SIZE REDUCTION AND BAND DOUBLING OF PATCH ANTENNA USING GENETIC ALGORITHM +

تصغير حجم الهوائي نوع مايكروسترب ومضاعفة حزمته الترددية باستخدام الطريقة الجينية

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Abstract:

In this research, the rectangular patch antenna dimensions are reduced by means of the Genetic Algorithm. Genetic algorithms are capable of handling a large number of design parameters and work for optimization problems that have discontinuous or non-differentiable multi-dimensional solution spaces, making them ideal for antenna optimization. In the present work, a genetic algorithm has been used for size reduction in microstrip patch antennas. A method for reducing the size of microstrip patch antennas by up to 45% by removing rectangular slots from the metal of the microstrip patch is presented. A solid patch antenna that resonates at (8.5 GHz) is forced to resonant at (10 GHz) through the removal of the different shaped slots. Given the number and shape of the slots, the genetic algorithm is used to optimize the size and location of the slot on the patch.

Key Words: Genetic algorithm (GA), dual frequency, patch antenna, slot antenna.

المستخلص:

يهدف هذا البحث لتقليل حجم هوائي نوع (Patch Antenna) بواسطة الخوارزمية الجينية ليكون أصغر حجماً من الهوائي المصمم بالطريقة الاعتيادية لملائمته مع أجهزة الاتصال صغيرة الحجم وبالتالي للاستفادة منه في تصنيع أجهزة اتصال أصغر حجماً. حيث تم تصميم شكل اعتيادي لهذا الهوائي ومن ثم تم تطبيق الطريقة الجينية عليه التي لها إمكانية الفضائات المتقطعة وحلول متعددة الأبعاد لغرض تصغير حجمه وجعله يعمل في حزمتين ترديتين مختلفتين (8.5 GHz) و (10GHz)وذلك من خلال إزالة عدد من المساحات المربعة من مساحته المعدنية بالاعتماد على الطريقة الجينية مما أدى إلى تصغير حجم الهوائي بنسبة (45%)، وتمت ملاحظة الفرق بالأبعاد قبل وبعد تطبيق الطريقة الجينية.

Introduction:

Microstrip antennas (MSAs) have found great acceptance among the electromagnetic and microwave theory practitioners due to their numerous advantages. Hence, considerable

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amount of studies have been devoted to the characterization of these structures with different geometries. Slot antennas are currently under consideration for use in broadband communication systems due to their attractive features, such as wide frequency bandwidth, low profile, lightweight, easy integration with monolithic microwave integrated circuits, low cost, and ease of fabrication [1].

These antennas have several appealing advantages over common microstrip antennas: they provide wide bandwidths, good impedance matching, and bidirectional or unidirectional radiation patterns.

Microstrip antennas have been employed in airborne and spacecraft systems because of their low profile and conformal nature. Many of these applications require a reducing the size of the radiating element to provide light weight, smaller size.

In 2007, an alternative approach using a Genetic Algorithm (GA) to design a matched slotted rectangular patch antenna which reduced in size and operate in (10 GHz) [1].

In 2010, Two printed wide-slot antennas with E-shaped patches and slots, for broadband applications, are proposed. They are fed by a coplanar waveguide (CPW) and a microstrip line with almost the same performances [2].

In 2000, Bandwidth improvement of microstrip antennas through a genetic-algorithm-based design of a feed network [3].

Many techniques have been used to attempt to achieve this reduction in size with varying success. It has been shown that increasing the effective dielectric constant of the substrate will lead to decreased dimensions [1],[3]. While this approach is straightforward, the materials used to produce this high permittivity are generally lossy in nature, expensive, and can increase the sensitivity of the design to small changes in antenna dimensions. A superstrate can be added to achieve a higher dielectric constant, however, the required thickness of the superstrate adds to the fabrication process and can lead to a large patch profile [4].

Shorting pins can be used to reduce the size of a patch antenna to about half of the original dimensions. When placed in the middle of the antenna, the shorting strips make use of image theory to act as a mirror and thus cause the antenna to behave as if it was double its actual length. Shorting pins however often produce antennas with a narrow bandwidth and a low gain. Decreasing the dimensions of a patch antenna results in a strong reactive input impedance [4].

Altering the geometry of the patch antenna can cause a size reduction. Cutting slots into the patch force the surface currents to meander thus effectively creating a longer electrical length and reducing the size of the antenna. Cutting slots into the ground plane can also cause a size reduction [5].

Recently, evolutionary algorithms, such as a genetic algorithm (GA) have been used to optimize patch antennas.

