Designing Different Shapes of Microstrip Antenna Using Genetic Algorithm

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Abstract

In this work, Genetic Algorithm (GA) models have been built to design a microstrip antennas in various forms such as rectangular, equilateral triangle and hexagon patch antenna. The design problem can be defined to obtain the resonant frequency for a given the thickness of dielectric material and dimension of geometrical structure. This approach has a few advantages: giving a clearer and simpler representation of the problem, simplifying chromosome construction, and totally avoiding binary encoding and decoding to simplify software programming. The antenna designed using GA is implemented using MATLAB program and the analysis of antenna is implemented using Microwave Office software 7.1 produced in 2007.

المستخلص

في هذا البحث ، تم بناء الخوارزمية الجينية لتصميم الهوائيات الشريطية لاشكال مختلفة من الرقع منها المستطيلة والمثلثة متساوية الاضلاع والسداسية. مسألة تصميم تلك الاشكال يمكن تعرفها للحصول على التردد الرنيني بوجود سمك المادة العازلة والابعاد الهندسية للتركيب. هذه الطريقة تملك عدة فوائد منها: تعطي تمثيل واضح وبسيط للمسألة وبساطة تركيب الكروموسوم وتجنب بشكل كامل تشفير وحل النظام الثنائي لتبسيط البرنامج. صمم الهوائي باستخدام الخوارزمية الجينية والتي نفذت باستخدام برنامج الماتلاب وتم تحليل الهوائي باستخدام الميكرويف أوفس 7.2 المنتج علم 2007 .

1. Introduction

Microstrip antenna is one of the most popular type of antennas, since it is light weight, simple geometries, inexpensive to fabricate and can easily be made conformal to host body [1, 2]. These attractive features have increased the applications of the microstrip antennas recently and simulated greater efforts to investigate their performance. Microstrip antenna has very narrow bandwidth which is not exceed several of percent from the resonant frequency and the antenna operates in a vicinity of the resonant frequency. This needs very accurate calculations for various design parameters of microstrip patch antennas. Patch dimensions for various microstrip patches is a vital parameter in deciding the utility of a microstrip antennas. CAD Models are generally developed using analytical, electromagnetic simulation, and measurement based methods. Accurate and efficient models for circuit components are essential for cost-effective circuit design.

Genetic Algorithm has a wide range in different applications. The antenna is one of these application .Chattoraj et al. (2006) have used genetic algorithm to the optimization of gain for a microstrip antennas with and without dielectric superstrate [3]. Chattoraj et al. (2007) have used genetic algorithm (GA) to the optimization of gain of microstrip antenna, fabricated on ferrite substrate, biased externally by a steady magnetic field [4]. Cengiz et al. (2008) have used GA to optimize the spacing's between the elements of the linear array to produce a radiation pattern with minimum SLL and null placement control[5].Yang et al. (2009) have produced the genetic algorithm in combined with Finite Element to design a single-patch broadband microstrip antenna [6].Yongsheng et al.(2009) have discussed the optimal design of line-tapered multimode interference devices using a genetic algorithm [7]. Reza et al. (2010) have investigated the effects of adaptive genetic algorithms (AGAs) on performance of optimization for tapered microstrip filter[8].

In this paper, the optimization of rectangular, triangular and hexagon is realized microstrip antenna responding to some constraints (frequency of the fundamental mode) some more advanced techniques, which give a global minimum, have been retained. One of these new approaches, more and more used, based on genetic algorithm (GA) method is well suited to our needs. The GA method, which is able to optimize different natural variables, is the most versatile approach. It can optimize the physical (dimension of the patch, thickness of substrate, and electric parameters (relative permittivity)).

2. Types of microstrip antennas

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of copper and gold, can assume virtually any shape [1-2]. In this paper rectangular, triangular and hexagon microstrip antenna Figure (1) are designed using GA.

