# DESIGN AND GLOBAL MULTI-OBJECTIVE OPTIMIZATION OF PLANAR TRI-BAND ANTENNA

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## ABSTRACT

The paper briefly uncovers techniques used for a design of compact planar antennas in order to achieve wideband and multi-band capability. The main topic is aimed to the multi-objective optimization using genetic algorithms (GA), which is provided by cooperation between MATLAB and IE3D. Impedance match and direction of maximum gain are desired parameters to improve.

## 1. INRODUCTION

Currently, the wireless and mobile communication is one of the most growing branches. The demand for hand-held devices operating in a wide spectrum of wireless applications involves miniature and multi-band antennas. Only high-quality equipments can be successful at the market [1], [2], [4].

## 2. ANTENNA DESCRIPTION

Planar inverted-F antenna (PIFA) has been chosen for the investigation. It using a shorting pin to convert $\lambda/2$ structure into $\lambda/4$ structure, so that we obtain a half-dimension patch antenna. In this design is used substrate with low permittivity and elevation of antenna above the groundplane. It follows to decreasing of $Q$ factor, subsequently to increase bandwidth of the planar antenna. Broadband and multi-band capabilities are achieved by embedding suitable slot in the main patch in order to create a dual-band antenna, by doubling of main patch resonations by using of two parasitic gap coupled resonators and by creating a new band by using one parasitic gap coupled resonator. Frequency response of the reflection coefficient at feeding point is mentioned later in comparison with optimized one [1], [2].

## 3. GENETIC ALGORITHM

Whole optimization process is performed by matlab except evaluation of antenna where IE3D is used. Working principle of used GA is shown in Fig. 1. Antenna was described by 19 variables and all of them are used in optimization process. We can see 14 variables in Fig. 2. Remain variables are elevation and position of antenna above the groundplane and dimensions of the ground plane.

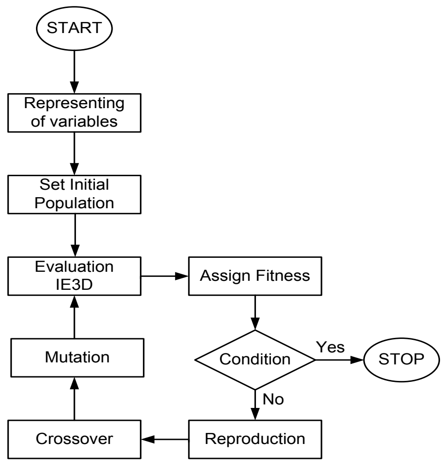


**Fig. 1:** A flowchart of the working principle of used GA.

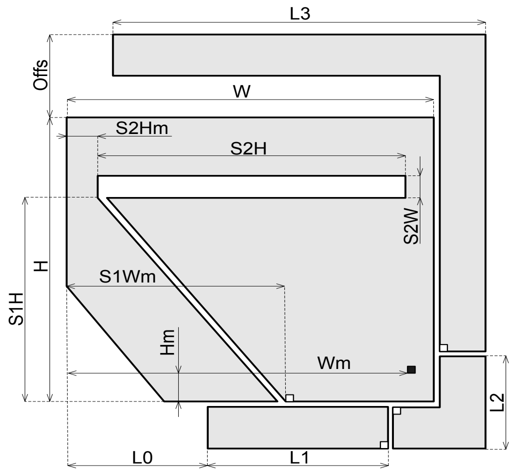


**Fig. 2:** Set variables for optimization.

The initial population consists of five random individuals, ten derived from initial one by mutation and initial individual himself. Antenna performance is evaluated at five frequencies (see Tab. 1.). Impedance match (1) and maximum gain direction (2) objective functions are expressed as:

$$F_1 = \frac{1}{\sqrt{N}} \sqrt{\sum_i^N (|S_{11}|_i)^2} \quad (1)$$

$$F_1 = \frac{1}{\sqrt{N}} \sqrt{\sum_i^N (\vartheta_i / 180)^2} \quad (2)$$

where $N$ is number of evaluated frequencies, $|S_{11}|_i$ is the magnitude of reflection coefficient and $\vartheta_i$ is angle at maximum gain measured from Z axis at $i^{\text{th}}$ frequency.

