Optimisation of a PIFA Antenna Using Genetic Algorithms

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Abstract

This work presents the optimisation of PIFA (Planar Inverted-F Antenna) antennas in order to achieve a large bandwidth in the 2 GHz band, using an optimisation technique based on genetic algorithms. During the optimisation process, the different antenna models have been evaluated using the finite-difference time domain (FDTD) method. As a result of this optimisation, a simple PIFA antenna was obtained with a bandwidth of 460MHz and an even greater bandwidth of 570MHz was achieved with a double PIFA antenna with the same overall dimensions.

I. INTRODUCTION

The increase in the capacity and quality of the new services provided by mobile communications requires the development of new antennas with wider bandwidths. At the same time, due to the miniaturisation of the transceivers, the antennas should have small dimensions, low profile and the possibility to be embedded in the terminals. In this context, PIFA antennas are able to respond to such demands [1]. Its conventional geometry, i.e., the simple PIFA is shown in Figure 1a and an alternative geometry, the double PIFA, is shown in Figure 1b.

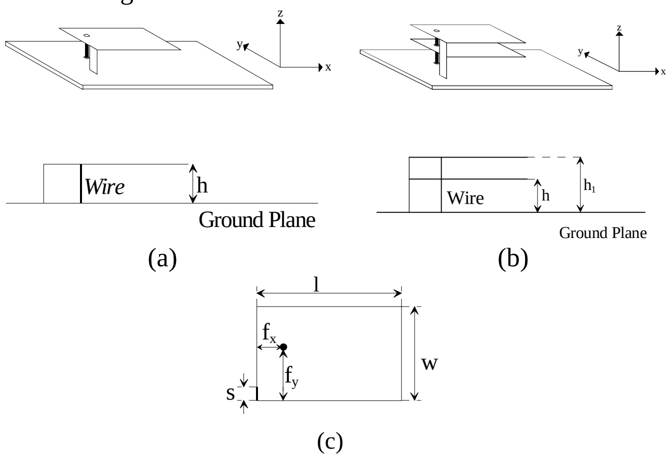
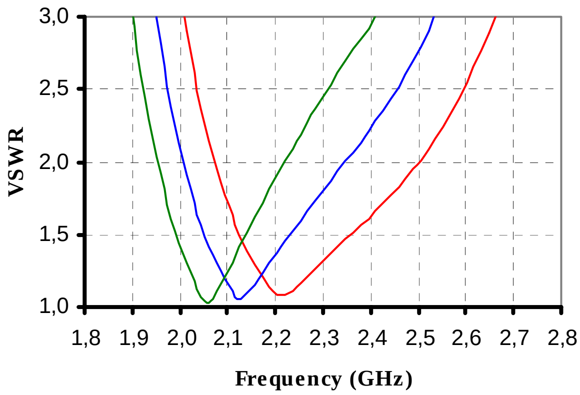


Fig. 1 Geometry of the PIFA antennas
(a) Simple PIFA (b) Double PIFA (c) Top view

As seen in Figure1, PIFA antennas have several parameters such as the heights h and h_1 of the radiating plates, the feed position f_x and f_y, the radius r_o of the feeding wire, the width s of the short circuit plate, etc.. All these parameters play a key role in the performance of the antennas, as has been shown by the authors in previous works [2], [3], and as it shown, for a particular case, in Figure 2.



—fx=6 fy=0 h=10 —fx=4 fy=2 h=8 —fx=4 fy=4 h=8 (in mm)

Fig. 2 Influence of the feed position in the input impedance

In order to achieve optimal performance from these antennas for a particular application, the geometry of the antenna must be optimised. The search for the best geometry requires an optimisation tool, and one promising tool for this purpose is based upon genetic algorithms. These algorithms are global numerical-optimisation methods, patterned after the natural process of genetic recombination and evolution, [4].

This work follows a sequence of previous work done by the authors and it describes the optimisation of two PIFA antennas to achieve the largest bandwidth in the 2 GHz band, using an optimisation technique based on genetic algorithms. During the optimisation process, the different antenna models were evaluated to determine their performance. The finite-difference time domain (FDTD) method was used to carry out this evaluation [5], [6].

II.METHOD OF ANALYSIS AND EVALUATION

The authors have already used the FDTD method for the simulation of PIFA antennas in previous works [2], [3]. The derivation, as well as the practical implementation of this algorithm, are well covered in literature [5], [6] and therefore will not be covered in this paper.

