

# EA-Based Optimization of Hybrid T-Slot Patch Antenna

Anindita Das, Mihir Narayan Mohanty, Laxmi Prasad Mishra  
and L. Padma Suresh

**Abstract** Evolutionary algorithm for optimization is the popular one and is referred to genetic algorithm. It is based on soft computing method. It has occupied a very good space in optimization techniques. In the same fashion it has been also applied for antenna parameters. Microstrip antenna is an essential component of wireless communication systems. The optimization leads for improving the performance of the system. As handsets improve in compactness with multifunctions in recent age, the antennas for these equipments have come under the spotlight. In this paper, the optimization has been applied for the design of hybrid slot antenna. The design is based on the T-slot combination with the L-slot microstrip patch. 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 dielectric constant and thickness of the antenna is 4.4 and 1.6 mm, respectively. The patch antenna is analyzed for different metrics for performance. A comparative analysis between nonoptimized patch design and optimized patch design has also been presented.

**Keywords** Microstrip antenna · T-slot · L-slot · Evolutionary algorithm · Multiband

## 1 Introduction

Biological concepts are used in the genetic algorithm due to which it has been named as evolutionary algorithm. The population, chromosomes, represent solutions to a problem. The chromosomes are represented as binary sequences. Genetic

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A. Das · M.N. Mohanty (✉) · L.P. Mishra  
Department of ECE, ITER, SOA University, Bhubaneswar, Odisha, India  
e-mail: mihirmohanty@soauniversity.ac.in

L. Padma Suresh  
NICE, Noorul Islam University, Kanyakumari, India

algorithms (GA) are a method for solving optimization or search problems inspired by biological processes of inheritance, mutation, natural selection, and genetic crossover. Genetic algorithms (GA's) are adaptive methods, which can be used to solve search and optimization problems. The principles behind the power of GA's are based upon the genetic processes of biological organisms which over many generations, evolve according to the principles of natural selection and *survival of the fittest*.

Antennas are used for wireless communication systems, but also more and more for other applications such as navigation, security, surveillance, and various medical sensor systems. Recently wireless systems demand antennas where space value is quite limited. New technologies for wideband, multifunction and multielement antenna systems will be developed, and integration with electronics plays an important role. 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.

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 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]. 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. 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: Sect. 2 presents a design approach for combined T-L slot rectangular patch antenna, Sect. 3 gives a brief about

optimization using EA, Sect. 4 presents simulation results and finally in Sect. 5 conclusion is drawn.

## 2 Combined T-L 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 the 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 calculation of the dimensions of the patch antenna is based on the following relation [7]:

(a) Width of Patch

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

(b) Effective Dielectric Constant

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

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

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

(d) Length of Patch

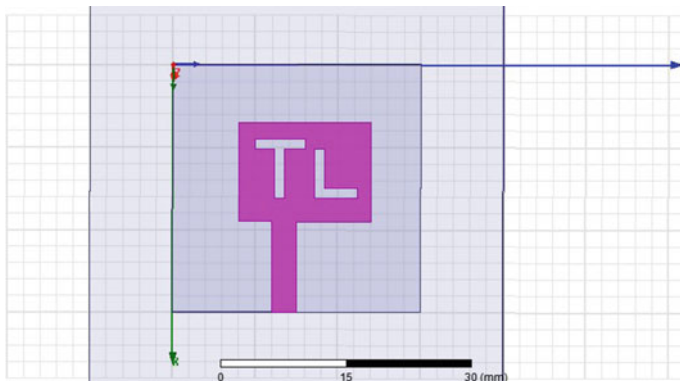
$$L = \frac{c}{2f_0 \sqrt{\epsilon_{\text{reff}}}} - 2\Delta L$$

where

$f_0$  = Operating Frequency

$\epsilon_r$  = Dielectric Constant

$h$  = Substrate Thickness



**Fig. 1** Combined T-L slot microstrip patch antenna design

The configuration of the proposed antenna is shown in the Fig. 1.