Now the dual-objective function can be expressed as:

$$F = \sqrt{\frac{(w_1 \cdot F_1)^2 + (w_2 \cdot F_2)^2}{w_1^{\,2} + w_2^{\,2}}} \quad (3)$$

where the partial objective functions $F_1$ and $F_2$ are weighed by $w_1$ and $w_2$.

Tournament selection was implemented as method of reproduction. The dual-point crossover is applied on six coupled individuals chosen at random to create six offspring. One offspring is created by the bitwise mutation operator with a probability of 5%. These operations providing search aspect of genetic algorithm [3], [4], [5]. The worst seven individuals in current population are replaced by seven offspring, so new population is set.

| | **Original** | | **Optimized** | |
|---|---|---|---|---|
| **Frequency [GHz]** | **$\|S_{11}\|$ [dB]** | **$\vartheta$ [°]** | **$\|S_{11}\|$ [dB]** | **$\vartheta$ [°]** |
| **0.88** | **-7.8** | **45** | **-24.0** | **40** |
| **0.96** | **-12.6** | **35** | **-27.2** | **20** |
| **1.71** | **-11.8** | **30** | **-18.2** | **35** |
| **1.88** | **-16.5** | **35** | **-11.4** | **35** |
| **2.442** | **-8.6** | **120** | **-20.4** | **15** |

**Tab 1:** Comparison of original and optimized antennas.

## 4. RESULTS

The best results were obtained by using weights $w_1 = 4$ and $w_2 = 3$. Progress of the lowest fitness value in population during 250 iterations is shown in Fig. 3. Frequency response of reflection coefficient is shown in Fig. 4. The significant improvement of impedance match is evident at all desired frequencies. Comparisons of results are transparently presented in Tab. 1.

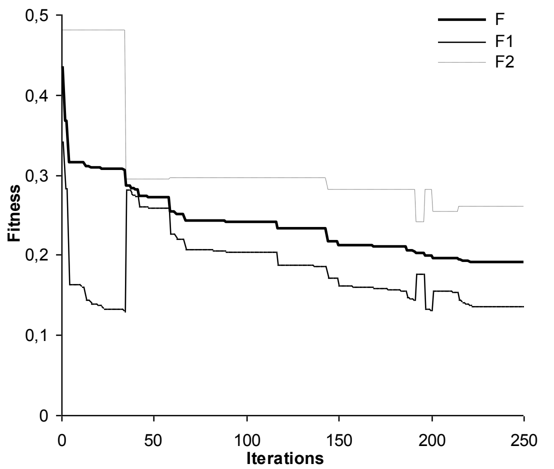


**Fig. 3:** Progress of objective functions $F_1$, $F_2$ and $F$ during optimization.

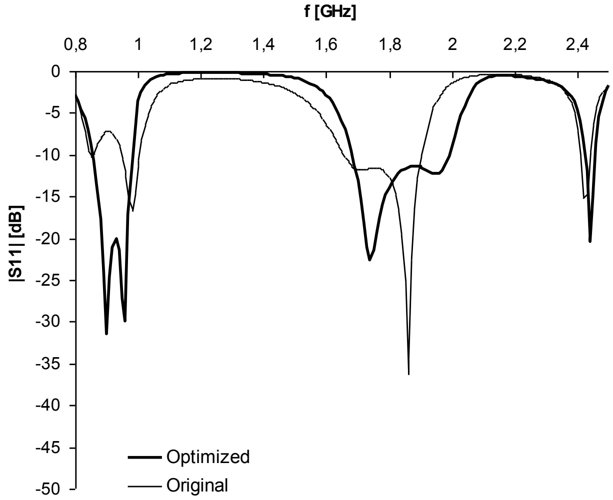


**Fig. 4:** Frequency response of reflection coefficient of original and optimized antenna.

## 5. CONCLUSIONS

In this paper is presented the design of compact tri-band antenna suitable for hand-held devices. The multi-objective optimization using genetic algorithm is chosen to improve impedance match and direction of maximum gain. The significant improvement of impedance match and new constellation of the antenna elements with better pattern properties is obtained. The gradient-based methods cannot provide this solution.

## REFERENCES


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