EA Based Optimized T-Slot Patch Antenna for Bandwidth Improvement

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Abstract—Microstrip antenna is a vital component of modern wireless communication systems. Therefore it requires optimized design for improving the overall performance of the system. The advancement of wireless devices including mobile equipments is ever growing area towards implementation. In this field importance of the antenna technologies grow accordingly. As handsets improve in compactness with multi functions in recent age, the antennas for these equipments have come under the spotlight. In this paper, the designing and analysis of T-slot microstrip patch antenna are presented. The shape will provide the broad bandwidth which is required for the operation of next generation wireless systems. Evolutionary Algorithm based optimization has been utilized in HFSS-ANSOFT to optimize the microstrip line feed antenna dimensions in order to obtain reliable return loss and high directivity. The operating frequency of antenna is 7GHz, the dielectric constant and thickness of the antenna is 4.4 and 1.6mm respectively. The simulation results of antenna are done by the help of HFSS and MATLAB programming. The microstrip patch antenna is designed with different centre frequencies such as 5.5GHz, 11.25GHz and 12.25GHz. The patch antenna is analyzed for different metrics for performance. A comparative analysis between non-optimized patch design and optimized patch design has also been presented.

Keyword-Microstrip Antenna, T-slot, Evolutionary Algorithm, multiband

I. INTRODUCTION

This document is a template. The popularity of wireless communication systems has increased significantly during the last decades along with the customer demand. Recently wireless systems demand antennas where space value is quite limited. Antennas for wireless devices are required to have the compactness, multiband operation as well as broad bandwidth. Such antennas are highly essential for both commercial and military applications. Each antenna operates in a single or dual frequency bands, where different antenna is required for various applications [1-3]. To subsidize this problem, multiband antenna is, where a single antenna can operate with many frequency bands. One of the techniques to construct a multiband antenna is by etching a T-slot in the antenna geometry [4]. Hence, antenna is one of the most important design issues in modern wireless communication systems. Since antennas are dependent on frequency, they have to be designed to operate for certain frequency bands. Though the antenna can satisfy the reduction in size, other factors like bandwidth, efficiency are taken care of. The idea of microstrip antenna arose from utilizing printed circuit technology and transmission lines [5-6]. A microstrip antenna, in its simplest form, consists of a rectangular shape patch mounted on a substrate backed by a ground plane as shown in Figure 1.

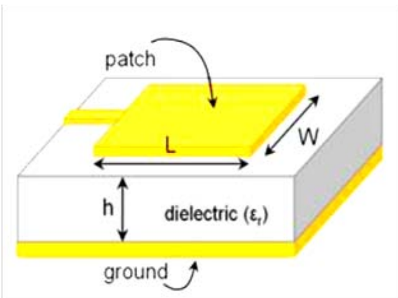

Fig.1. Rectangular Patch Antenna

Over the years, techniques have been developed for this process using electromagnetic carrier waves operating at microwave frequencies as well as radio frequencies. The communication technology brings an important responsibility to antennas for wireless transmission among those devices. The antennas in microwave links will have compact structures and ease of construction for various wireless devices. In many applications where size, volume, cost, performance and ease of fabrication are very much required, patch antennas are preferred and made this field as the the fastest growing segments in communication industry. These antennas have been used in various fields such as mobile communication, radar, GPS system, Bluetooth, space technology, aircraft, missiles, satellite communication etc [1-2]. But the major two disadvantages that limit the applications of microstrip antennas are low bandwidth and low gain. Microstrip antenna consists of radiating patch on one side of a dielectric substrate where as on the other side the ground plane is present as shown in Figure 1.The patch is generally made of conducting material with any possible shape. The radiating patch and the feed lines are to be photoengraved on the dielectric substrate [7].The reduction in size with gain and increase in bandwidth has become a major consideration in the microstrip patch antennas. Various techniques for bandwidth and gain enhancement have been suggested such as cutting slot in a patch.

Operation with Multiband

The GSM system offers dual frequency bands at 900 and 1800 MHz where as multiband operation based mobile phones are advancing day by day. The application of multiband communication systems with combinations of frequency bands is increasing, whereby the international roaming is progressing globally, the communication capacity is expanding and new functions are being added including GPS (1.57 GHz) and Bluetooth (2.4 GHz) [8]. Therefore, it is to be expected, that the handsets should be compatible with multiband in future. In such multiband systems, a multiband antenna is one of the key devices as it is well suited for all the frequency bands without resort to multiple antennas [2, 9].

The paper is organized as follows: Section 2 presents a design approach for T-slot rectangular patch antenna, Section 3 gives a brief about optimization using EA, in section 4 simulation results are presented and finally in section 5 conclusion is drawn.