The proposed antenna is designed on a layer substrate having a relative permittivity of 4.4 (FR4 Epoxy) and loss tangent of  $\tan\delta = 0.02$ . The substrate thickness is 1.6 mm. This antenna is excited by microstrip line feed. Generally,  $50\ \Omega$  microstrip line is used to feed the radiating patch. In this work, two slots T and L have been etched on the surface of the antenna. The length and width of the vertical arms of both T and L slots are taken as 6 and 1.2 mm, respectively. The length and width of the horizontal arm of T slot are considered as 6 and 1.2 mm, respectively whereas the length and width of the base arm of L slot are taken as 4 and 1.2 mm.

### 3 Optimization Method

The implementation of the GA method starts with the initial population as the first approximation of the solution. This generation genes are selected randomly. The fitness function is used to evaluate each member of the population. New members are produced in successive generations. It is usually consistent with the rules of roulette. Members with the larger segments of the roulette wheel have better chances to create a new generation. Members of the new generation modifies by crossovers and mutations. With an initially assumed crossover probability, both a pair of members and the crossover points are selected randomly. In a mutation process, genes may change their values [12–14]. As GA manipulates matrices, it is normally implemented using MATLAB. A number of binary digits are assigned to each variable so that the required accuracy of this variable is obtained in the final solution. The digital value of each variable is converted to analog value. Afterward the objective function ( $O$ ) is evaluated. Then the relative fitness of each chromosome ( $C_i$ ) is determined and is defined as

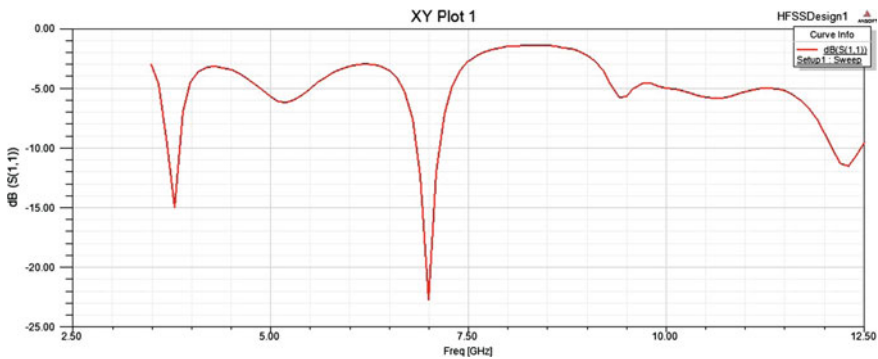
$$O = \sum_{i=1}^n \text{eval}_i[C_i]. \quad (1)$$

The illustration for the antenna parameter design based on the optimization technique is given as follows [15]:

- Step 1 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 Analyze the performance of the patch antenna designed in terms of return loss.
- Step 4 If the return loss is better than  $-20$  dB, then the proposed antenna is optimized; otherwise go to Step 3.

## 4 Results

The return losses of the nonoptimized antenna are found to be  $-20$  dB at 6.7 GHz which is shown in Fig. 2 and its corresponding bandwidth is 250 MHz. The return losses of the optimized antenna are found to be  $-15$  dB at 3.75 GHz and  $-23$  dB at 7 GHz as shown in Fig. 3 where its corresponding bandwidths are found to be 150 and 400 MHz. There is an increase in the bandwidth of the antenna. Figure 4 shows the VSWR of the nonoptimized antenna which is found to be 1.02 at 6.7 GHz



