The Optimum Design of PIFA Based on HFSS and Genetic Algorithm

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***Abstract*—In this paper we demonstrate the optimization of planar inverted F antenna (PIFA) for broadband operation by optimizing the geometry/size of the inverted-F patch and the position of the shorting pin. The optimization technique based on the combination of Genetic Algorithm(GA) with HFSS is presented to facilitate the PIFA design. The technique is compiled by Matlab and the VB scrip of HFSS. The simulation results show that the method broadens the bandwidth of the PIFA antenna.**

Keywords-Genetic algorithm (GA); HFSS; PIFA; optimum design; broadband

I. INTRODUCTION

It is well know that standard microstrip patch antennas are an attractive solution to many wireless communication applications due to their low-cost, low-profile, conformable, and easy-to-manufacture architecture. However, the bandwidth of the primary structure in many applications is not sufficient to cover the desired operating frequency range. In the past years the planer inverted-F antenna (PIFA) has appeared to be the best substitute for the monopole or helix antennas unitized in many portable and small wireless devices [1]. However, due to limiting the operation bandwidth of PIFA, it makes the antenna not suitable for wideband applications. This paper is to overcome the inherent limitation by broadening the bandwidth of a PIFA.

Because electromagnetic optimization parameters can be either continuous, discrete, or both, making the design process slow and complicated, many researchers have applied genetic algorithms to the design of broadband patch antennas [2-3]. Several methods have been investigated to broaden the bandwidth of a PIFA [4-6]. Recently, Initial antenna parameters are set up and PIFA antenna model is run in CST environment [7]. This paper presents a Genetic algorithms optimum approach of the position of the inverted-F patch and shorting pin based on the combination of GA with the commercial electromagnetic simulation tool, the FEM based software, HFSS by ANSOFT. The attractiveness of GA optimization is that improved bandwidth performance doesn't increase overall dimensions or manufacturing cost.

The design process of PIFA optimization with GA is described in Section II. In Section III the GA optimized antenna designs and results are proposed. This is followed by the conclusion in Section IV.

II. THE OPTIMIZATION OF PIFA WITH GENETIC ALGORITHM

Genetic algorithms were first described by John Holland in the 1960s and were developed by Holland and his students and colleagues. Genetic algorithms in engineering electromagnetic have been widely used [8]. The GA procedure based on the Darwinian principle of survival of the fittest is capable of facing multi-variable problems, such as the design of antennas. A block diagram of the GA optimizer is shown in Figure 1. Six basic tasks must be performed in a simple GA: encode the solution parameters in the form of chromosomes, create a string of the genes to form a chromosome, initialize a starting population, evaluate fitness values to individuals in the population, perform reproduction through the fitness weighted selection of individuals from population, and perform recombination and mutation to produce of the next generation. In order to find an optimum PIFA structure with operational bandwidth, the method of GA is applied.

A strategy for the combination of genetic algorithm with HFSS is illustrated in Figure 2. The genetic algorithm operations are compiled by MATLAB. It generates the parameters of each structure .The calculation of fitness values are complied by HFSS. The calculated fitness values are then returned to genetic algorithm module for GA model. The electrical characteristic parameters of PIFA antenna are justified by a comparison with an evaluation of a fitness function. If the fitness meet requirement, the procedure is completed. Otherwise, those new structures are produced by a GA procedure. Those new structures are used in the next iteration for HFSS analysis to justify their performances with respect to the expectations. The GA operation specifies the parameters to produce a new structure based on selection, crossover and mutation.

GA optimizer parameters are set up as shown in Table Ⅰ.

TABLE I. GA OPTIMIZER PARAMETERS

Size of population (individuals)	30
Maximum number of iterations	20
Cross over	0.8
Mutation	0.02
Number of the sample	200