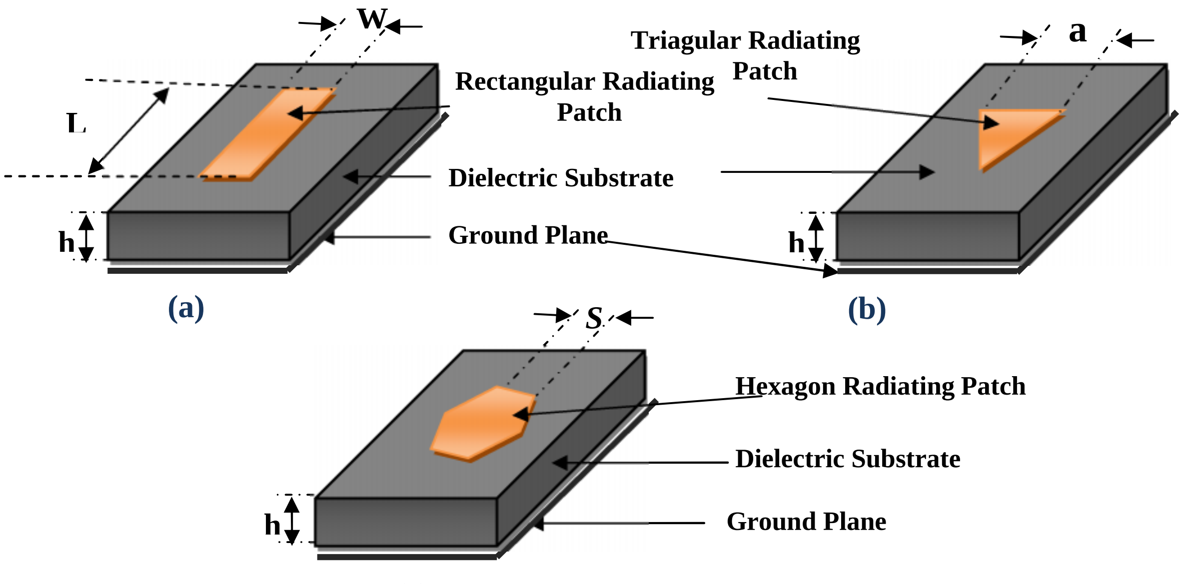


Figure (1). Microstrip antenna structure - a) Rectangular, b) Triangular, c) Hexagon .

3. Gentic algorithms (ga)

One of the most fundamental principal in our world is the search for an optimal state. Optimization is the process of modifying the inputs or characteristics of a device, mathematical process to obtain minimum or maximum of the output [9]. Genetic Algorithm is an Artificial Intelligence based methodology for solving problems. It is a non-mathematical, Non-deterministic, but stochastic process or algorithm for solving optimization problems [10, 11]. It is considered a sophisticated search algorithm for complex, poorly understood mathematical search spaces [12]. Genetic Algorithm (GA) is an optimization technique that attempts to replicate natural evolution processes in which the individuals with the considered best characteristics to adapt to the environment are more likely to reproduce and survive [12,13]. These advantageous individuals mate between them, producing descendants similarly characterized, so favorable characteristics are preserved and unfavorable ones destroyed, leading to a progressive evolution of the species. Artificial genetic algorithm aims to improve the solution to a problem by keeping the best combination of input variables. It starts with the definition of the problem to optimize, generating an objective function to evaluate the possible candidate solutions (chromosomes), the objective function is the way of determining which individual produces the best outcome. The next step is to generate an initial random population of *n* individuals called chromosomes that are symbolized by real weighting vector, where each position of the chromosome is called a gene and denotes a specific characteristic (input variable). Therefore the combination of all the different characteristics of the real weights in the vector represents an individual who is a candidate for the solution [13].

Each chromosome is evaluated in the objective function and the best individuals are selected to survive for mating (parents), while the worse ones are discarded to make room for new descendants.

Random mutation is used to alter a certain percentage of the genes of the chromosomes. The purpose of mutation is to introduce diversity into the population, allowing the algorithm to avoid local minima by generating new gene combinations in the chromosomes. Finally, after mutation is done the new generation of chromosomes is evaluated with the objective function and used in the next iteration of the described algorithm.

The GA process could be simplified as following: 1) Initialize a random pool of Individuals. 2) Evaluate each Individual. 3) Choose couples (Mating). 4) Breed them together (Crossover). 5) Evaluate each Individual. 6) Selection. 7) Mutation. 8) If the pool has converged, or a number of pre-determined cycles have been completed, finish the cycle. If not, return to step #3[13,14].

In this paper coding and decoding avoided , operation directly works with complex numbers to simplify computing programming and to speed up computation. The resonance frequency of the antenna is obtained from the output of the GA for a chosen dielectric substrate and patch dimensions at the input side Figure (2).

