Design of a Compact Genetic Microstrip Antenna with improved performance

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Abstract

In this paper the design issues of compact genetic microstrip antennas for mobile applications has been investigated. The antennas designed using Genetic Algorithms (GA) have an arbitrary shape and occupies less area (compact) compared to the traditionally designed antenna for the same frequency but with poor performance. An attempt has been made to improve the performance of the genetic microstrip antenna by optimizing the ground plane (GP) to have a fish bone like structure. The genetic antenna with the GP optimized is even better compared to the traditional and the genetic antenna.

Keywords: Genetic algorithm, compact, microstrip antenna, ground plane optimization.

1. Introduction

The new generation cellular systems pose many requirements on antennas that are used. The most common ones are low cost, weight, and compact designs with increased bandwidth and high-performance. This paper reports on two issues, the amount of compactness that can be achieved using GA in a microstrip antenna operating at 1.8 GHz and the improvement in performance that can be obtained by optimizing the GP. Design of a compact antenna involves the search for an antenna which has lesser patch as well as GP dimensions compared to the traditional one. This can be achieved by applying GA to the traditional antenna. There may be many patches (solutions) for 1.8 GHz but the compact one is chosen. The performance of this compact antenna is poor compared to the traditional one. To improve the performance of the Genetic Microstrip antenna, the GP has been modified. All the analysis in this paper has been done using IE3D software.

2. Genetic Algorithm (GA)

GAs is search and optimization algorithms (Goldberg, D.E, Genetic Algorithms in search optimization and machine learning, Addison-Wesley, New York, 1989.) based on the mechanics of natural selection and natural genetics. A simple flowchart showing the process of GA is shown in Fig. 1.

2.1 Coding of a Microstrip patch

An electromagnetically coupled square MSA is shown in Fig. 2. For the purpose of coding the microstrip patch is divided in to n x n cells. All cells have equal dimensions. Each cell is assigned a binary random number '1' or '0' as shown in Fig. 3. A population (initial) with N numbers of such patches is generated in the form of random binary strings. GA is then applied. Each one in the population is analyzed and its resonant frequency is obtained using Integral Equation method

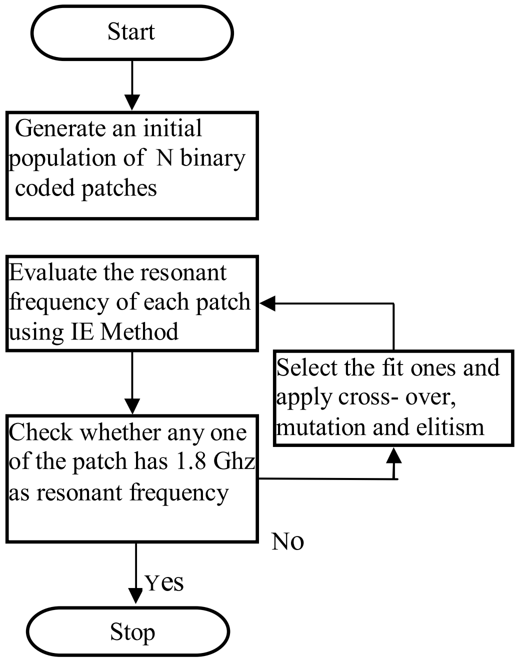

Figure.1 A simple flowchart for microstrip antenna design using GA

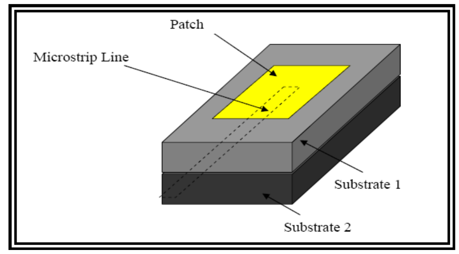

Figure.2. An electromagnetically coupled MSA

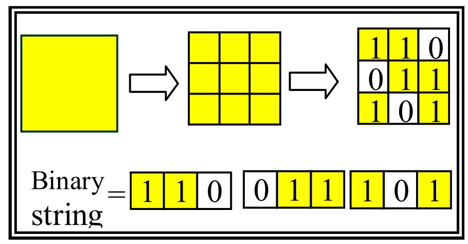

Figure.3 A typical coding of a 3x3 patch

2.2 Fitness function

The fitness of each antenna in the population is evaluated using a fitness function. The fitness function for the antennas whose frequencies do not fall in the 1.6 to 2 GHz is defined by