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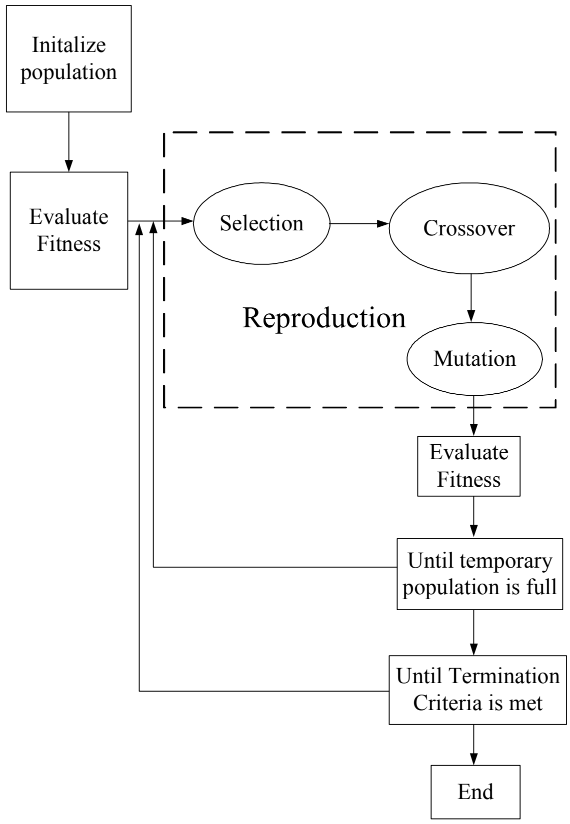


Figure 1. A block diagram of the GA optimizer

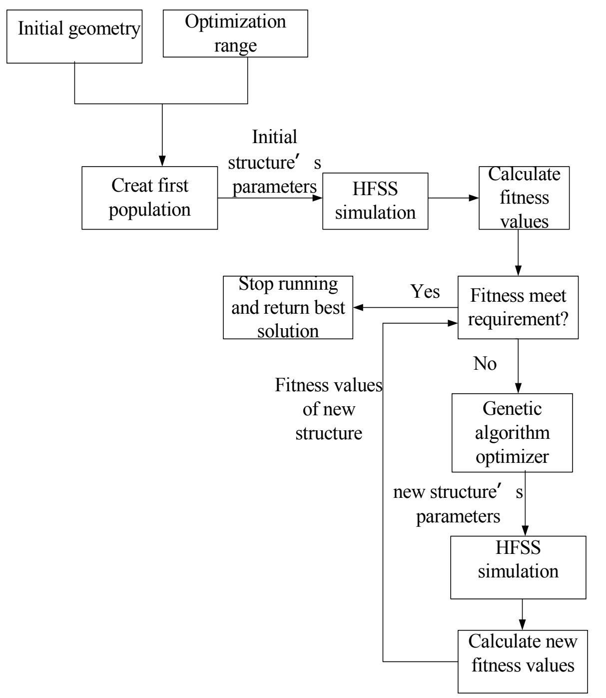


Figure 2. The combination block diagram of Genetic Algorithm with HFSS.

The design goal is to broaden the bandwidth of the PIFA antenna by optimizing the positions of the top patch and the shorting pin. In our case, the bandwidth selected to be optimized is between 1 and 3 GHz. To achieve this goal, the fitness function is defined as the average of those S_{11} values over the frequency band of interest.

$$fitness = \frac{1}{N}\sum_{i=1}^{N}\left|S_{11}(f_i)\right| \tag{1}$$

In the equation above, f_i is the sampling frequency, N is the number of the sample.

III. The PIFA Antenna Design and Simulation Results

Figure 1 shows the configuration of the PIFA antenna with HFSS and its some dimensional parameters. The antenna is composed of a ground plate, a top patch, shorting pin, probe and feed. The ground plate size is characterized by L_1 and w_1 .The top plate size is characterized by L_2 and w_2 ,the height of top plate (h_1) is shown in Figure 3. Materials on the probe and the shorting pin are selected as a perfect conductor. The short cut (CW_1, CL_1), the long cut (CW_2, CL_2) , the coax radius (R_2), the shorting pin radius (R_3) and its position (s_x, s_y), the top patch position (p_x, p_y), the probe radius (R_1) and its position ($f_x = p_x + 1mm$, $f_y = p_y + 1mm$) are shown in Figure 4.