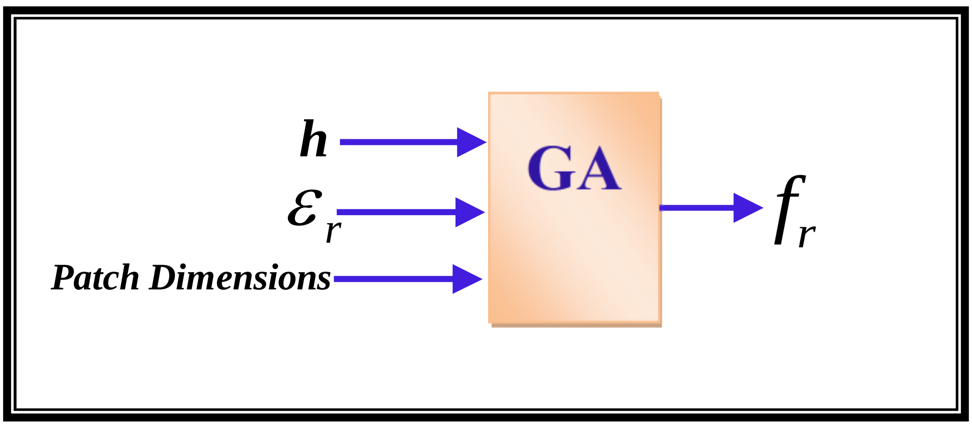


Figure.(2) GA Model for microstrip antenna design.

3-1-Construction of chromosomes

The using of genetic algorithms for design a microstrip antenna is corresponding to living beings and vectors represent chromosomes. Genetic algorithms were invented to manipulate a string of binary coding. Conventional genetic algorithms encode the parameters in binary chromosomes and perform binary genetic operation. In this paper, chromosomes are represented directly by real weighting vector [12].

$$d = [d_1 d_2 d_3 \ldots d_n \ldots d_N] \quad (1)$$

Where d_n (known as a genetic material in a GA) which represents the dimensions of radiator (Length, width, radius,…) , height of the substrate material, and its relative permittivity.

3-2- Initial population

For fast convergence of genetic algorithms , the initial population was included.

3-3- Fitness function

In order to show the feasibility of this paper, the case of a rectangular, triangular and hexagon microstrip antenna form were studied.

3-3-1 Rectangular patch

It is assumed that the antenna has length (L), width (W), thickness (h) posed on a substrate of permittivity (ε_r). The objective is to find the values of the four parameters :(L, W, h, and ε_r), so that the antenna satisfies the constraint (a resonant frequency is assumed to be 10 GHz). The resonant frequency of TM_{nm} mode of the rectangular radiant element is[1]:

$$f_{nm} = \frac{c}{2(L + 2\Delta\ell)\sqrt{\varepsilon_e}} \quad (2)$$

Where:

c is velocity of light in free space($3*10^8\ m/s$)

ε_e is effective dielectric constant

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} \quad (3)$$

$\Delta\ell$ is line extension

$$\Delta\ell = 0.412\,h\,\frac{(\varepsilon_e + 0.3)(W/h + 0.264)}{(\varepsilon_e - 0.258)(W/h + 0.8)} \quad (4)$$

3-3-2 Equilateral triangular patch

It is about an antenna of length side (a), thickness (h) posed on a substrate of permittivity (ε_r). The objective is to find the values of the three parameters :(a, h, and ε_r), so that the antenna satisfies the constraint (a resonant frequency of 10 GHz).

The resonant frequency of TM mode of the triangular radiant element is[1]:

$$f = \frac{2 * c}{3 a_e \sqrt{\varepsilon_e}} \quad (5)$$

Where:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4}\left(1 + \frac{12h}{a}\right)^{-1/2} \quad (6)$$

Effective length of the patch is equal to.

$$a_e = a + \frac{h}{\sqrt{\varepsilon_r}} \quad (7)$$

3-3-3 Hexagon patch

It is about an antenna of length side (*s*), thickness (*h*) posed on a substrate of permittivity (ε_r). The objective is to find the values of the three parameters: :(*s*, *h*, and ε_r), so that the antenna satisfies the constraint (a resonant frequency equal to 10 GHz)[1].

The resonant frequency of TM_{11} mode of the Hexagon radiant element is:

$$f_{nm} = \frac{1.1 K_{nm} * c}{2\pi s \sqrt{\varepsilon_r}} \quad (8)$$

K_{mn} is the m^{th} zero of the derivative of the Bessel function of order n and is equal to 1.84118 for TM_{11} –mode.

3-4- Selection

The selection operator distinguishes the better individuals from the worse individuals using their fitness. It’s is an important function in genetic algorithms (GAs), based on an evaluation criterion that returns a measurement of worth for any chromosome in the context of the problem. It is the stage of genetic algorithm in which individual genomes are chosen from the string of chromosomes. The commonly used techniques for selection of chromosomes are Roulette wheel, rank selection and steady state selection [9, 15]. In this approach Roulette Wheel selection is used in which parents are selected according to their fitness and the better chromosomes are the more chances to be selected.

3-5- Crossover

Crossover is another process that involves exchange of genetic materials between two parent chromosomes to make child chromosome. The simplest way how to do this is to choose randomly some crossover point and then everything before this point copies from the first parent and then everything after a crossover point copies from the second parent. There are many types of crossover, single point, two points, uniform and arithmetic crossover. In this paper a single point crossover is used with crossover probability is equal to 85%. One crossover point is selected at random position; the parts of two parents after the crossover position are exchanged to form two offspring [15, 16] as shown in Figure (3).

