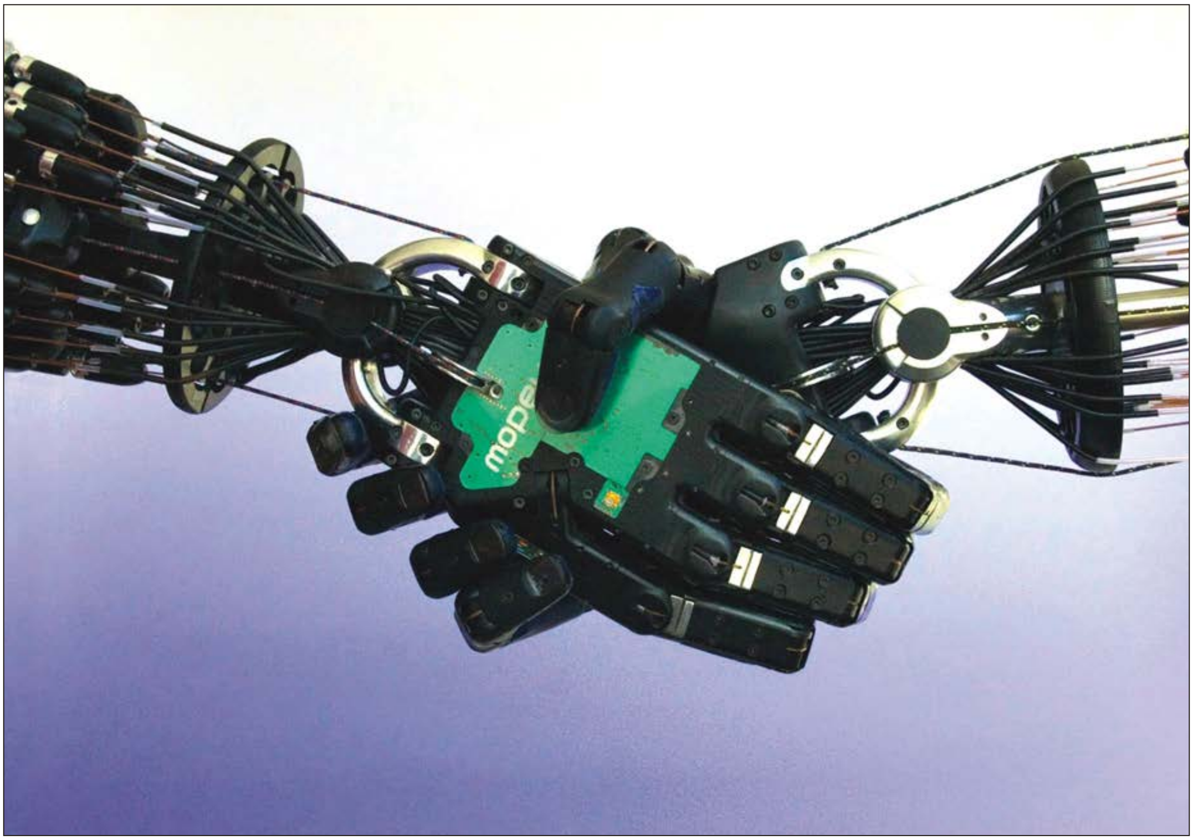

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GA Analysis of Parameters of Magnetically Biased Microstrip Rectangular Patch Antenna

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ABSTRACT

Genetic Algorithm (GA) analysis and optimization of the important parameters (Directivity, Radiation Power, Impedance etc.) of magnetically biased microstrip antenna, fabricated on ferrite substrate, is studied. Functions for the fitness of the GA program is developed using transmission line model of the analysis of microstrip antenna. The genetic algorithm was run for 500 generations. The probability of crossover was varied from 0.70 to 0.85 and the probability of mutation was varied from 0.001 to 0.002. The computed results are optimized and in good agreement with the results obtained experimentally.