$$fitness = \left(\frac{1}{error}\right) * 100 \tag{1}$$

And for the rest it is defined as

$$fitness = \left(\left(\frac{1}{error}\right) + dbfit\right) * 100 \tag{2}$$

$$error = \frac{(f_{target} - f_{evolved})}{f_{target}} \tag{3}$$

$f_{target} = 1.8$ GHz for this particular work and *dbfit* is a small bonus value added to the fitness based on the return loss (R.L) i.e., performance of the antenna.

2.3 Selection Process, Crossover, Mutation and Elitism

Based on the fitness assigned in the previous section the fittest of the population is selected and paired for the application of genetic operators like crossover, mutation etc. Roulette wheel selection is used. Single point cross over has been used. After cross over the resultant off spring chromosomes are mutated randomly i.e. a ‘1’ to ‘0’ and ‘0’ to ‘1’ with a very low probability rate similar to natural evolution. Elitism is the process of retaining or inserting the best individual in to the next generation from the current generation. This is done to avoid the loss of the best individual in any population during the crossover and mutation operations. After this we have the next generation population. The chromosomes are once again checked for fitness and the entire process continues until the fit patch with compact dimension but still resonates with 1.8 GHz arrives. This antenna has a poor performance and it cannot be used for practical applications. Hence it has to be further modified for improving its performance.

3. Ground plane optimization

The genetic microstrip antenna's (MSA) GP is modified such that its Gain, Radiation and Antenna efficiency are maximized. This was done using a trial and error basis. A fish bone like structure gave better performance. The GP was divided in to small strips with a central line and the strip dimensions were modified randomly using GA to obtain the resultant shape and performance.

4. Simulation results

An electromagnetically coupled square MSA was designed for 1.8 GHz with 50x50mm GP and 37.7x37.7 mm patch. ε_r = 4.4 and height = 1.6 mm for both substrates. Loss tangent = 0.02. Strip feed dimension was 3x20 mm. The patch was divided in to 12x12 cells and coded in to binary strings called chromosomes. GA was applied to these chromosomes and their return loss characteristics were obtained. The dimensions were reduced and the same process was repeated. It was found that the patch and the GP can go down to 18x18 mm and 30x30 mm. This patch could still resonate at 1.8 GHz. The original square patch, its R.L curve and radiation patterns are shown in Fig.4. The MSA obtained using GA, its return loss curve and radiation patterns are shown in Fig. 5. From the figures it can be seen that the performance is poor. Hence the GP is modified to improve the performance and is shown in Fig.6.