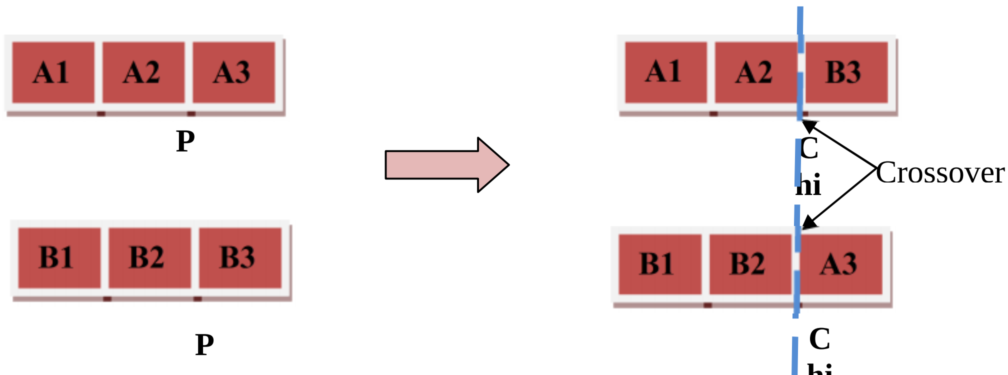


Figure. (3)Single point crossover.

3-6- Mutation

A common view in the GA community is that the crossover is the major instrument of variation and innovation in GA, with mutation insuring the population against permanent fixation at any particular locus and thus playing more of backgrounds role. The appreciation of the role of mutation is growing as the GA community attempts to understand how GA solves complex problems. After a crossover is performed, mutation takes place. This is to parent falling all solutions in population into a local optimum of solved problem. Mutation changes randomly the new offspring (children).There are many types of accomplishing mutation (binary mutation, and real mutation). Real mutation is used according to the following equation, as [15,16]:

$$d_i' = \begin{cases} r(L_o, U_p) & \text{if} \quad z' \leq P_m \\ d_i & \text{otherwise} \end{cases} \tag{9}$$

Where: $\mathbf{z'}$ **:** is random number, $\mathbf{r(L_o,U_p)}$: is random number with limited range (L_o,U_p).

$\mathbf{d_i}$: is the value of gene before mutation. $\mathbf{d_i'}$:is the value of gene after mutation.

$\mathbf{P_m}$: is probability of mutation equal to (0.5%-1%) .

4. Results and discussion

The genetic characteristics are as follows:

*Real value chromosomes, the numbers of chromosomes by population are 100 chromosomes.

* The probability of crossover is 90% and probability of mutation is 1%.

Figure(4) shows the chromosome representation for the three types of microstrip antenna which means the representation of the variables that required to be optimized through the GA, while Figure (5) shows the genetic algorithm for the design of microstrip antenna using MATLAB program. A rectangular, equilateral triangular, and hexagon patches that desiged using genetic algorithm have been constructed and analysis in Microwave Office software 7.1.

Tables (1, 2 and 3) show the design of rectangular ,equilateral triangular and hexagon patches microstrip antenna using GA program and microwave office. The genetic algorithm has been proved to be useful for the design of different types of microstrip antenna (rectangular ,triangular and hexagon patches) that gives good accuracy in compared with MWO as shown in third, fourth, and fifth columns in tables(1,2,and3).

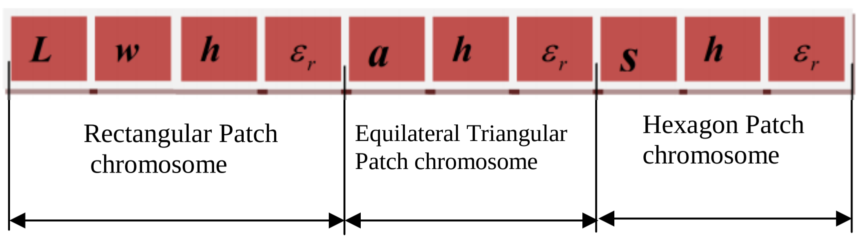


Figure (4). Chromosome representation for microstrip antenna.

Analysis of rectangular

Figure (6) shows the construction of rectangular microstrip antenna using microwave office. Figure (7) shows polar pattern in H-planes and it is found the HPBW in H-plane is equals to 62 degrees. Figure (8) shows the relation between VSWR and frequency. Figure (9) shows the polar pattern in E and it is found the HPBW in E-plane is equal to 61 degrees .