Key words: Genetic algorithm, transmission line model, rectangular ferrite microstrip antenna, magnetically biased

INTRODUCTION

Microstrip patch antennas of all shapes are widely used in communication systems where their small size, conformal geometry and low cost can be used to advantage. Dual band, multiband, reconfigurable, electronically polarized, etc. are some advance microstrip antennas revolutionized the whole world communication system (Islam *et al*., 2009a-c; Misran *et al*., 2008; Saeed and Sabira, 2005; Salem *et al*., 2011). Due to the recent availability of low loss, commercial microwave ferrites there is an increasing interest in the performance of the patch antennas printed on ferrite substrates. Although, some work (Haupt, 1995; Villegas *et al*., 2004; Wyant, 2007; Akdagli and Guney, 2000; Saxena *et al*., 2010, 2011) have been performed for microstrip antenna with GA approach for the patch antennas without magnetic biasing but analysis of almost all important parameters for ferrite substrate under magnetic biasing for circular patch antenna is new one. Present analysis also incorporate the dispersion effects due to magnetic field biasing in the form of effective propagation constant (K_e) which is not discussed in the referenced articles. Some similar referenced works also have done mathematically or by conventional methods for optimization but this technique is rather precise, accurate and sensitive to optimize parameters of patch antenna as well as other type of antenna also. In this study, a precise and effective approach is applied to calculate important parameters of rectangular patch antenna. It is well known that search technique, the genetic algorithm is a parallel, robust and probabilistic search technique that is simply and easily implemented without gradient calculation, compare with the conventional gradient base search procedure. Most important of all, the GA proposed also provides a mechanism for global search that is not easily trapped in local optima. The GA proposed here an adaptive mutation rate strategy (Saxena *et al.*, 2009; Chiu *et al.*, 2007; Jackson and Alexopoulos, 1991; Li and Volakis, 1999; Pozar, 1992; Goldberg, 1989).

GENETIC ALGORITHM

Genetic Algorithm (GA) is a robust stochastic based search method that can handle the common characteristics of electromagnetics which cannot be handled by other optimization techniques like hill climbing method, indirect and direct calculus based methods, random search methods etc. A chromosome in a computer algorithm is an array of genes. Each chromosome has an associated cost function assigned to the relative merit. The algorithm begins with a large list of randomly generated chromosomes. Cost function is evaluated for each chromosome. Genes are the basic building blocks of a genetic algorithm. A gene is a binary encoding of a parameter. The populations which are able to reproduce best fitness are known as parents. Then the GA goes into the production phase where the parents are chosen by means of a selection process. The selected parents reproduce using the genetic algorithm operator called crossover. In crossover random points are selected. When the new generation is complete, the process of crossover is stopped. Mutation has a secondary role in the simple GA operation. Mutation is needed because, even though reproduction and crossover effectively search and recombine extant notions, occasionally they may become overzealous and lose some potentially useful genetic material. In simple GA, mutation is the occasional random alteration of the value of a string position. When used sparingly with reproduction and crossover, it is an insurance policy against premature loss of important notions. Mutation rates are of the order of one mutation per thousand bit transfers. According to the probability of mutation, the chromosome are chosen at random and any one bit chosen at random is flipped from ‘0’ to ‘1’ or vice versa. After mutation has taken place, the fitness is evaluated. Then the old generation is replaced completely or partially. This process is repeated. After a while all the chromosome and associated fitness become same except for those that are mutated. At this point the genetic algorithm has to be stopped (How *et al.*, 1994; Goldberg, 1989).

STRUCTURE AND THEORY OF ANTENNA

Structure of microstrip rectangular patch antenna is depicted in Fig. 1. Here, ‘L’, L_{eff} and ‘W’ are the length, effective length and width of rectangular patch, respectively. Patch is modeled on LiTi ferrite substrate of thickness ‘h’. The dielectric constant and saturation magnetization ($4\pi M_s$) of substrate is 17.5 and 2200 Gauss, respectively.

It has been established that, for a biased ferrite slab, a normal incident plane wave may excite two types of waves (ordinary and extraordinary wave). In the case of normal incident magnetic field biasing ordinary wave is same as the plane wave in the dielectric slab. On the other hand, the extraordinary wave is a TE mode polarized parallel to the biasing direction with its phase propagation constant K_e (Pozar, 1992; Dixit and Pourush, 2000; Stern *et al.*, 1987; Henderson and James, 1988; Pozar and Sanchez, 1988; Pozar, 1989).

