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Circular Polarized Patch Antenna Minimization for 5 GHz Applications Based on Genetics Algorithm

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***Abstract*— This paper examines the construction of a rectangular patch antenna with circular polarization and strip line feed with the goal of reducing the microstrip patch antenna's size. With the help of a genetic algorithm, we were able to cut a rectangular slot in the corner of the patch and keep cutting it until we got the ideal design at the operating frequency (5 GHz) with a reduced size of (68.6%) based on the current distribution on the patch (GA). With the proposed design, there is a noticeable increase in bandwidth. COMSOL simulation software was used for the simulation. The first antenna design's operating frequency is set to 6 GHz, and it is then forced to run at that frequency (5 GHz).**

Keywords*— *Genetic algorithm (GA), COMSOL, Patch antenna, Slot antenna, Circular polarization.

I. Introduction

Microstrip antennas (MSAs) have been widely acknowledged by practitioners because to their numerous advantages, according to electromagnetic and microwave theory. As a result, a large number of studies have been dedicated to characterizing these structures with various geometries [1]. Lightweight, wide frequency bandwidth, easy integration with monolithic microwave integrated circuits, low profile, cheap cost, and easy fabrication were the best attributes that made slot antennas nominated to be utilized in broadband communication systems.

These antennas have various advantages over traditional microstrip antennas, such as large bandwidths, good resistivity matching, and dual directional or one-way radiation patterns [3]. Microstrip antennas have been determined to be the best choice for any airborne or spacecraft system because of its low profile and conformal nature. Many of these applications necessitate shrinking the size of the radiating element in order to achieve lighter weight and smaller dimensions.

Antenna designs for both ground-based and airborne-based subsystems pose a unique challenge in that they must be as basic and low-cost as feasible while also meeting the specific electrical requirements. As a result, designers have had to come up with ever-more inventive ways to achieve their objectives. The application of evolutionary optimization algorithms for electromagnetic design has been increasingly common during the last few years. Genetic algorithms (GA) in particular have exploded onto the research scene with great success, owing to its unique characteristics that make it an ideal tool that works well with existing EM analysis techniques [1][4], and typically produces results that satisfy the given requirements in a nonintuitive manner.

A lot of work has already gone into improving the computational maturity of GA optimization in electromagnetics [3], [5] [6], as well as expanding the domain of applications to encompass some really clever designs. Novel pattern synthesis and broadband (or multiband) operation are two unique focal areas in which GA optimization has achieved extremely successful results. The creation of "smart" antennas is another area where GA designs show potential.

In practice, a GA optimization technique's accuracy and convergence rate are essentially determined by two key factors: the parameter encoding scheme and the fitness function chosen.

Both of these are fundamentally responsible for the solution space's settopological properties. Despite the fact that the GA is a very robust technique due to its stochastic nature, it is still prudent to choose a fitness function and encoding scheme that are consistent with the underlying physics of the problem, because the optimization routine has no direct knowledge of what is being optimized. In our situation, we've gone with a binary encoding scheme, with a -gene chromosome comprised of the OFF/ON subsections of a rectangularly discretized patch template.

When activated at the impedance matched position, the gain of a microstrip antenna constructed on a dielectric substrate relies on the size of the patch, relative dielectric constant, and thickness of the substrate at a specific resonance frequency. However, in the case of a microstrip antenna constructed on a ferrite substrate and magnetized by a d. c. magnetic field, the antenna gain is additionally affected by the bias magnetic field and the saturation magnetization of the ferrite, in addition to the preceding factors.

In this work, a standard rectangular patch antenna resonating on the (6 GHz) band is pushed to resonate on an extra band (5 GHz) via GA, resulting in a patch size decrease after altering its shape and creating slots of various sizes.

