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OPTIMIZATION OF MINIATURIZED MICROSTRIP PATCH ANTENNAS WITH GA

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ABSTRACT

This study proposes a method to enhance the performance of miniaturized microstrip patch antennas (MPAs) loaded with a high relative permittivity thin film. The thin film decreases the resonance frequency while maintaining the antenna's patch dimensions. Genetic Algorithms (GAs) are used to optimize the patch dimensions. The resonance frequency is reduced from 5.8 GHz to 4.0 GHz, and the antenna area is minimized. The proposed antenna improves return loss, bandwidth, and Voltage Standing Wave Ratio (VSWR), enhancing its overall performance. Hence, this analysis shows high accuracy and less area.

Keywords: Micro-Strip Patch Antenna, Thin Films, High Permittivity Dielectric Material, Antenna Miniaturization, Genetic Algorithm Optimization.

1. INTRODUCTION

Due to rapid decrease in size of personal communication devices, the size reduction of microstrip antennas is becoming an important design consideration. However, antenna design has grown more stringent and difficult over the years with inherent tradeoffs that exist between gain, radiation pattern, bandwidth, and physical size making antenna design a lengthy process. Recently, several methods have been used to optimize patch antennas with varying success, such as using a dielectric substrate of high permittivity [1], Defected Microstrip Structure (DMS), Defected Ground Structure (DGS) at the ground plane or a combination of them, and various existing optimization algorithms such as particle swarm optimization (PSO) and genetic algorithm.

The latter is one of the global optimization algorithms that have been used widely in the past by antenna designers for the optimization of the patch shape and size in order to achieve better overall performance of the antenna. Genetic algorithm (GA) is a powerful optimization technique useful in a wide area of electromagnetics [2]. It is based on the Darwinian concepts of natural selection and evolution. GA has been used to enhance the performance of microstrip patch antennas (MPAs) by optimizing the bandwidth, multi-frequency, directivity, gain, size etc.

The concept of GA is to divide a regular square microstrip patch antenna into a grid of symmetrical squares and use genetic algorithms to selectively remove smaller metallic grid squares from the patch, and then, novel non-intuitive shapes can be produced [3]. This method has been employed to create dual-band antennas because of several current paths on the patch, wide-band antennas, and longer meandering current paths on the patch lead to miniature performance of patch antennas. This paper is focused on a miniaturization procedure of rectangular patch antenna based on GA, by improving a cost function and using a uniform crossover technique. The typical shape of a rectangular patch is modified in order to reduce its resonance frequency keeping the physical volume of the antenna constant. The resonance frequency of a square microstrip patch is reduced from 4.9 to 2.16 GHz. The patch is divided into 10 × 10 small uniform rectangles (Pixel) [4].

Now a day, wireless devices are widely employed in a variety of domains, including telecommunications, aeronautics, medical, and military. The growing use of these systems has led manufacturers to focus on the improvement of wireless devices. Therefore, microwave circuit technology has shown a considerable development in recent years. This evolution became possible after the significant progress in electronics and numerical information processing techniques. The connection between these terminals, mobile phones, computers, base stations, and other infrastructures is carried out by electromagnetic waves [5].

The antenna is one of the most essential elements of wireless systems. These elements transform the electrical signal into electromagnetic signals and radiate these in space and vice versa. The antenna takes up the most space in the communication system chain; thus, increasing the antenna's total size makes the implementation of a wireless device difficult in a small area. In recent decades, reducing the size of antennas has been one of the main focuses in the designers of antennas. Miniature antennas are especially used in micro-fabrication technologies to manufacture wireless devices. In fact, the length of an ordinary antenna that operates at some frequency is generally of the order of a half-wavelength of that frequency, e.g., the conventional length of an antenna resonating at 1 GHz in the case of a dielectric constant of 2.2 is approximately 100 mm. However, this length is practically unacceptable for several devices [6]. Moreover, most devices such as satellite, radio frequency identification (RFID) chips, and phones need the use of multiple antennas. Thus, the development of wireless devices will continue to challenge researchers to design smaller antennas.