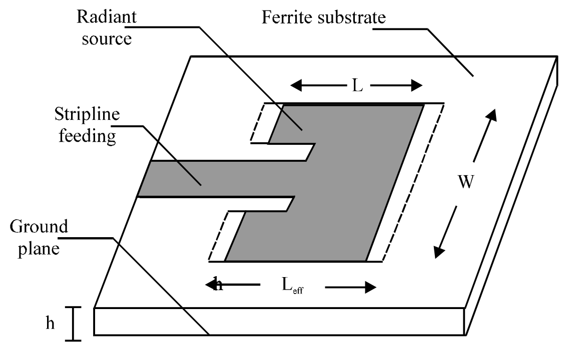

Fig. 1: Schematic diagram of Microstrip Rectangular Patch Antenna where 'L', L_{eff} and 'W' are the length, effective length and width of rectangular patch respectively. Here 'h' is the thickness of substrate

$$K_e = \frac{w}{c}\sqrt{\epsilon_{eff}\,\mu_{eff}} \tag{1}$$

$$K_d = \frac{w}{c}\sqrt{\epsilon_{eff}} \tag{2}$$

$$\mu_{eff} = \frac{\mu^2 - k^2}{\mu} \tag{3}$$

$$\mu = 1 + \frac{w_o w_m}{w_o^2 - w^2} \tag{4}$$

$$k = \frac{w w_m}{w_o^2 - w^2} \tag{5}$$

where, $w_o = \gamma H_o$ and $wm = \gamma 4\pi M_s$

The far zone expressions for rectangular patch microstrip antenna are obtained as follow:

$$E_\theta = 0 \text{ and } E_\varphi = -2jV_o WkF(\theta,\phi) \tag{6}$$

where, V_o = Voltage across the patch:

$$F(\theta,\phi) = \frac{\sin\left(\frac{kh}{2}\sin\theta\cos\phi\right)}{\left(\frac{kh}{2}\sin\theta\cos\phi\right)} \times \frac{\sin\left(\frac{kW}{2}\cos\theta\right)}{\left(\frac{kW}{2}\cos\theta\right)}\sin\theta$$

where:

$$k = K_\pm = K_d\left(\frac{w_o + w_m \mp w}{w_o \mp w_m}\right)^{1/2}$$

APPLICATION OF GENETIC ALGORITHM TO THE MICROSTRIP ANTENNA AND COMPUTED RESULTS

All the vital parameters like thickness of the substrate, bias magnetic field, length, width and dielectric constant etc. were coded into 5 bit scaled binary coding as the requirement of fitness function. The Roulette wheel selection was used for GA population. The genetic algorithm was run for 500 generations. The probability of crossover was varied from 0.7 to 0.85 and the probability of mutation was varied from 0.001 to 0.002. The fitness functions expressions of antenna used for optimization are:

Fitness Function: 1- Effective Length

$$L_{eff} = L + 2\Delta L \tag{7}$$

where:

$$L = \frac{c}{2f\sqrt{\frac{(\varepsilon_{reff}+1)}{2}}} - 2\Delta L$$

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

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{10h}{W}\right)^{-1/2}$$

Fitness Function: 2- Radiation Power

$$P_{Rad} = \frac{V_o^2}{240\pi^2}\int_0^{\pi}\left[\sin^2\left(\frac{k_o L\cos\theta}{2}\right)\times\tan^2\theta\sin\theta d\theta\right] \tag{8}$$

Fitness Function: 3- Directivity

$$D_g = \frac{W}{\lambda}\times\left(\frac{2}{15\times 2P_{Rad}}\right) \tag{9}$$