For a long time, the smallest antenna size was considered more vital, particularly in cellular transmission and receiver equipment. Physical size is more important than scattering circumstances, while antenna cross polarization characteristics are less important. Naveen Jaglan and Samir Dev Gupta employed electromagnetic band gab (EBG), which is surface selective and supports surface waves, to help boost bandwidth by minimizing excitation waves in the patch antenna surface [3]. To construct a patch antenna with a resonating frequency found in the EBG substrate and to analyze the achievement of a single patch antenna and an array of patch antennas embedded in the EBG substrate. It is noted the achievement of the realized antenna is found more suitable comparing It with the micro strip patch antenna which using the natural substrate through return losses and impedance [1]. Wi-MAX can solve this problem by employing antennas with higher bandwidth and strength. Broadband Internet cannot be used in residential areas or rural +blackout zones. As a result, A.S.M. Bakibillah, Md. Sakhawath Hossain, and Ivy Saha Roy have proposed designing a rectangular microstrip patch antenna at 3.5 GHz to achieve the largest bandwidth range and antenna performance at many operating frequencies [4].

Traditional techniques, such as installing the antenna in a dielectric medium with a high permittivity, inserting a resistive component in series with the antenna, and so on, were used to reduce the actual size of the antenna previously, but little effort was put into essentially creating different calculations, which, by their characteristic properties, transmit at a lower frequency than the notable old style antennas which possess a similar actual volume.

Because of the importance of microstrip patch antennas in military and civilian applications [5], and because acquiring a compact antenna is an important aim for many academics, researcher Muhammad Aamir Afridi created an antenna in CST Microwave Studio with a resonant frequency of 2.4 GHz. The built antenna has a rise of 8.27 dB and a VSWR of 1.18. [6]. Another group of researchers, including Mohammed Lamsalli, Abdelouahab El Hamichi [7], used a new method to reduce the size of a microstrip patch antenna by using a genetic algorithm, in which the underlying patch is partitioned into 1010 small uniform square shapes (Pixel), and the genetic algorithm investigates the ideal design for the ideal objective [8].

II. The Genetic Algorithm

The Genetic Algorithm is an excellent example of evolution theory because it assumes that survival is determined by the fittest. The Genetic Algorithm (GA) is a robust stochastic based search approach that can manage the common properties of electromagnetics that other optimization techniques such as hill climbing, indirect and direct calculus based methods, random search methods, and so on can't handle.

A gene is a parameter's binary encoding. Parents are members of the population who are capable of reproducing in the best possible way. The GA then moves on to the production phase, during which the parents are picked through a selection process. The crossover genetic algorithm operator is used to reproduce the chosen parents. Random points are chosen at crossover. When the next generation is finished, the crossover process comes to an end. In the simple GA operation, mutation plays a supporting function. Even if reproduction and crossover effectively search for and recombine existing ideas, they can occasionally become overzealous and lose some potentially important genetic material.

The fittest, on the other hand, must pass the test for random gene injection in order to survive the hypothesis [6]. Because the Genetic Algorithm directly pulls a string of matrices, it is commonly used with Matlab software.

The method of the software program generating [1, 6] is shown in the steps below:

Step 1: Any variants are assigned a number of digits so that, at the end of this step, the requested accuracy of these variants is achieved.

Step 2: The variants will be grouped into a chromosome, which is a string made up of their pairs of digits.

Step 3: A population is formed by selecting a specified number of any potential chromosomes from the total number of chromosomes displayed by Matlab software. The current generation is referred to as such.

Step 4: It will determine the relative fitness of each chromosome (Pi) and the objective function (F) to be assessed by changing the digital value of each variable in a chromosome to an analogue value.

A. Fitness Function

The length and width of the spring, as well as the BIST voltage (stimulus), will be used to calculate the fitness function for our problem.

$$r = mphplot(out.'pg4') \quad (1)$$

Where (r) denotes the MEMS' COMSOL structure, and (mphplot) is the MATLAB function that reads the MEMS from the COMSOL structure. As shown in Eq. (2), this (r) will be multiplied by the desired MEMS response:

$$F = r.d \quad (2)$$

As seen in Eq. (3), the required answer is (u):

$$u = MA + c \quad (3)$$

Where (A) represents the points that will be selected from the original answer, (M) represents the original (desired) response slope, and (c) represents the offset that will be applied to the original response. Finally, if the mean square is used, the error output will be as shown in Eq. (4):

$$Error = \frac{1}{N}\sum_{k=1}^{N}|d_k - F_k|^2 \quad (4)$$

III. Antenna Design

The antenna geometry was changed using the GA in the design below. Many portions of the antenna patch can be removed to provide a longer channel for the patch's surface current. As a result, the antenna's operation will be switched from the 6 GHz to the 5 GHz band but the dimensions (length and width) remain the same. It would reduce the size on a regular basis. The field that must be removed is chosen based on its surface current division, which has a specific effect on the patch impedance. The region is reduced using (GA) in order to provide a satisfactory antenna resonance. Before the circular polarized antenna, there was a simple circular polarized antenna. The Fig (1) depicts minimization.