The general features of the present algorithm are as follows: the spatial region where the fields are computed was divided by a three dimensional rectangular grid with cell size Δx, Δy, Δz in the x, y, and z directions, respectively. For the results that follows, cell sizes were $\Delta x=\Delta y=\Delta z=2$mm, with the time increment at the Courant limit. The outer boundaries of the FDTD computational space were terminated by second-order Mur numerical absorbing boundaries to reduce the reflection of scattered fields. The absorbing boundaries were at 20 cells away from the antenna in all directions. The structure modelled for this work consists of rectangular conducting plates and a feed pin. The feed pin was modelled by forcing E_Z to zero on a single line, and the feed point is a one cell wide gap, located between the ground plane and the feed pin. The plates were modelled by setting the tangential electric fields to zero, including the electric fields at the edges.

Using FDTD, it is possible to obtain the input impedance in the frequency domain and consequently the S_{11} parameter. To do this, both the source voltage and the input current are sampled in the time domain. The source voltage is known because it is the voltage used to excite the problem. The input current can be computed by the approach developed in [7] by solving Ampere's law on a contour placed around the feeding point. The next step is to Fourier transform both signals, to obtain the voltage and the current in the frequency domain. Then, dividing both responses the input impedance is obtained.

III THE OPTIMISATION PROCESS

The optimisation technique that has been used is based on genetic algorithms. In this method, a key point is to define a cost function to translate the desired performance requirements. A cost function will be evaluated for each antenna model to determine a quality factor for that model.

The basic block of the genetic algorithm is the chromosome. Each chromosome is composed of genes described as a binary sequence of zeros and ones. Each gene is associated with a parameter to be optimised. For the simple PIFA, we used three parameters: the coordinates of the feeding wire, f_x and f_y and the height h of the radiating plate (see figure 1). For the double PIFA, we used four parameters: the co-ordinates of the feeding wire, f_x and f_y and the heights h and h_1 of the radiating plates (see Fig. 2). We also assigned for the parameters: f_x, f_y and h four discrete possible values, and therefore 2 bits are sufficient to quantify them. For the parameter h_1 we assigned two discrete possible values and therefore 1 bit is enough to quantify it. Hence, 6 bits represent each chromosome associated with a simple PIFA, and 7 bits represent each chromosome associated with a double PIFA. In any case, each chromosome describes a particular geometry.

The aim of this work is to design PIFA antennas with the largest bandwidth in the 2 GHz band. The bandwidth is defined by the range of frequencies where the VSWR is less than 2. For each geometry (i.e., for each chromosome) the bandwidth is computed and a cost function assigned. The cost function is given by the absolute value of the bandwidth.

The minimum requirement is to achieve a bandwidth equal or greater than a given value. If, during the optimisation process, a model is found which satisfies this requirement, then the process terminates, and the corresponding model is chosen.

The process starts with the computation of a first model to be used as a starting approximation. This model is determined by formulas given in [1] and already used by the authors [2], and also based in their own experience obtained in previous works [3].

The basic structure identified for the 2GHz band has the following elements: A ground plane with a length of 50mm and a width of 26mm. Radiating plates with a length of 22mm and a width of 14 mm., and a short circuit plate with a width equal to the width of one cell, i. e., 2mm. The dimensions of these elements are fixed in all models. Since the objective is the optimisation of the heights, h and h_1, and the feed position, f_x and f_y, the values of these parameters depend on the generated chromosome.

In order to avoid a long search, we decided to stop the program if the number of analysed chromosomes exceeded half of all the possible combinations.

The flowchart of the optimisation algorithm is shown in the Figure 3.