In this paper a traditional rectangular patch antenna resonating on (8.5 GHz) band will be forced to resonate on additional band (10 GHz) by means of GA, which leads to reduction in the size of the patch after modifying its shape making slots with different size.

Genetic Algorithm (GA):

The (GA) is based on the evolution theory where weak species face extinction but strong ones survive and pass their genes to the next generation. However for the strong species to survive there is also a requirement for random injection of genes. As GA mainly manipulates matrices it is normally implemented using Matlab software. The step by step procedure of generating the software program is shown below [1, 6]:

Step 1: Each variable is assigned a number of binary digits so that the required accuracy of this variable is obtained in the final solution.

Step 2: All the variables in their binary form are grouped into a string which is called a chromosome.

Step 3: Selecting a fixed number of random chromosomes called a population out of all possible number of chromosomes that are present by using Matlab software. This is called the current generation.

Step 4: Converting the digital value of each variable in a chromosome to an analogue value, the objective function (F) is evaluated and the relative fitness of each chromosome (Pi) determined. This relative fitness is defined as:

$$F = \sum_{i=1}^{n} eval_i[P_i] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

Step 5: The selective probability is determined by:

$$P_{si} = \frac{eval_i[P_i]}{F} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

The cumulative probability of the chromosomes is given as:

$$q_i = \sum_{j=1}^{n} P_{sj} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3$$

Step 6: Crossover is applied for random chromosomes between the parent and next generation to produce new off -springs.
Step 7: The population is mutated by changing in a random way the value of the genes with the least significant bit having the highest probability of mutation and the most significant the least.
The next generation now becomes the parent generation and the above process is repeated until the genetic variation in the population is below a certain threshold.
As the number of generations increases both the cross over rate and the mutation rate are gradually reduced.

Antenna Design:

In our design, the antenna geometry modified by using the GA. The antenna shape is rectangle and will divided into two symmetrical halves, each half is divided into (m × n) small elements as shown in the figure.1. and treated as a mirror of the other half to preserve the symmetry of the patch antenna's radiation pattern.

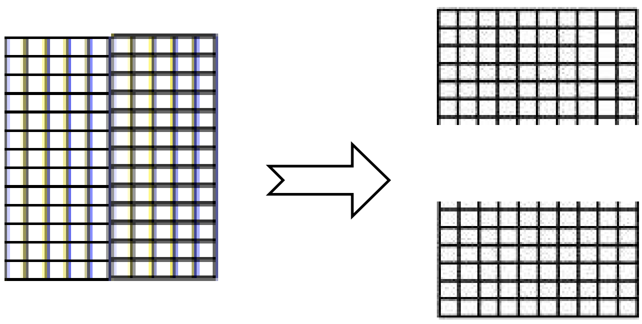

Figure.1 Patch antenna area division

One of the two halves is responsible of one resonance band as the other one does. By applying GA to this geometry, some of the small elements are removed, while others are remained as in the figure.2 (the × symbol indicates the rectangle to be removed). This process will lead to introduce inductance, capacitance and matching components to the equivalent circuit of the patch antenna. Thus, antenna band can be widened or doubled.

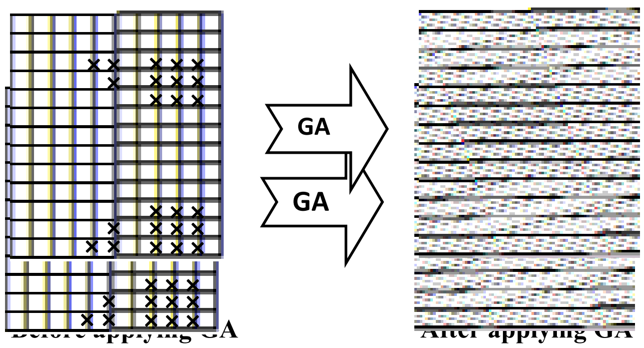

Figure.2 Patch geometry before and after GA

Simulation and Results:

This results is un optimization for the patch in [1], where the patch was resonating at single frequency. A genetic algorithm is used to control the removal of slots from the metal of a patch antenna. The increase in electrical length of the patch antenna can get as a result of the surface current meanders, which in turn causes a downward shift in the resonant frequency. A standard rectangular microstrip patch antenna that resonates at (8.5 GHz) (figure.3) is used as the base antenna from which slots are cut as seen in the figure (2) with the dielectric permittivity of (2.2) and the dielectric height of (0.79 mm) are all constants in the optimization problem. A particular slot shape is specified in addition to the number of such slots that need to be removed from the patch surface to the genetic algorithm and this is seen in figure (2). This led to the size reduction.
Figures (4,5) show the return loss (S11) and smith chart with the frequency using (MSTRIP40) software, which demonstrate that this antenna is operating at (8.5 GHz). As the resonance frequency decrease, the patch dimension will increase, while using Genetic Algorithm the patch dimensions remain same for the two bands. Therefore, a size reduction is done.