Analysis of triangular

Figure(10) shows the construction of triangular microstrip antenna using microwave office. Figure (11) shows polar pattern in H-planes and it is found the HPBW is equal to 64 degrees. Figure(12) shows the relation between VSWR and frequency. Figure (13) shows polar pattern in E and it is found the HPBW in E-plane is equal to 66 degrees .

Analysis of Hexagon

Figure(14) shows the construction of hexagon microstrip antenna using microwave office. Figure (15) shows polar pattern in H-planes and it is found the HPBW is equal to 67 degrees.
Figure (16) shows the relation between VSWR and frequency. Figure (17) shows polar pattern in E-plane and it is found the HPBW is equal to 63 degree. From the above achieved results, using genetic algorithm is practically acceptable and it's successfully implemented for designing the microstrip antenna with different shapes.

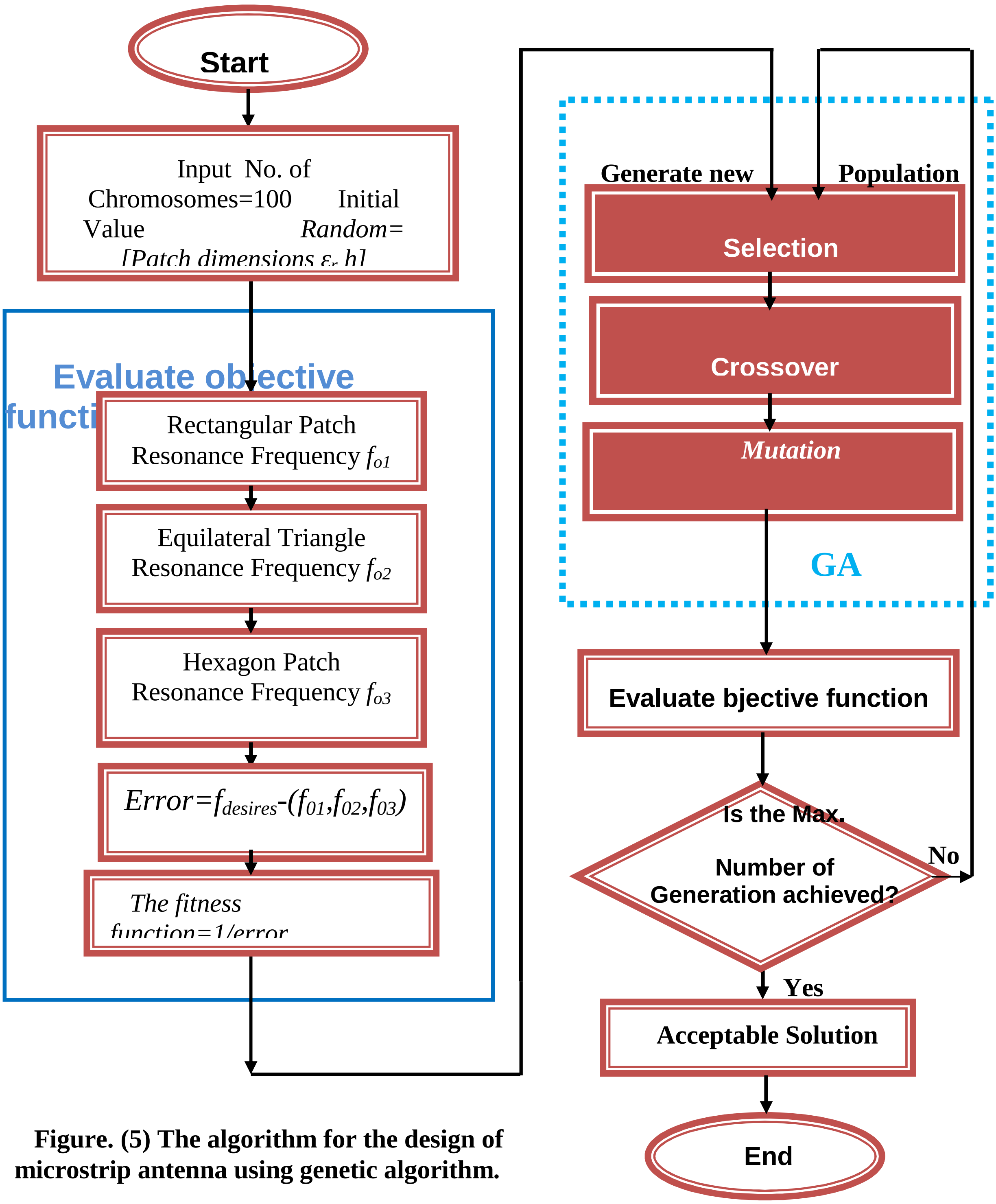


Figure. (5) The algorithm for the design of microstrip antenna using genetic algorithm.