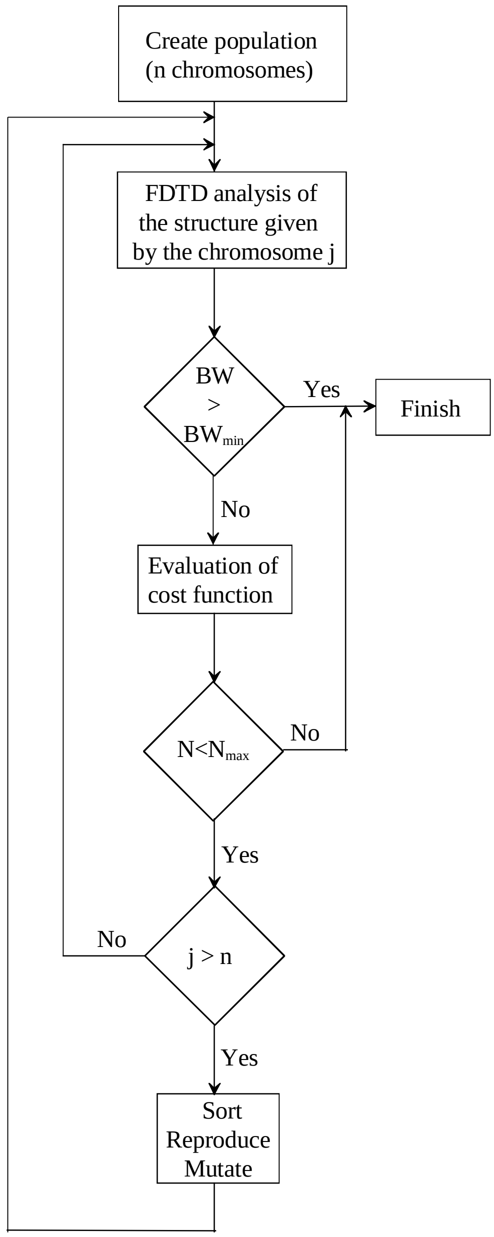


Fig. 3 Flowchart of the optimisation algorithm

IV APPLICATIONS EXAMPLES

The optimisation algorithm has been used in two application examples. The first example to be considered was the optimisation of a simple PIFA in order to achieve a bandwidth equal or greater than 450MHz. Applying the optimisation algorithm it was possible to find a model with bandwidth of 460MHz with a minimum VSWR equal to 1,02 at 2.28 GHz, as it shows in Figure 4. For this model, *h* is 8 mm, f_x is 6mm and f_y is 6mm and the feed wire radius is equal to 0,45mm.

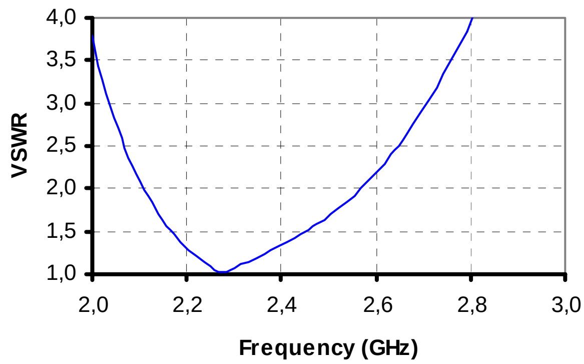


Fig 4 Simulated results of the optimised simple PIFA

Given the good results achieved with above simulations, a second optimisation was performed using different design objectives. Specifically, a double PIFA antenna was optimised in order to have a bandwidth greater than 460MHz. The aim was to show that a larger bandwidth could be achieved with a double PIFA. Applying the optimisation algorithm it was possible to find a model with bandwidth of 570MHz with a minimum VSWR equal to 1,09 at 2.36 GHz, as it shows in Fig. 5. For this model, f_x is 6mm, f_y is 10mm, *h* is 4mm, h_1 is 8mm and the feed wire radius is equal to 0,45mm.

This last example shows that using a double PIFA it is possible to achieve a larger bandwidth while maintaining the same overall dimensions of the antenna.

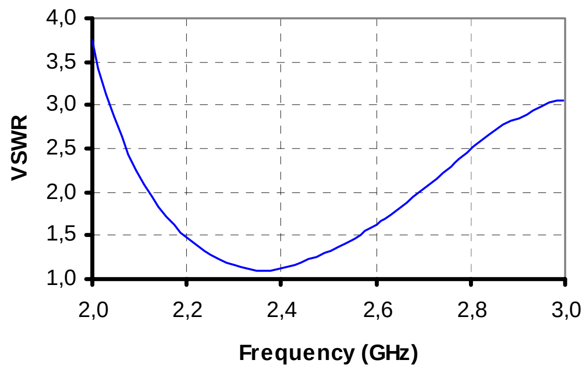


Fig 5 Simulated results of the optimised double PIFA

V. CONCLUSIONS

In this work we have used an optimisation technique, based upon genetic algorithms, to design two wideband PIFA antennas in the 2 GHz band. During the optimisation process, the different antenna models were evaluated to determine their performance, using an engine developed by the authors, based upon the finite-difference time domain (FDTD) method.

As a result of this optimisation, a simple PIFA antenna was obtained with a bandwidth of 460MHz and a VSWR equal 1,02 at 2.28 GHz. An even greater bandwidth was achieved with a double PIFA antenna with the same overall dimensions. The obtained was 570MHz with a VSWR equal 1,09 at 2.36 GHz.

VI. REFERENCES

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