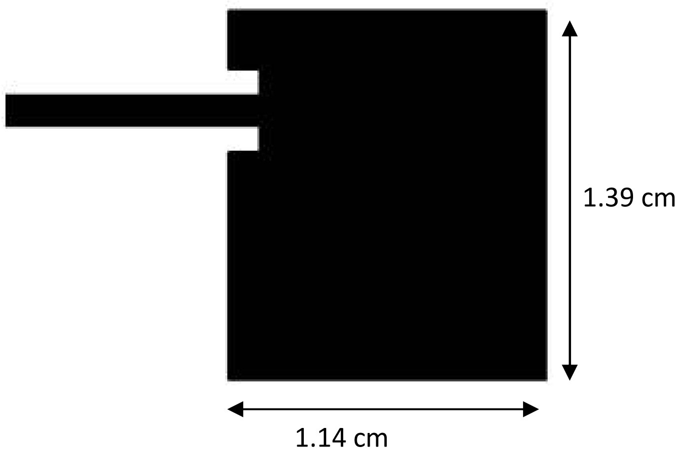

Figure.3 Basic patch antenna (8.5 GHz) from which slots would be cut

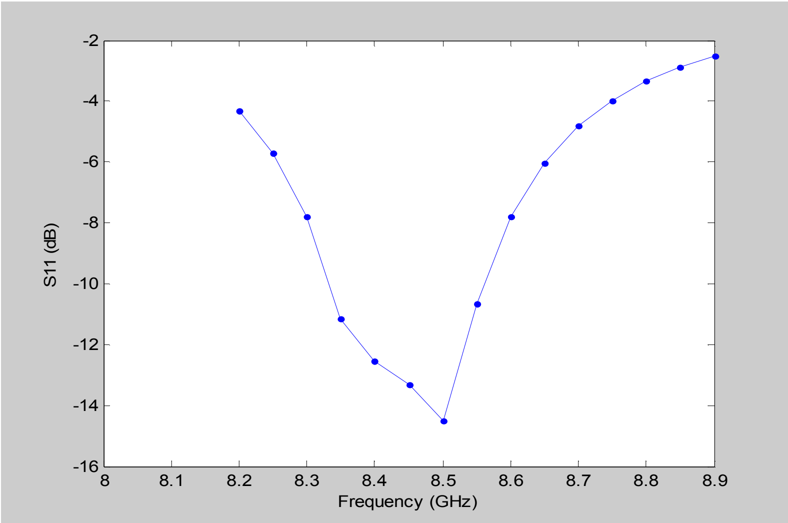

Figure.4: Return loss S(11) with frequency for the basic patch antenna using MSTRIP40 software

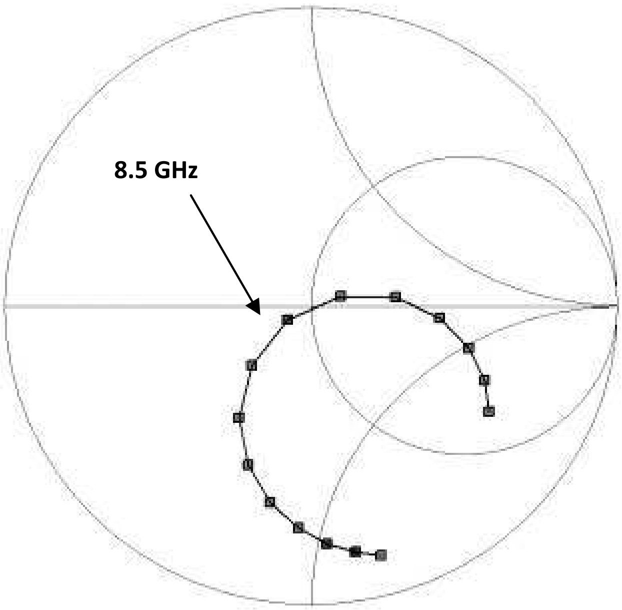

Figure.4: Smith chart of the basic patch using MSTRIP40 software

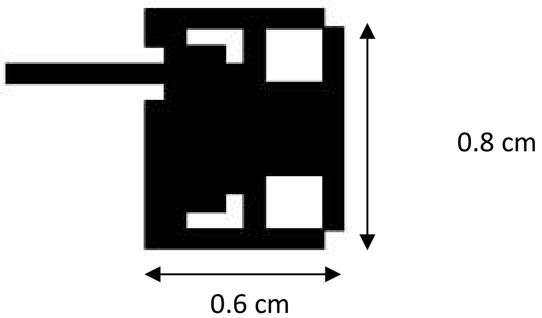

Figure.2 The new antenna configuration (size reduced) after removing rectangles from the basic patch copper using Genetic Algorithm