Fitness Function: 4- Input Impedance

$$Z_{in} = \left(\frac{1}{4\times P_{Rad}}\right) \tag{10}$$

Fitness Function: 5- Quality Factor

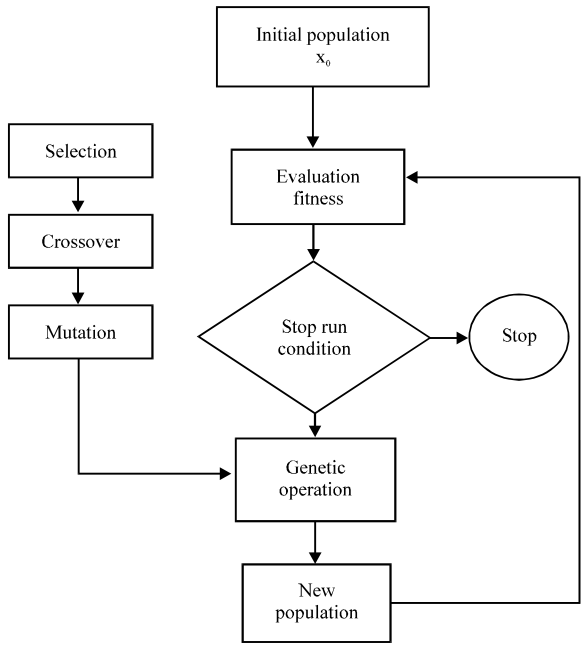

Fig. 2: Flow chart of Genetic Algorithm consists of five components: the random number generator, a fitness evaluation unit and genetic operators for reproduction, crossover and mutation operations

$$Q_t = \frac{Q_r R_T}{R_r / 2} \tag{11}$$

Where:

$$R_T = \frac{R_r}{2} + R_d = R_c$$

$$R_c = 0.00027\sqrt{f_r(GHz)} \times \frac{c}{w} Q_r$$

$$R_r = 1.2\lambda_0 \Omega / cm$$

$$Q_r = \left[\frac{c\varepsilon_{reff}}{4f_r \times h}\right]$$

The antenna parameters are characterized by a particular of combination of input variables like dielectric constant, patch length, width and substrate thickness of the ferrite which is determined using transmission line model. The GA consists of five components. These are the random number generator, a fitness evaluation unit and genetic operators for reproduction, crossover and mutation operations. The flow chart, for optimization of microstrip antenna, using GA, is shown in Fig. 2.

RESULTS AND CALCULATIONS

Obtained Graphs (Fig. 3-7) show the variation of best, mean and expected values of radiation power of antenna. During calculation GA program at every generation calculate expected value, mean and best value, then plot them for the corresponding parameter fitness functions. Every graph has a certain generation points above which convergence become very slowly and variation among mean and best values become negligible.

All graphs (Fig. 3-7) show the appreciate variation in mean values but in best value, carry a very little variation due to big generation attempt which precise or accurate the desired result. This big generation amount (500) has been applied to removing the inaccuracy in the best result which can be judge by expected value graphs shown in every figure. The performance graphs (Fig. 6, 7) of Input impedance and quality factor show a little bit variation in the best value

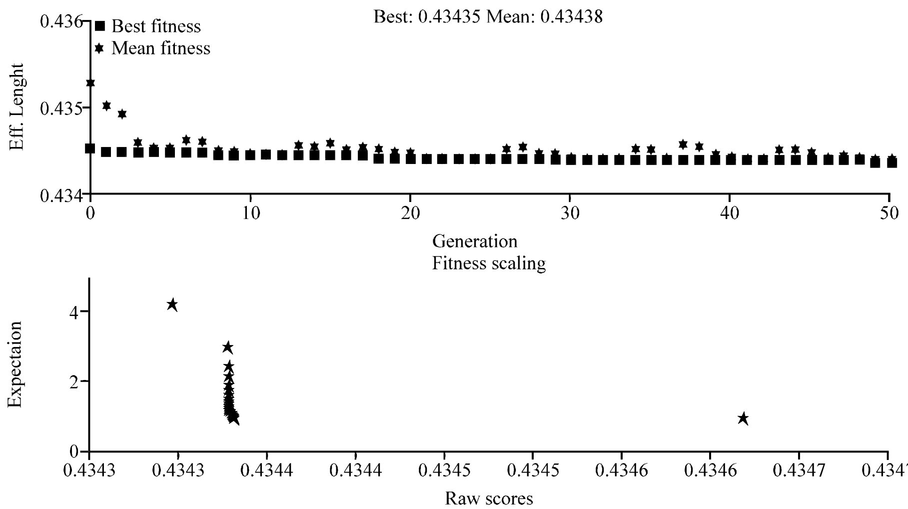

Fig. 3: Variation of best, mean and expected value of Eff. Length of rectangular patch antenna