Generally, there are three principal ways to miniaturize an MPA: introducing slots, shorting and folding, and material loading. During the first method (introducing slots), the reduction of the size of a patch antenna can be realized by creating slots or changing the shape of the patch. For the purpose of obtaining a large electrical length in a small area, miniaturized patches can be optimized using a genetic algorithm (GA) [7]. However, this technique will be complicated because the geometry of the antenna and its gain will be very low. Fractal geometries are employed to reduce the size of the microstrip patch antenna. However, this antenna suffers from a considerable reduction in bandwidth. The second technique (shorting and folding) is the ground plane deformation. In this method, researchers use defected ground structures (DGSs) to miniaturize the antenna. In the literature, DGSs have several shapes: simples ones, e.g., spiral, H-shape, and U-shape or complex ones, for example, split-ring resonators (SRRs). The realization method is simple but there is no standard design procedure and it provides a low efficiency and a narrow bandwidth. The third and simplest method to miniaturize a patch antenna (material loading) is the utilization of a substrate with a high relative permittivity (ε_r), as the antenna's resonance frequency is scaled by $1/\varepsilon r \mu r$ (μ_r is the relative permeability of the substrate). Nevertheless, the last technique suffers from a decrease in the bandwidth when a substrate with a high relative permittivity.

2. LITERATURE SURVEY

T. -Y. Kim and S. -S. Hwang, et.al [8] described 5G mobile communication using a high carrier frequency can operate a massive array antenna. A large-scale antenna element is a major factor that increases the hardware and software complexity of an array antenna. In such a massive array antenna, beamspace conversion is a very efficient method to reduce the high complexity of element space. This paper presents a mathematical model that analyzes the total number of addition/subtraction and multiplication/division of beamspace transformation formulas for a dual array antenna among various massive array antennas and provides results of computational complexity analysis.

T. Gabillard, V. Sridhar, A. Akindoyin and A. Manikas, et.al [9] described about upcoming trends of wireless communications, such as massive MIMO, the number of antennas at the transmitter(TX) and receiver (RX) are expected to increase dramatically, aiming to provide a substantial improvement in system performance and spectral efficiency. However, an increase in the number of antennas also results in an increase in hardware, computational complexity and energy dissipation of the MIMO system. Therefore, the antenna array geometry plays a crucial role in the overall system performance. This paper is concerned with planar antenna array geometries with emphasis given to the family of 2D "grid" arrays and presents an insight into the relation between the array geometry and various performance metrics, such as detection, resolution and data-rate maximization, that may be used in different applications.

C. -M. Chen, V. Volski, L. Van der Perre, G. A. E. Vandenbosch and S. Pollin, et.al [10] Massive MIMO is considered a key technology for 5G. Various studies analyze the impact of the number of antennas, relying on channel properties only and assuming uniform antenna gains in very large arrays. In this paper, we investigate the impact of mutual coupling and edge effects on the gain pattern variation in the array. Our analysis focuses on the comparison of patch antennas versus dipoles, representative for the antennas typically used in massive MIMO experiments today. Through simulations and measurements, we show that the finite patch array has a lower gain pattern variation compared with a dipole array. The impact of a large gain pattern variation on the massive MIMO system is that not all antennas contribute equally for all users, and the effective number of antennas seen for a single user is reduced. We show that the effect of this at system level is a decreased rate for all users for the zero-forcing MIMO detector, up to 20% for the patch array and 35% for the dipole array. The maximum ratio combining on the other hand, introduces user unfairness.