Table (1). Design of rectangular microstrip antenna using GA.

Substrate Material(ε_r)	Height (h) in cm	Width (W) in cm	Length (L) in cm	Center frequency in GHz Using GA	Center frequency in GHz Using MWO	Accuracy%
2.6791	0.316	1.7922	0.6811	10.012	10.1	99.13%
2.7051	0.0957	0.3773	0.9038	10.011	9.9	98.88%
2.6556	0.8104	1.3152	0.3551	10.003	9.19	91.15%
2.4676	0.0605	1.1414	0.9348	9.91	9.94	99.70%
2.6011	0.0943	1.7951	0.8632	10.047	10.1	99.48%
2.3248	0.2763	0.6208	0.8361	9.9495	9.78	98.27%
2.2498	0.0812	0.41	0.9999	9.9033	9.88	99.76%
2.0152	0.2848	1.5129	0.834	9.9591	9.71	97.43%
2.7089	0.2848	0.2517	0.834	9.976	9.8	98.20%
3.0328	0.0782	0.4629	0.8631	9.932	9.88	99.47%
3.0328	0.0782	0.4101	0.8631	9.9836	9.67	96.76%

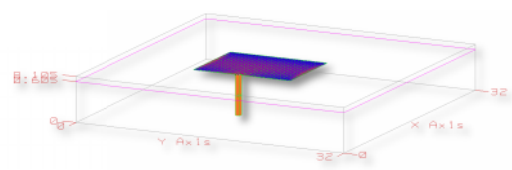


Figure.(6) The construction of rectangular microstrip antenna using microwave office.

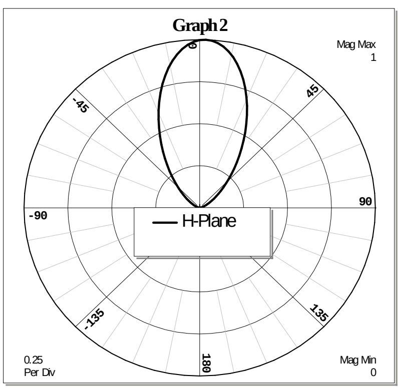
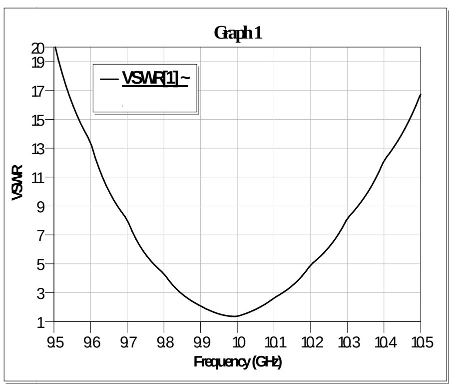


Figure (7). Polar pattern in E-planes of rectangular microstrip antenna using microwave office.



Figure(8). Shows the relation between VSWR and frequency of rectangular microstrip antenna using microwave office.

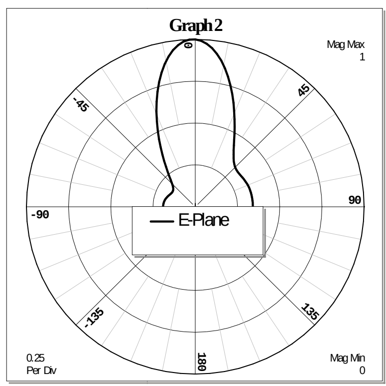


Figure (9).Polar pattern in H-planes of rectangular microstrip antenna using microwave office.

Table (2). Design of equilateral triangular microstrip antenna using GA .

Substrate Material (ε_r)	Height (h.) in cm	Length of Sides (a) in cm	Center frequency in GHz Using GA	Center frequency in GHz MWO	Accuracy%
2.6791	0.306	1.2238	9.903	9.7	97.91%
2.2435	0.1849	1.3423	10.135	9.77	96.26%
2.0886	0.2049	1.3822	10.043	9.81	97.62%
3.5023	0.1624	1.1386	10.062	9.75	96.80%
2.4451	0.0469	1.3665	10.06	9.99	99.30%
3.3242	0.1362	1.1810	9.997	9.81	98.09%
3.0716	0.1156	1.2275	10	10	100.00%
3.4813	0.0661	1.1775	9.998	9.5	94.76%
2.8977	0.3151	1.1694	10.001	9.3	92.46%
2.2433	0.0421	1.4273	9.999	9.98	99.81%
2.2747	0.056	1.4132	10.005	9.9	98.94%