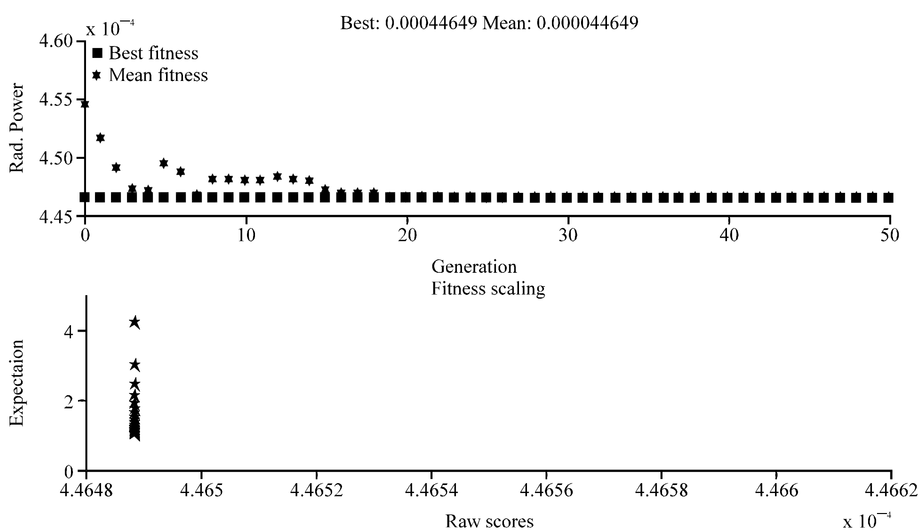

Fig. 4: Variation of best, mean and expected value of radiation power of rectangular patch antenna

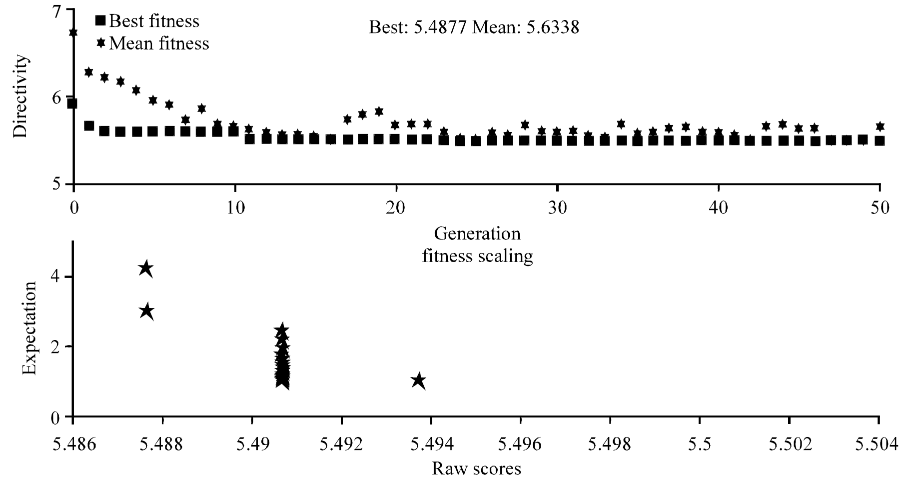

Fig. 5: Variation of best, mean and expected value of directivity of rectangular patch antenna