T. -Y. Kim, H. -S. Park, S. -B. Jeon, T. -H. Jo and S. -S. Hwang, et.al [11] explains the next-generation communication system, various communication services employs beamforming and massive array antenna techniques for reliable and efficient wireless communications. Based on the massive array antenna with a huge number of elements, the beamforming technique such as the estimation of Angle Of Arrival (AOA) may not operate in real time, because the computational complexity for this situation should be extremely high. In order to enhance this problem, in this paper, we propose the cascade AOA estimation algorithm based on the Flexible Massive Combined Array (FMCA) antenna. The proposed algorithm finds AOA groups including multiple signal AOAs employing Capon based on some elements of the FMCA antenna, and it estimates the detail signal AOAs in the found AOA groups employing Beamspace Multiple Signal Classification (MUSIC) based on entire elements of the FMCA antenna. In addition, we provide the received signal model for applying the FMCA antenna and the proposed cascade AOA estimation algorithm.

M. Nandakumar and T. Shanmuganantham, et.al [12] Proposes SIW flower shaped fractal antenna for 60GHz applications. This frequency is used for wireless communication applications. The proposed antenna is intended by using Rogers substrate with εR=2.2, height is 0.381 mm and the microstrip feed is used with the input impedance of 50ohms. The structure provides 4 GHz impedance bandwidth in between 57-64 GHz band and matches with VSWR 2:1. The Computer simulation technology software is used for simulation and observed the generlalized parameters of the anteena.

S. Cheng, H. Yousef and H. Kratz, et.al [13] design, fabrication and characterization of 79 GHz slot antennas based on Substrate Integrated Waveguides (SIW) are presented in this paper. All the prototypes are fabricated in a polyimide flex foil using Printed Circuit Board (PCB) fabrication processes. A novel concept is used to minimize the leakage losses of the SIWs at millimeter wave frequencies. Different losses in the SIWs are analyzed. SIW-based single slot antenna, longitudinal and four-by-four slot array antennas are numerically and experimentally studied. Measurements of the antennas show approximately 4.7%, 5.4% and 10.7% impedance bandwidth (S_{11} =-10 dB) with 2.8 dBi, 6.0 dBi and 11.0 dBi maximum antenna gain around 79 GHz, respectively. The measured results are in good agreement with the numerical simulations.

3. METHODOLOGY

In fig.1 block diagram of Optimization of Miniaturized Microstrip Patch Antennas with GA. The purpose of a GA is to compute the extrema of a function identified in a space of data. An evolutionary process is utilized to resolve a problem using GA, in which possible solutions (chromosomes) will be utilized to develop new solutions. Such a group of possible solutions will be named a population. For the objective of creating the next generation of the population, only one population (particular) will succeed and will be employed. Solutions utilized for creating novel solutions (offspring) are selected based on their fitness function.

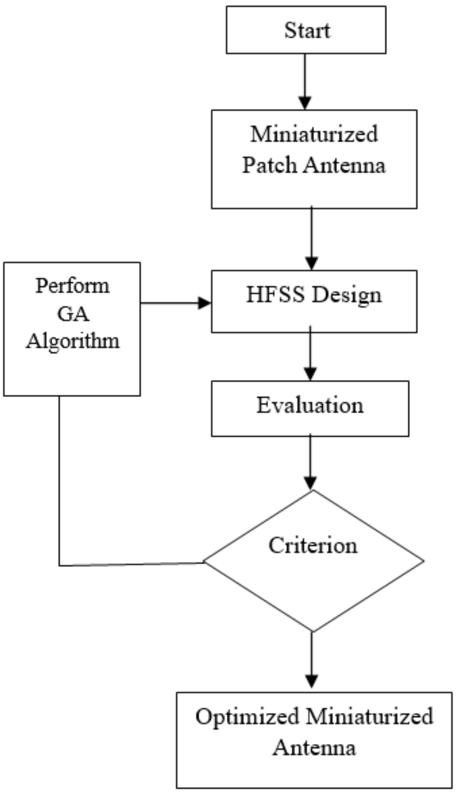

Fig.1: Block Diagram Of Optimization Of Miniaturized Microstrip Patch Antennas With GA

Initially Microstrip Patch Antennas with GA begins and proceeds by designing a miniaturized patch antenna with a thin flim. This thin flim will solve the model by designing with HFSS. The HFSS extract loss. Then it continues with an evaluation. If criterion is satisfied then miniaturized antenna is optimized. If criterion is not satisfied then again it performs GA operations to adjust patch dimensions.