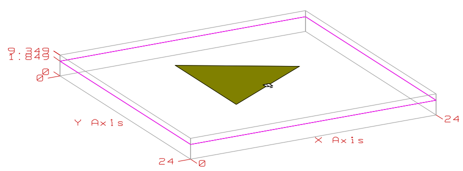
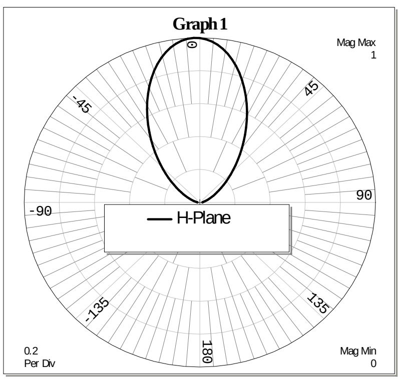


Figure.(10) The construction of triangular microstrip antenna using microwave office.



Figure(11).Polar pattern in H - planes of triangular microstrip antenna using microwave office.

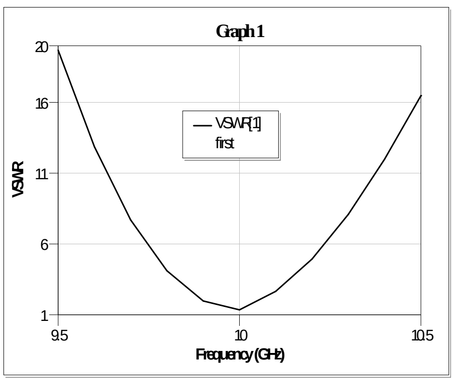
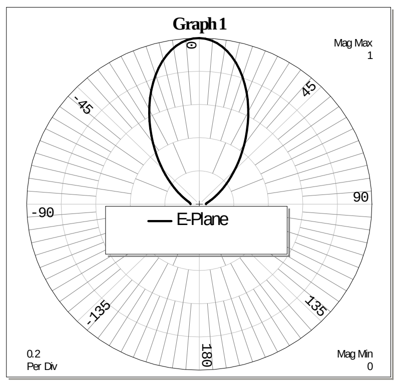


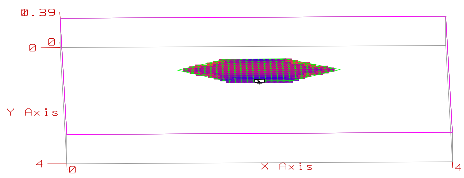
Figure (12). Shows the relation between VSWR and frequency of triangular microstrip antenna using microwave office.



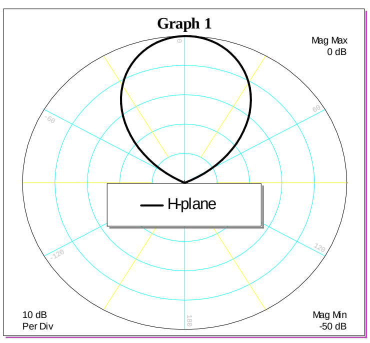
Figure(13). Polar pattern in E - planes of triangular microstrip antenna using microwave office.

Table (3). Design of hexagon microstrip antenna using GA .

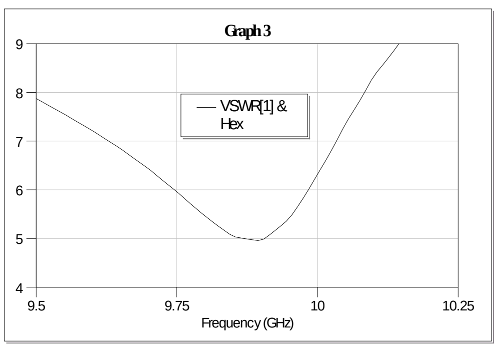
Substrate Martial(ε_r)	Height (h.) in cm	Length of Sides (s) in cm	Center frequency Using GA	Center frequency Using MWO	Accuracy%
2.1788	0.294	0.6746	10.021	9.8	97.74%
2.4181	0.425	0.6384	10.052	10.1	99.52%
2.8642	0.5746	0.5845	10.088	9.87	97.79%
2.1214	0.0443	0.6836	10.023	10.2	98.26%
2.6669	0.1584	0.6105	10.01	9.94	99.30%
2.6224	0.0466	0.6154	10.013	10.13	98.85%
2.6082	0.2747	0.6137	10.069	10	99.31%
2.473	0.0458	0.6292	10.086	9.988	99.02%
2.5656	0.0475	0.62	10.048	10.11	99.39%
2.2016	0.5698	0.6709	10.024	9.89	98.65%



Figure(14). The Construction of Hexagon Microstrip Antenna Using Microwave Office.