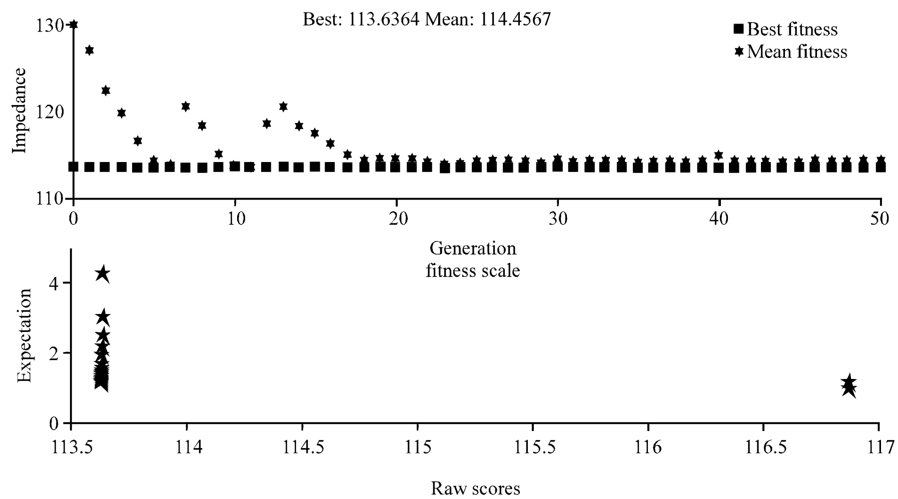

Fig. 6: Variation of best, mean and expected value of impedance of rectangular patch antenna

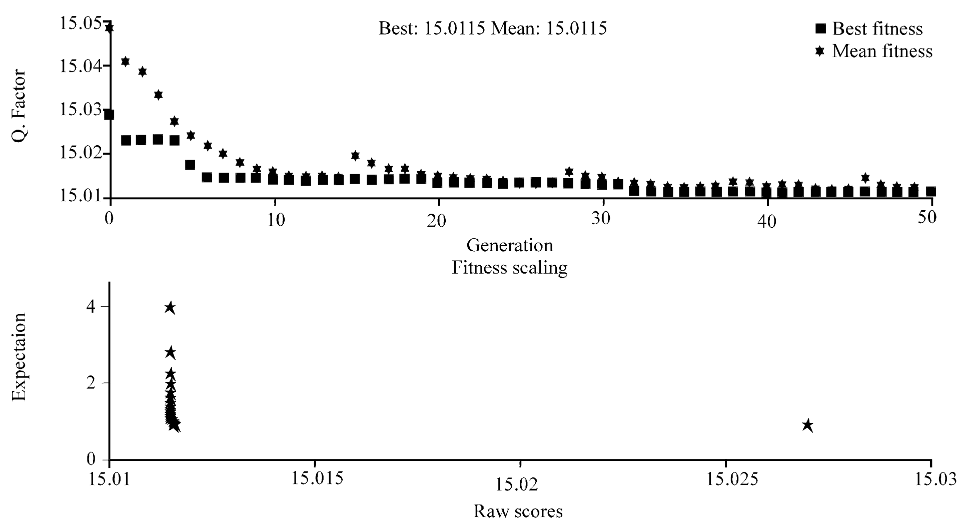

Fig. 7: Variation of best, mean and expected value of quality factor of rectangular patch antenna

Table 1: Comparison of parameters calculated by GA program and experimentally obtained

Parameters	Opt. values	Exp. values
Eff. length	0.4343 cm	0.4505 cm
Rad. power	0.44 mW	0.33 mW
Directivity	5.48 dB	3.4 dB
Impedance	113.63 ohms	96.35 ohms
Quality factor	15.011%	~ 12%

Opt: Optimized, Exp: Experimentally

which shows the requirement of more generation attempt but could not be performed due to inefficiency of computer program.

Calculated values of parameters of microstrip circular patch antenna with GA program have been compared with some theoretical and experimental results obtained by other methods and referenced in the research articles (Roy *et al*., 1992a; Das *et al*., 1983; Roy *et al*., 1992b; Roy and Chattoraj, 2002; Green and Sandy, 1974; Leon *et al*., 2004, 2002) which are in good agreement and given in Table 1.

CONCLUSION

To design an antenna with best performance First, the problem should formulated for the size, shape and material properties associated with the antenna. Next, an appropriate mathematical description that exactly or approximately models the antenna and electromagnetic waves is applied. Finally, numerical methods are used for the solution. One problem has one solution. Finding such a solution has proved quite difficult, even with powerful computers.

Rather than finding a single solution, optimization implies finding many solutions then selecting the best one. Optimization is an inherently slow, difficult procedure but it is extremely useful when well done. The difficult problem of optimizing an electromagnetic design has only recently received extensive attention

The method of application of Genetic Algorithm to the optimization of important parameters of microstrip rectangular antenna printed on ferrite substrate is reported. The fitness functions for the GA program is developed using transmission line method for the analysis of microstrip antenna. The computed graphs and results show a good agreement with the results obtained experimentally.

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