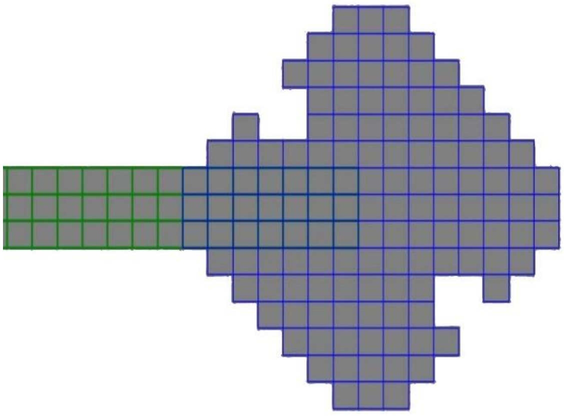

Fig. 1 Basic patch antenna (6 GHz) with circular polarization.

IV. Simulation and Results

These are unoptimized findings for the patch in [1], which was resonating at a single frequency. The evolutionary algorithm is used to gain control over the process of eliminating the slots from the patch antenna's metal. Surface current meanders can cause an increase in the electrical length of any patch antenna, resulting in a descendant shift in the resonant frequency. The conventional antenna is a rectangular microstrip patch antenna that resonates at 6 GHz (Fig.3), with the slots separated as shown in Fig (1) and a dielectric permittivity of (2.2) and a dielectric height of (0.79 mm), all of which are factors in the optimization problem. Fig. 1 shows a special slot form with all the other known slots that are urged to be erased from the patch surface by the genetic algorithm (4). As a result, the size was reduced.

Fig. 5 and Fig. 6 show the smith chart and return loss (S11) with frequency, indicating that this antenna is working at that frequency (5 GHz). The patch dimension increases as the resonance frequency decreases [10], but the patch dimensions for the two bands are the same when employing the Genetic Algorithm. As a result, there is a size reduction.

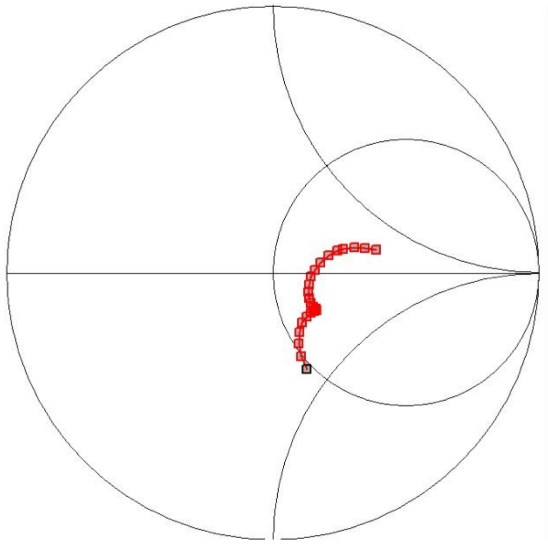

Fig. 2 S11 parameter chart with the frequency for the patch antenna.

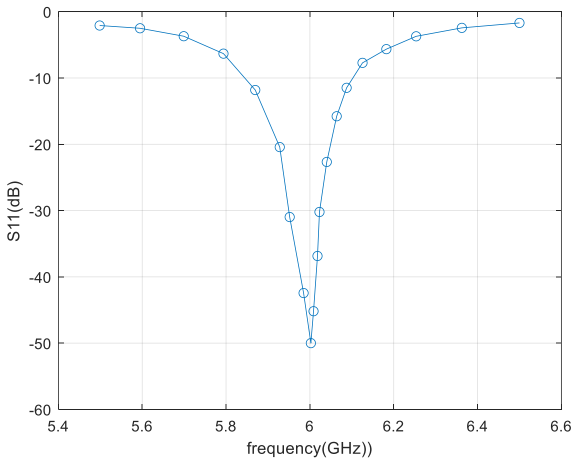

Fig. 3 S11 parameter chart with the frequency for the patch antenna.