Figure(15). Polar pattern in H -planes of triangular microstrip antenna using microwave office.



Figure(16).Shows the relation between VSWR and frequency of hexagon microstrip antenna using microwave office.

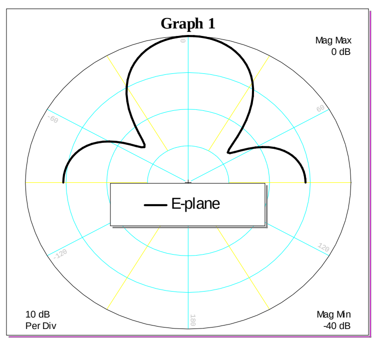


Figure (17) Polar pattern in E -planes of triangular microstrip antenna using microwave office.

5. Conclusions

1- The genetic algorithm has been proved to be useful for the design of different types of microstrip antenna. A simple and flexible genetic algorithm GA is proposed as a general tool for design of microstrip antenna in various forms such as rectangular, equilateral triangle and hexagon patch antennas. The design procedure is to determine the resonance frequency in terms of patch dimensions, dielectric constant (ε_r) and thickness h.

2- The output of the GA (the resonance frequency , patch dimensions ,dielectric constant (ε_r), and thickness h) is examined against the simulation which done in MWO 2007 software.

6. References

[1] Bahil I.J., and Bhartia P., "Microstrip Antennas", Artech House,1980.

[2] Balanis C.A. ,"Moderen Antenna Handbook",John Wiley and sons, tenth edition, 2008.

[3] N. Chattoraj, Jibendu Sekhar Roy," Application of Genetic Algorithm to the Optimization of Microstrip Antennas with and without Superstrate". Microwave Review.V12,(2006),No2.

[4] N. Chattoraj and Jibendu Sekhar Roy," Application of Genetic Algorithm to the Optimization of Gain of Magnetized Ferrite Microstrip Antenna". Engineering Letters. V14, (2007), EL_14_2_15.

[5] Y. Cengiz and H. Tokat ," Linear Antenna Array Design with Use of Genetic , Memetic and TABU Serach Optimization Algorithm" Progress In Electromagnetic Research C, Vol. 1, (2008).pp: 63–72.

[6] Si-Yang Sun, Ying-Hua Lu," Design of Broadband Microstrip Antenna Utilizing Genetic Algorithm", IEICE,(2009).

[7] X. Yongsheng, J. Zhou, Shujing Li, and L. Huang, " Optimization of line-tapered MMI devices uses a genetic algorithm". Chinese Optical Letters . Vol.7,(2009), No.11.

[8] A. Reza D., Gholamreza D. and Mohammad Hossein S. ," New Design Method of UWB Microstrip Filters Using Adaptive Genetic Algorithms with Defected Ground Structures". International Journal of Microwave Science and Technology. Vol.2010, (2010),671515.

[9] R. Malhotra, Narinder S. and Yaduvir S.," Genetic Algorithms: Concepts, Design for Optimization of Process Controllers", Computer and Information Science, Vol. 4, March (2011), No.2.

[10] S. Mehrjoo, Hassan A. and Hossein K.," A Novel Hybrid GA-ABC based Energy Efficient Clustering in Wireless Sensor Network". Canadian Journal on Multimedia and Wireless Networks Vol. 2, April (2011), No.2.

[11] I. Abiodun M., L. Olawale N. and A. Adebowale P." The Effectiveness of Genetic Algorithm in Solving Simultaneous Equations". International Journal of Computer Applications (0975 – 8887), Vol.14, February (2011), No.8.

[12] Y. Wang, Shangce G., Hang Yu and Zheng T.," Synthesis of Antenna Array by Complex-valued Genetic Algorithm". IJCSNS International Journal of Computer Science and Network Security, Vol.1, January (2011), No.1.

[13] A. Correa, Andrés G., and Camilo L.," Genetic Algorithm Optimization for Selecting the Best Architecture of a Multi-Layer Perceptron Neural Network: A Credit Scoring Case", SAS Global Forum, Data Mining and Text Analytics, (2011).

[14] J. Jin, H. L. Wang, W. M. Zhu, and Y. Z. Liu ," Array Patterns Synthesizing Using Genetic Algorithm" Progress In Electromagnetic Research Symposium, Cambridge, USA, March 26-29, (2006).

[15] K. Keng Yan, and Yilong ,"Side Lobe Reduction in Array Pattern Synthesis Using Genetic Algorithms ،" IEEE, Antenna and propagation, Vol.45, July(1997).No.7. pp:1117

[16] M. Obitko, "Introduction to Genetic Algorithms", Hochschule for Technik and Wirtschaft Dresden, September (1998).