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4. RESULT ANALYSIS

In this section performance analysis of Optimization of Miniaturized Microstrip Patch Antennas with GA is observed.

Table.1: Performance Analysis

Parameters	Existing System	Proposed System
Accuracy	86.4	98.5
Area	9145	7981

In Fig.2 accuracy comparison graph for existing system and proposed system is observed.

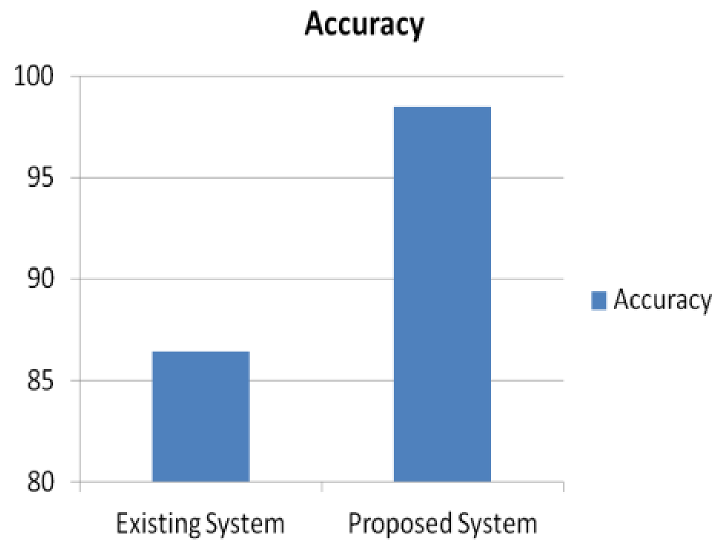

Fig.2: Accuracy Comparison Graph

In Fig.3 area comparison graph for existing system and proposed system is observed. Proposed system shows lower area occupation.

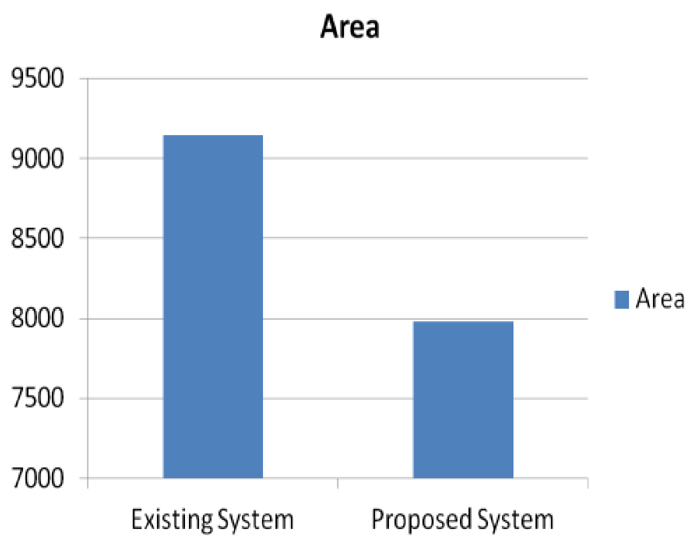

Fig.3: Area Comparison Graph

5. CONCLUSION

A new method for designing and optimizing miniaturized microstrip patch antennas for telecommunications is presented. A thin-film material with high permittivity is used to reduce the antenna's resonance frequency while maintaining patch dimensions. A genetic algorithm is used to estimate optimal parameters for the patch. The results show that the designed antenna's resonance frequency increased from 5.8 GHz to 4.0 GHz and the area of the proposed antenna reduced. This improvement in performance, such as bandwidth, return loss, gain, and VSWR, is particularly noteworthy. The method can be easily applied to designing filters or antennas with diverse frequencies or geometries. Hence, this analysis achieves better results interms of accuracy and low area occupation.

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