**Fig. 2** Return loss plot for nonoptimized combined T-L slot patch antenna

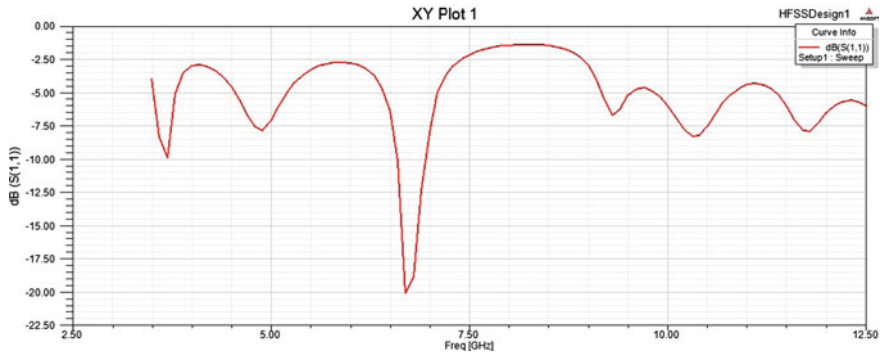


Fig. 3 Return loss plot for optimized combined T-L slot patch antenna

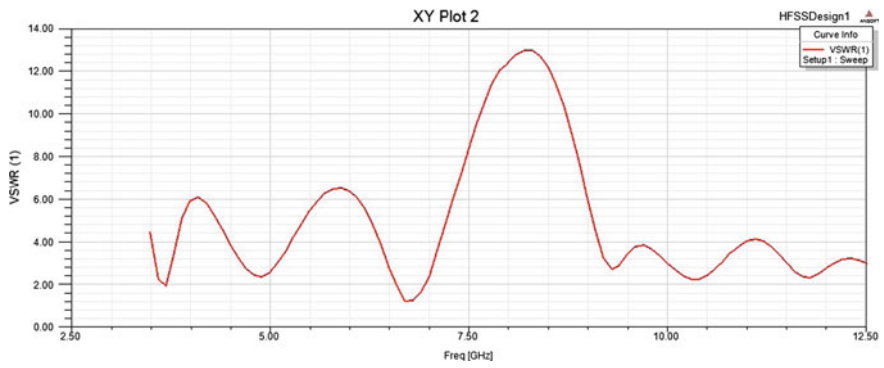
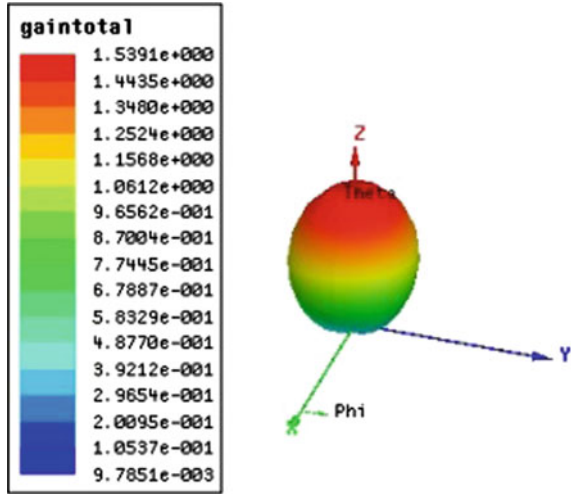


Fig. 4 VSWR plot for nonoptimized combined T-L slot patch antenna

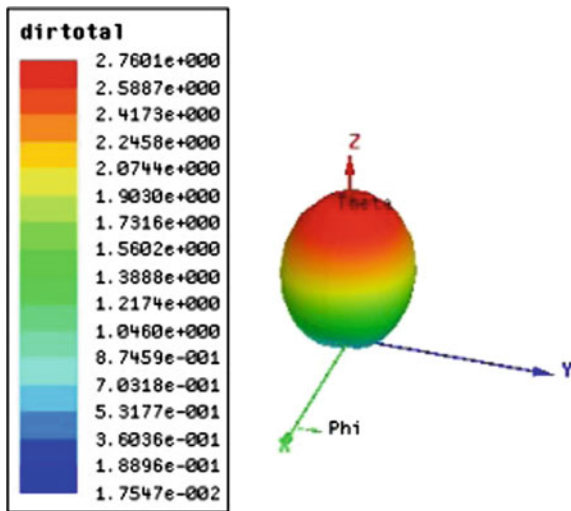


Fig. 5 VSWR plot for optimized combined T-L slot patch antenna

**Fig. 6** 3D polar plot of gain for optimized combined T-L slot patch antenna



**Fig. 7** 3D polar plot of directivity for optimized combined T-L slot patch antenna



where as Fig. 5 shows the VSWR of the optimized antenna which are found to be 1.065 at 3.75 GHz and 1.01 at 7 GHz. Figure 6 shows the gain of the optimized antenna whose value is found to be 1.59 (2.01 dB) and Fig. 7 denotes the directivity of the optimized antenna and is found to be 2.76 (4.4 dB). Figure 8 shows the multiple radiation pattern of the optimized antenna and its gain. Table 1 is the comparison among nonoptimized and optimized parameters of the proposed antenna. For these results the conclusion can be drawn about the optimized antenna and presented in the following section.

