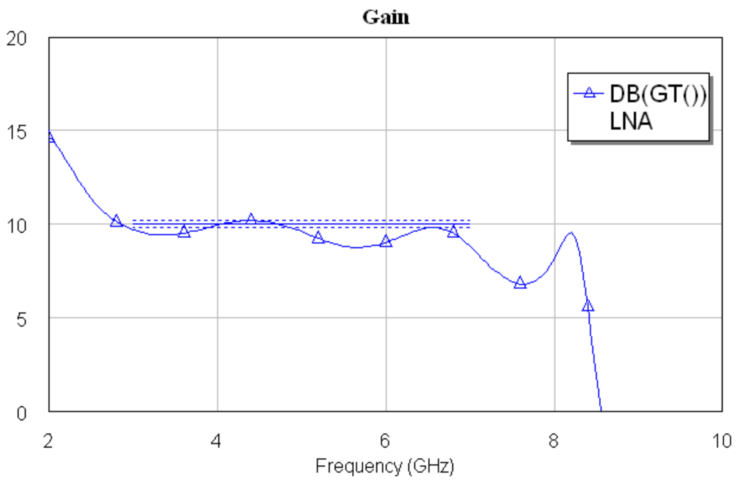

Figure 4.17 Gain of LNA

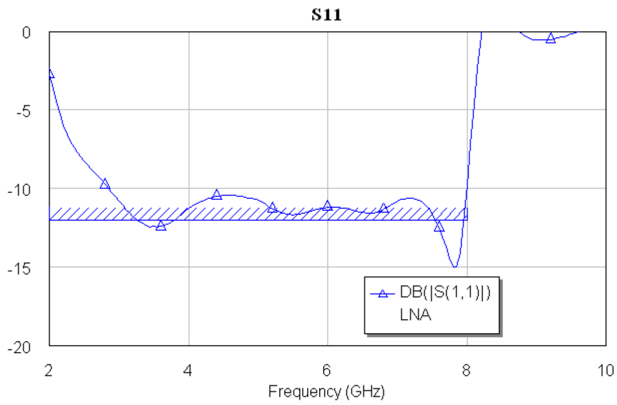

Figure 4.18 S_{11} of LNA

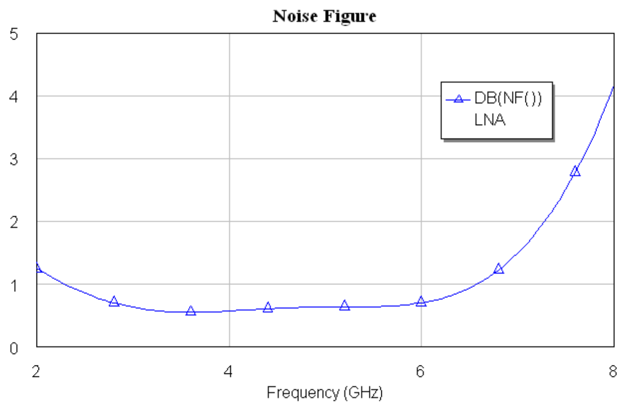

Figure 4.19 Noise Figure (F) of LNA

Table 4.1 Compartment of Honey Bee Mating with Particle swarm optimization for input matching circuits

IMC	Particle Swarm Optimization PSO	Honey Bee Mating Optimization HBMO
iteration	10K	15
Population Number for Each İteration	20	50K
Total Population Number	200K	760K
Average Calculation Time for 10 tries	00:01:45	00:00:35
Average Error for 10 tries	0.4154	0.4114

Table 4.2 Compartment of Honey Bee Mating with Particle swarm optimization for output matching circuit

OMC	Particle Swarm Optimization PSO	Honey Bee Mating Optimization HBMO
iteration	10K	15
Population Number for Each İteration	20	50K
Total Population Number	200K	760K
Average Calculation Time for 10 tries	00:01:45	00:00:35
Average Error for 10 tries	0.362	0.00376

As it seen in tables our proposed algorithm is much faster than particle swarm optimization algorithm. But HBMO algorithms calculation time is increased exponentially with the increase of iteration number.

CHAPTER 5

RESULTS AND DISCUSSION

In the previous Chapters of the Thesis, we have managed to design an algorithm inspired from mating of Honey Bees. Then, the proposed HBMO algorithm is applied to determine the feasible design target space for a wide-band front-end low noise microstrip amplifier and found both computationally efficient and fast convergent to the target within the high accuracy.

In the fourth Chapter of the Thesis, by using the results from the previous Chapter algorithm have managed to design a matching circuit for the selected transistor in order to design a wide-band front-end low noise amplifier.

The proposed modified HBMO algorithm is applied to determine the feasible design target space and design of matching circuit design for a wide-band front-end low noise microstrip amplifier and found both computationally efficient and fast convergent to the target within the high accuracy.

5.1 FEATURE WORKS

The proposed Honey Bee Mating Optimization algorithm has a good potential to be used in electromagnetic and microwave applications. This algorithm can be used in microstrip antenna, microstrip filters or other kind of microwave structures applications easily.

Since the algorithm is a genetic algorithm that makes a random global search it can also be used in nonlinear applications like PA design or any other application as long as it can be described with an objective function.

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CURRICULUM VITAE

PERSONAL INFORMATION

Name Surname	: Peyman Mahoutı
Date of birth and place	: 28/08/1989 Tehran
Foreign Languages	: Farsi, English
E-mail	: pmahouti@gmail.com

EDUCATION

Degree	**Department**	**University**	**Date of Graduation**
Undergraduate	Electronics Communication Eng.	Yıldız Technical University	2011
High School	Fajr Istanbul		2007

PUBLISHMENTS

Conference Publications

1. Mahouti, P., GÜNEŞ, F., DEMIREL S. (2012). "Honey-Bees Mating Algorithm Applied to Feasible Design Target Space For a Wide-Band Front-End Amplifier". ICUWB 12, 251-255