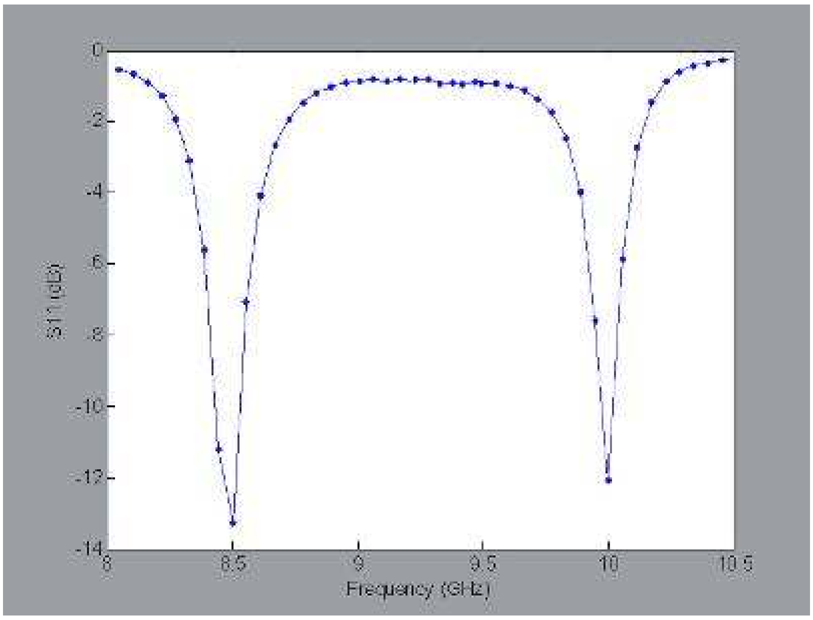

Figure.3: Return loss S(11) with frequency using Genetic Algorithm using MSTRIP40 software

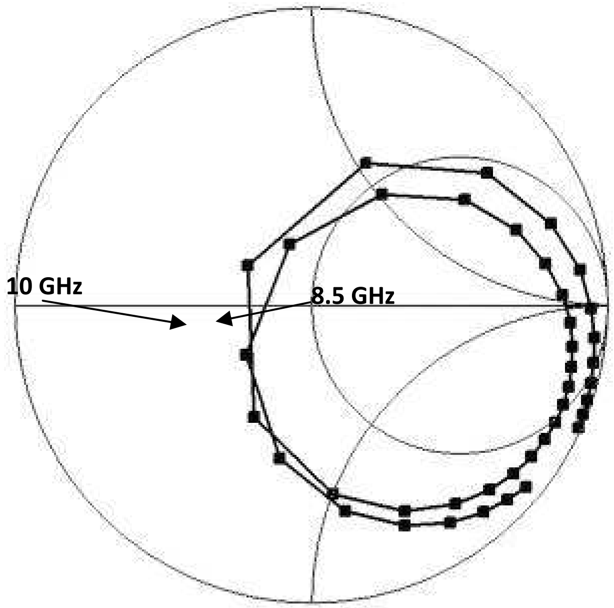

Figure.4: Smith chart of the patch using Genetic Algorithm using MSTRIP40 software

Conclusion:

A genetic algorithm is an active tool for modification that can be made to the standard rectangular patch antenna that will cause the properties of the antenna to change to reduce a rectangular patch antenna size by removing slots (rectangular) from the copper patch which causes meandering of the surface current. The increase of the current path leads to an increase in electrical length of the patch antenna, which in turn causes a downward shift in the resonant frequency. This shift in resonant frequency is analogous to a reduction in size, as a solid patch antenna that would resonant at this new reduced frequency would be much larger than the slotted antenna. The patch can be divided into two symmetrical parts and each one can be seen as single patch, then by mean of GA, the slots can be removed to cause the resonance.

Specifying the number and shape of the slot, the genetic algorithm is used to optimize the size and location of the slot on the patch. The current path can be increased by the slot, were the patch size will be effected and will resonate at a lower frequency instead of increasing its dimensions. Various slot shapes and numbers can be tried in order to optimize for gain as well as size reduction.

References:

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