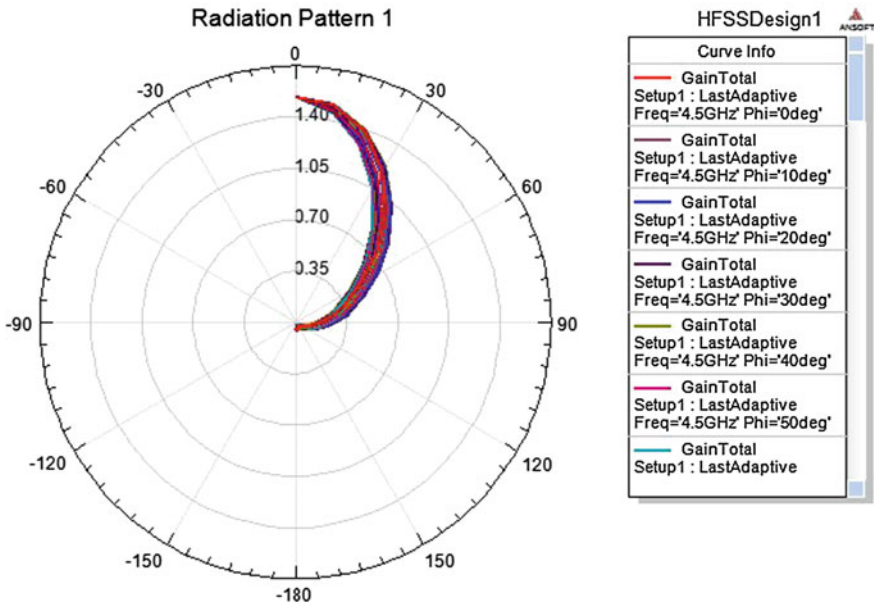


Fig. 8 Radiation pattern showing gain of the optimized antenna

Table 1 Comparison for nonoptimized and optimized parameters

Parameters	Non-optimized results	Optimized results
Substrate material	FR4 epoxy (dielectric constant = 4.4)	FR4 epoxy
Loss tangent	0.02	0.02
Length of substrate	30 mm	30 mm
Width of substrate	30 mm	30 mm
Substrate thickness	1.6 mm	1.6
Length of patch	12.6 mm	12 mm
Width of patch	16.6 mm	16 mm
Feed length	11 mm	10.4 mm
Feed width	2.5 mm	3 mm
Feed type	Microstrip line feed	Microstrip line feed
Feed location	(19, 12, 0)	(19.6, 12, 0)
'T' slot cut length and width	6, 1.2 mm	6, 1.2 mm
'L' slot cut vertical arm length and width	6, 1.2 mm	6, 1.2 mm
'L' slot cut base arm length and width	4, 1.2 mm	4, 1.2 mm
Return loss	-20 dB at 6.7 GHz	-15 dB at 3.75 GHz and -23 dB at 7 GHz
VSWR	1.02 at 6.7 GHz	1.065 at 3.75 GHz and 1.01 at 7 GHz
Bandwidths	250 MHz	150, 400 MHz



## 5 Conclusion

An antenna is designed to operate on multibands. The antennas are useful in the design of single antenna. A rectangular microstrip antenna with hybridization of T-slot and L-slot are described in this paper for multiband applications. This antenna is microstrip line fed and its structure is designed with the help of dielectric constant, substrate height, and resonant frequency. Antenna properties such as return loss, gain, VSWR, directivity and bandwidth are analyzed and discussed in this project. Design and analysis of this antenna are done by using high frequency structure simulator (HFSS). The GA is very precise and fast when compared to other techniques because it encodes the parameters and the optimization is done with the encoded parameters. Genetic algorithm is used to optimize the parameters. In the result section it has been exhibited. Patch antenna is suitable for mobile phone handsets moderately and accordingly has been developed. The antenna developed in this work has been confirmed to have better characteristics in terms of broad bandwidth and multiband operation.

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