II. T-SLOT PATCH ANTENNA DESIGN

Microstrip patch antennas have been widely used in many applications because of their low profile and easy manufacturing process. However, most patch antennas provide a wide beamwidth and low radiation efficiency [10]. To overcome the disadvantages of the patch antenna it is required to design optimized antenna for an effective performance. Many optimization algorithms are considered in literature [10-12]. Genetic algorithm is one of the global optimization techniques and has been used in this work for optimizing the patch shape and size to have better performance of the antenna. It was exactly used to optimize the patch length, the slot dimensions and the dimensions of the feed line [12]. The work has been performed by interfacing the genetic algorithm to Ansoft High Frequency System Simulator (HFSS).The calculation of the dimensions of the patch antenna is based on the following relation [7]:

a)Width of Patch:

$$W = \frac{c}{2 f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

b)Effective Dielectric Constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

c) Due to fringing effects the change in dimension of length:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}$$

d)Length of Patch:

$$L = \frac{c}{2 f_0\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

where f_0 =Operating Frequency

ε_r =Dielectric Constant

h =Substrate Thickness

The configuration of proposed antenna is shown in the figure:

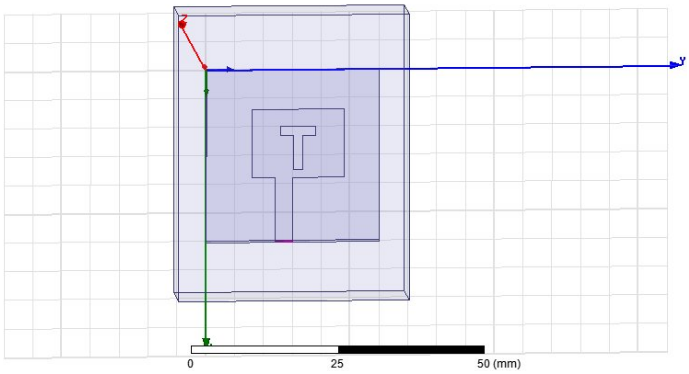

Fig.2. T-slot Microstrip Patch Antenna Design

The proposed antenna is designed on one layer substrate having a relative permittivity of 4.4 (FR4 Epoxy) and loss tangent tanδ=0.02. The substrate thickness is 1.6mm. This antenna is excited by microstrip line feed. Generally 50Ω microstrip line is used to feed the radiating patch. The slot which has been etched on the substrate is of T shape having slot cut length 6mm and width 1.6mm.

III. Optimization Using EA

The Evolutionary Algorithm has been considered in this paper as genetic algorithm based optimization. For the offsprings to survive is also a requirement for random injection of genes. As GA manipulates matrices it is normally implemented using MATLAB. The step wise procedure is shown below [12-14]:

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

Step 2: All the variables in binary form are combined into a string that is said as a chromosome.

Step 3: Fixed number of random chromosomes are selected out of a number said as a population. The selected population is called the current generation.

Step 4: The digital value of each variable is converted to analog value. Afterwards the objective function (O) is evaluated. Then the relative fitness of each chromosome (Ci) is determined and is defined as

$$O = \sum_{i=1}^{n} eval_i \left[C_i \right] \tag{1}$$

Step 5: Crossover is applied for random chromosomes between the parent and next generation to produce new off -springs.

Step 6: The population is mutated by changing in a random way the value of the genes with the least significant bit which has 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 decreased.

There are many challenges to carrying out real world optimization, including the presence of noise in the function evaluations, the difficulties in distinguishing a globally optimal solution from locally optimal solutions. EA based optimization methods are especially useful in treating some of these challenges. During a few last years, research in evolutionary computation and application of EAs has steadily and significantly expanded. There are several advantages distinguishing EAs from traditional optimization techniques [14]:

• no in-depth mathematical complexities in EAs

• EAs are relatively cheap and quick for implementation

• EAs are adaptable to changes of the problems.

The classical genetic algorithm maintains a population of encoded candidate solutions to a given optimization problem. The illustration for the antenna parameter design based on the optimization technique is given as follows [15]:

<u>Step-1</u>

Enter the center frequency, dielectric constant and substrate thickness in patch calculator programmed by MATLAB.

Step-2

Use the outputs (W, L) where W and L represent the width and length of the patch respectively for designing T-slot patch antenna in HFSS.

Step-3

Analyse the performance of the patch antenna designed in terms of return loss.

Step-4

If the return loss is better than -20dB, then the proposed antenna is optimized otherwise go to Step-3.

IV. RESULTS

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