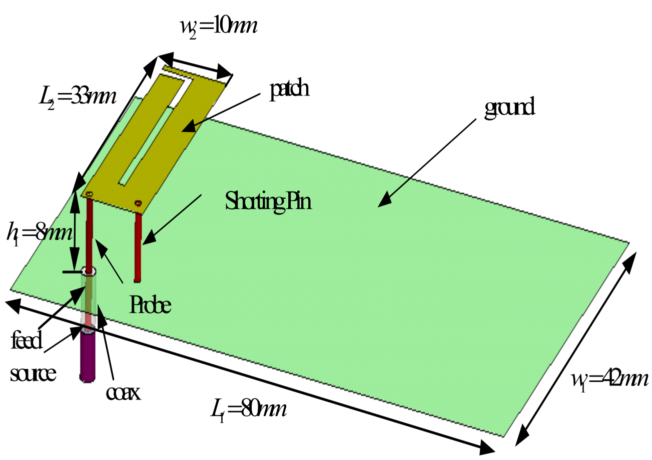
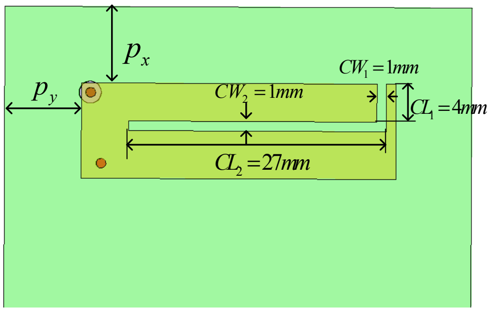
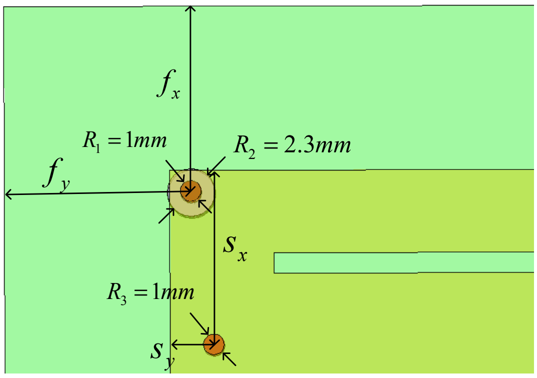


Figure 3. The configuration of the PIFA antenna



(a)



(b)

Figure 4. The top of PIFA (a) entire patch top view (b) feed and shorting pin top view

The optimum parameters are p_x, p_y, s_x, s_y. The ranges of these parameters to be optimized and the optimal results are shown in Table Ⅱ.

TABLE II. THE RANGES OF PARAMETERS TO BE OPTIMIZED AND OPTIMAL RESULTS

Parameters	p_x (mm)	p_y (mm)	s_x (mm)	s_y (mm)
Max.	65	40	10	31
Min.	5	5	3	2
Original Value	8	8	8.429	2.1
Optimal Value	5.70	36.99	5.11	10.29

Figure 5 shows the return loss comparison obtained in HFSS. In this figure, we can see that the operating bandwidth spans the frequency from 1GHz to 3GHz, and the bandwidth can be determined in terms of 10dB return loss. The proposed antenna has a available bandwidth of nearly 70%. It also presents the return loss of the proposed antenna at two resonant frequencies 1.8GHz and 2.4GHz. Figure 6 shows the VSWR of the optimized PIFA antenna from 0.5GHz to 3.5GHz. It presents the VSWR of the proposed antenna is smaller than 2 in the very broadband region. Figure 7 shows the best fitness value in each iteration. The last best fitness is 13.59dB. The convergence of best fitness value is from the 14th iteration. The design results are quite fine.

Figure 8-10 illustrate the radiation pattern of the optimized PIFA antenna at 1.4GHz, 1.8GHz and 2.2GHz, respectively. From figure 8 and figure 9, it can be seen that the directivity is very good when Phi is 150^0. From figure 10, it is noted that the directivity is very good when Phi is $90^0, 270^0, 300^0$. Here, Phi is relative to the direction orthogonal to ground shown in Figure 3.