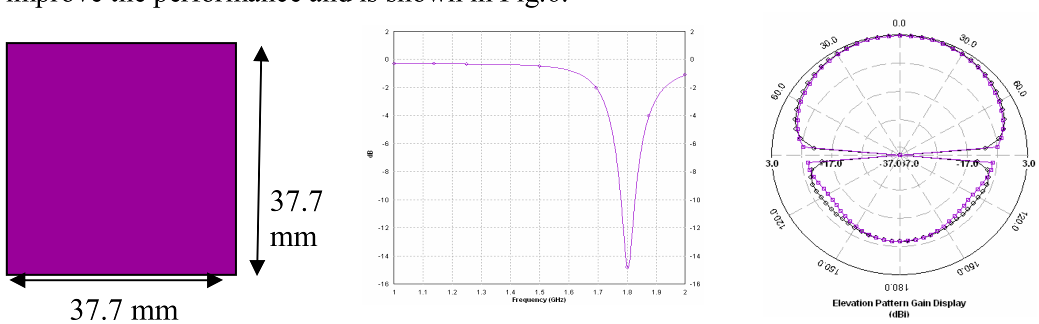

Figure.4 37.7x37.7mm square patch, R.L curve and radiation pattern

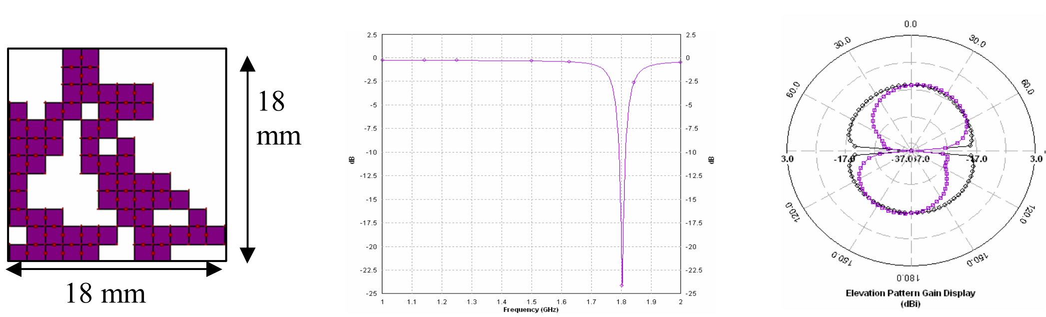

Figure.5 18x18 mm patch, R.L curve and Radiation pattern

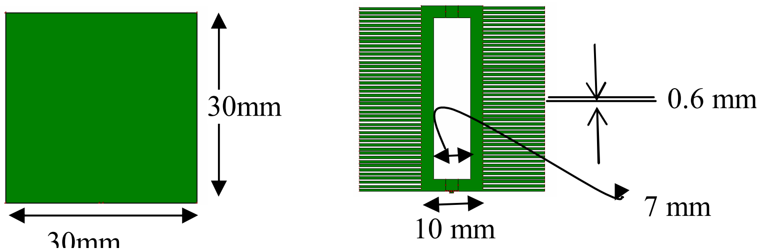

Figure.6 Ground plane 30mm x30mm before and after optimization

The GP size was 30x30 m. When the GP was optimized the resonant frequency of the genetic antenna slightly shifted. To avoid this some of the cells from the patch were removed to achieve 1.8 GHz back. The resultant patch, R.L and radiation pattern are shown in Fig.7.

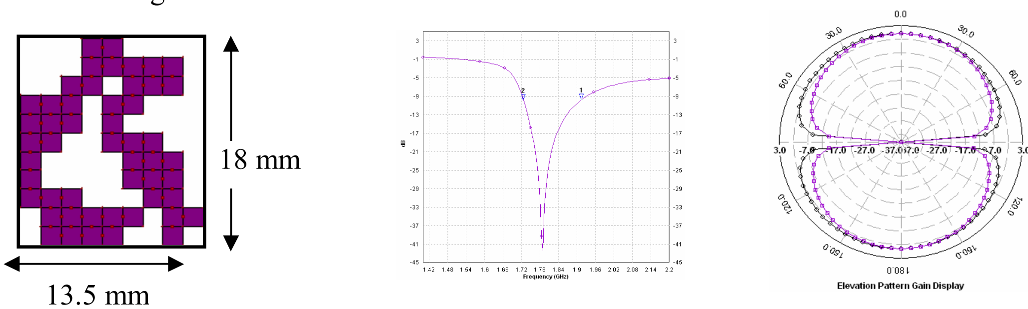

Figure.7 The final Genetic patch with optimized GP, R.L curve and Radiation Pattern

It can be seen from the figures that the radiation pattern of the genetic antenna was distorted with poor gain as shown in Fig.5 and it recovered back after the GP modification as shown in Fig.7. The performances of the antennas are compared in Table 1. From the table the genetic antenna with ground plane optimization has better performance compared to even the traditional one though it is smaller in size and has lesser patch area.

Sl.No.	Parameter	Traditional antenna (37.7x37.7 mm)	Genetic Antenna (18x18 mm)	Genetic Antenna after GP modification(18x13.5mm)
1.	f_r	1.8 GHZ	1.8 GHz	1.8 GHz
2.	Radiation η	46.1921%	1.38644%	49.821%
3.	Antenna η	44.6627%	1.36613%	49.746%
4.	Gain	2.78288 dBi	-15.0804 dBi	0.187 dBi
5.	%Bandwidth	4	2.7	12

Table 1 Comparison of traditional, genetic and ground plane modified genetic MSA

5. Conclusion

A compact MSA with 83% and 64% reduction in patch and GP respectively was designed for mobile application using GA. Its performance was improved using GP modification. The antenna had a better η, four times increase in % BW, Omni directional radiation pattern compared to the traditional one and many times better than the pure genetic antenna.

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