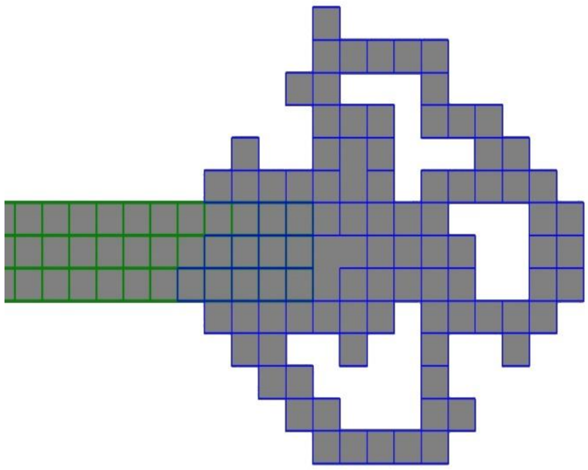

Fig. 4 S11 resultant patch antenna (5 GHz) from which slots would be cut.

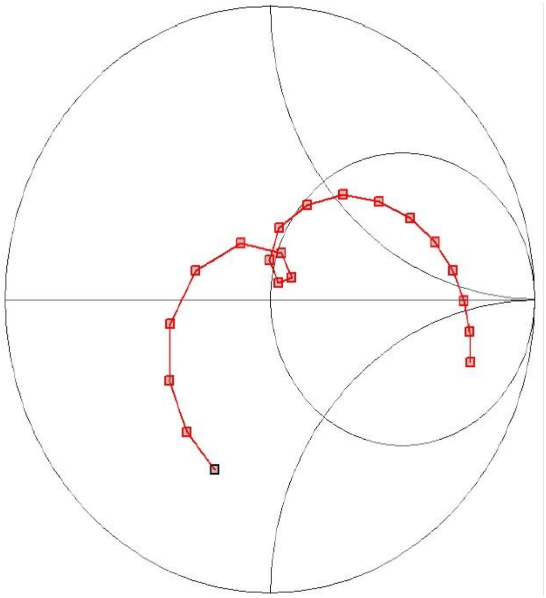

Fig. 5 S11 resultant patch antenna (5 GHz) from which slots would be cut.

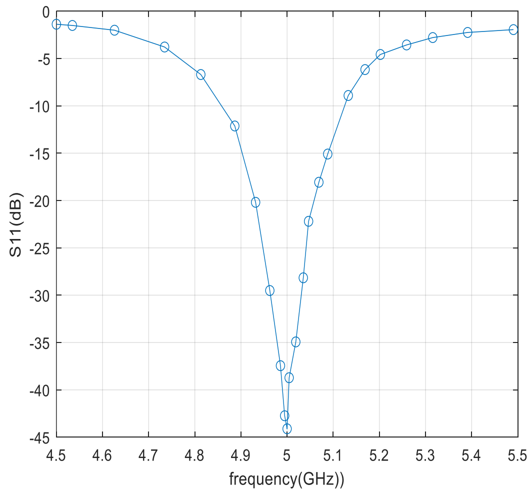

Fig. 6 S11 resultant patch antenna (5 GHz) from which slots would be cut.

V. Conclusion

A genetic algorithm is an active technique for changing the characteristics of a rectangular patch antenna by deleting slots (rectangular sections) from the copper patch, resulting in surface current meandering. The electrical length of the patch antenna is increased when the current path is increased.

A solid patch antenna that would resonance at this new lowered frequency would be much larger than the slotted antenna, therefore the shift in resonant frequency is similar to a reduction in size. The patch can be broken into two symmetrical halves, each of which can be viewed as a single patch, and the slots can then be deleted using GA to produce the resonance.

The evolutionary algorithm is used to alter the location of a slot on the patch and its size after specifying the amount and any slot and its shape. The current path can be lengthened by inserting a slot, but the patch size will be affected and will resonate at a lower frequency rather than lengthening. As a result, the resonance frequency would decrease. The circularly polarized microstrip antenna was designed to demonstrate the use of a GA for the difficult object function. For the given substrate qualities and operation frequency, the size and feeding point were optimized.

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