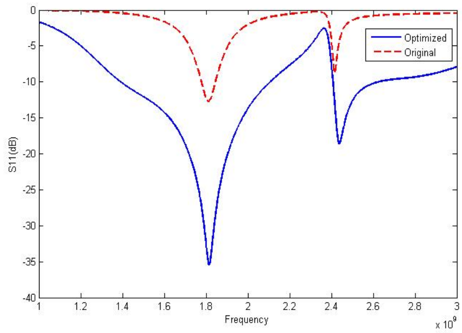


Figure 5. Return loss comparison between the optimized PIFA and original PIFA

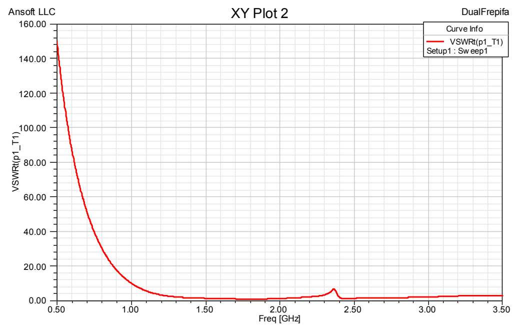


Figure 6. VSWR of the optimized PIFA antenna

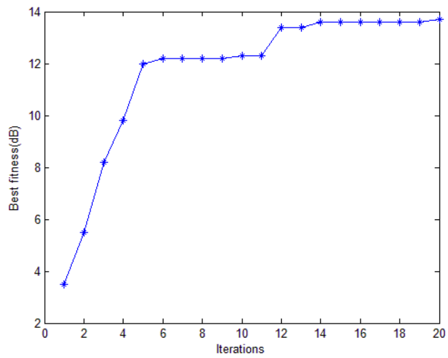


Figure 7. The best fitness value in each iteration

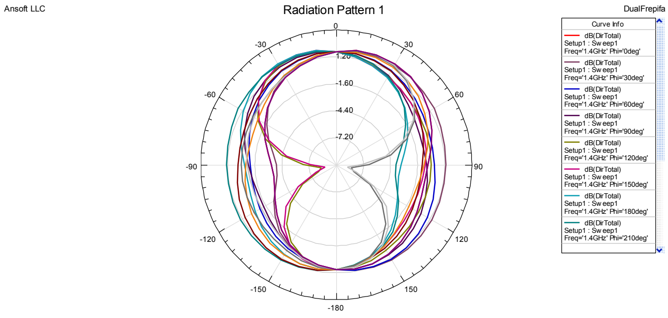


Figure 8. Radiation Pattern at 1.4GHz

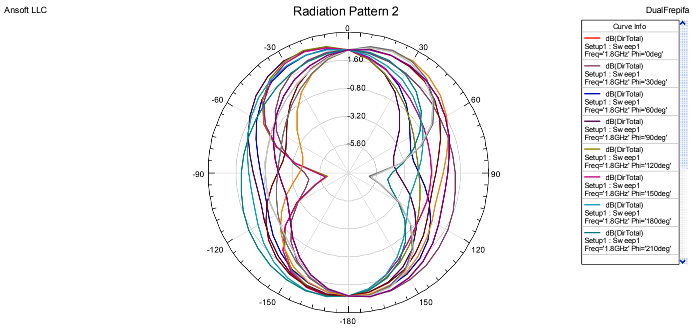


Figure 9. Radiation Pattern at 1.8GHz

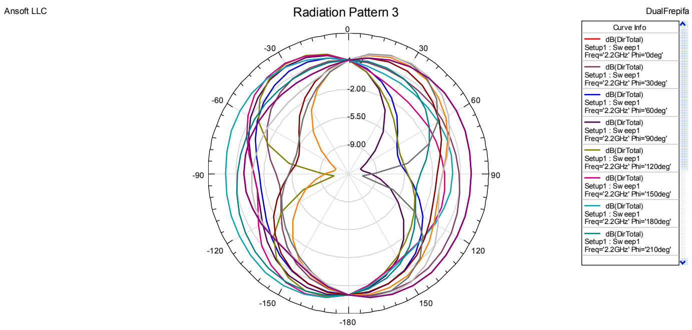


Figure 10. Radiation Pattern at 2.2GHz

IV. CONCLUSION

The proposed broadband PIFA antenna is based on the combination of genetic algorithm with HFSS. We don't change the size of PIFA antenna during optimization process, so the cost doesn't increase. The GA makes the random positions of rectangles on the patch and shorting pin. The original antenna design has small bandwidth. A available bandwidth about 70% was obtained with the optimized antenna and its central frequencies are 1.8GHz and 2.4GHz. Except some sporadic frequency points, VSWR is smaller than 2 for the above mentioned frequency region. The optimized results are very beneficial for the PIFA antenna to be used in UWB communications applications due to its extended operational bandwidth. It also can be used both as transmitter and as receiver in WiFi/WLAN system operating at 2.4GHz. So the GA is a powerful optimization tool suited for the broadband practical antenna design.

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