



# Design of a genetic microstrip patch antenna with broadside radiation for GSM applications

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## Abstract

Designing multiband antennas with broadside radiation becomes of practical interest in the ever growing wireless communication. In this regard, design of a multiband microstrip patch antenna (MPA) for GSM850, GSM900, GSM1800 and GSM1900 applications using Genetic Algorithms (GA) combined with Finite Element Method (FEM) is proposed to optimize the patch geometry and the feed position. A substrate with dielectric constant 3.2 and height 0.76 mm is used to support the MPA. Patch dimensions are (100 mm × 122 mm) similar to that of the conventional rectangular patch for the lowest frequency band (GSM850). In addition, there is an air gap of 10 mm between the substrate and the ground plane. This MPA with a reflection coefficient less than -10 dB and broadside radiation at all four GSM bands can be useful for base station antennas.

**Keywords:** Genetic Algorithm Optimization; GSM; Microstrip Patch Antennas; Mobile Communication.

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## 1. Introduction

Microstrip patch antennas (MPAs) consist basically of three layers, a metallic layer with the antenna element pattern, a dielectric substrate and another metallic layer as the ground plane. With the development in the field of wireless mobile communication, modifications to MPAs have been done to improve performance of them [1]. Different techniques such as air gaps [2], metamaterials [3], frequency selective surfaces [4], slots [5], modified patch ground plane [6], shorting [2], stacking [7], parasitic elements [8] and dual-patch structures [9] have been followed to design broadband/multiband MPAs which cover several bands such as GSM, UMTS and WLAN.

Some of the improved MPAs show broadside radiation in a single band or in multiple bands [10]-[11]. To obtain broadside radiation patterns, techniques such as slots [12], stacking [13], dielectric resonators [14], multiple patches [15], metamaterials [16] and electromagnetic band gap substrates [17] have been proposed by researchers.

Genetic Algorithm (GA) is a powerful optimization technique that has been used in the field of electromagnetics [18]-[20]. It is a robust, stochastic-based search method, which can handle the common characteristics of electromagnetic optimization problems that are not readily handled by other traditional optimization methods. GA is used in the field of antennas to design broadband [21], multiband [22], high-directivity [23] and miniature [24] MPAs.

It is an interesting research problem to design wideband/ multiband MPAs while obtaining broadside radiation patterns at all bands. In this paper, GA is used to design a dual-band MPA for GSM applications with broadside radiation at both bands. Two techniques, which are designing the patch geometry and optimizing the feed position, are used with GA to achieve the goal. Simulation of the MPAs is carried out by using HFSS (High Frequency Structure Simulator), which is a highly accurate electromagnetic solver based on Finite Element Method (FEM). Simulated reflection coefficient and radiation patterns are obtained for the optimized design and performance is analyzed.

The present paper is divided into the following sections. The architecture of the antenna and GA is presented in section II. Section III illustrates the performance of the optimized MPA. Finally, conclusions are given.

## 2. Antenna configuration and GA optimization

The substrate used to print the patch is Neltec NX9320 (IM) (tm), which has relative permittivity of 3.2, thickness of 0.76 mm and loss tangent of 0.0025. The substrate is suspended on air, spaced 10 mm from the ground plane (Fig.1). For this design, the length and the width of the patch are selected as 100 mm and 122 mm respectively, which have been adjusted to have the fundamental mode at the frequency of 850 MHz. The patch area is fragmented into 77 cells having an overlap of 1 mm between adjacent cells in order to search for the best solution of conducting cells [22]. In the chromosome, genes define the patch geometry by assigning conducting or non-conducting properties to each cell. As there are only two possible values, binary coding is used. First 77 genes of the chromosome define the patch geometry and final seven genes define the feed position. The solution space consists of  $2^{83}$  chromosomes. A 50 Ω coaxial cable is used to feed the antenna.

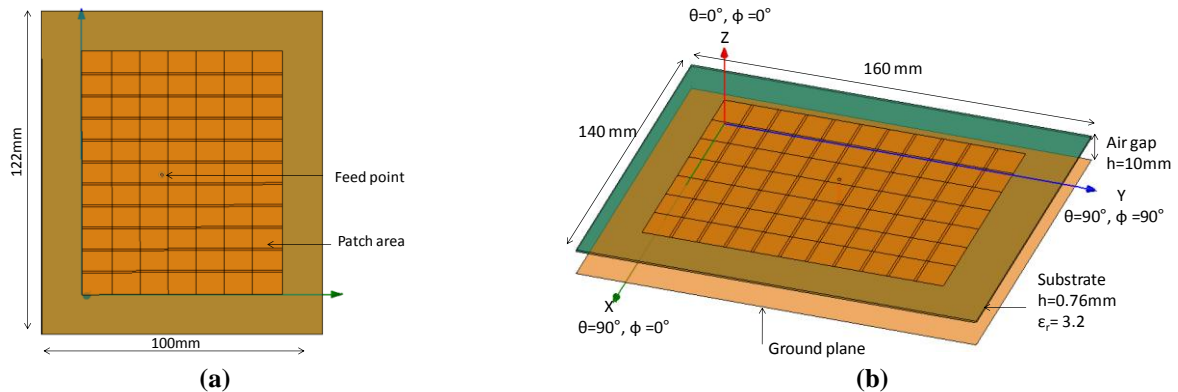


Fig. 1: Antenna Configuration. A) Top View of the Patch Where Overlap Is Permitted. B) 3D View.

Table1: Format of the Chromosome for Genetic Patch

| Patch geometry | Feed position |
|----------------|---------------|
| 0..... 76      | 77.....82     |

The fitness function  $F$  is the summation of reflection coefficient values taken at 10 MHz intervals including all four GSM bands, ranging from  $f_1=820$  MHz to  $f_2=960$  MHz and from  $f_3=1710$  MHz to  $f_4=1990$  MHz.

$$F = \frac{-\left( \sum_{f_i=f_1}^{f_2} L(f_i) + \sum_{f_i=f_3}^{f_4} L(f_i) \right)}{10 \cdot N} \tag{1}$$

Where  $N$  the total is number of samples and  $L(f_i)$  is defined as

$$L(f_i) = \begin{cases} \rho(f_i)_{dB} & \rho(f_i)_{dB} \geq -10dB \\ -10dB & \rho(f_i)_{dB} < -10dB \end{cases} \tag{2}$$

Where  $\rho(f_i)_{dB}$  is the reflection coefficient in dB. The termination criteria for the proposed multiband operation is defined as

$$F_{highest} = 1 \tag{3}$$

This can be achieved when all reflection coefficient values over the proposed frequency bands are less than -10dB. The GA architecture employs 20 chromosomes per generation. The crossover operation is performed with probability of 100%. The probability of mutation is 1%. Binary tournament selection method is used for generation replacement and preservation of higher fitness values is guaranteed.

## 3. Results

For simulations, an Intel Core i7 processor with 2 GHz speed and a RAM with 6 GB capacity have been used. The simulations consider an infinite ground plane. Once the solution is found, a ground plane with dimensions of 140 mm × 160 mm is taken into account.

The optimized MPA shows multi-frequency performance by having -10 dB bandwidth from 820-970 MHz and from 1650-2000 MHz covering GSM bands (Fig.2). The maximum radiation values along the broadside direction are 2.5 dB,

3.5 dB, 7.8 dB and 8 dB at the center of each GSM band which are  $f = 850$  MHz,  $f = 920$  MHz,  $f = 1800$  MHz and  $f = 1920$  MHz respectively (Fig.3).

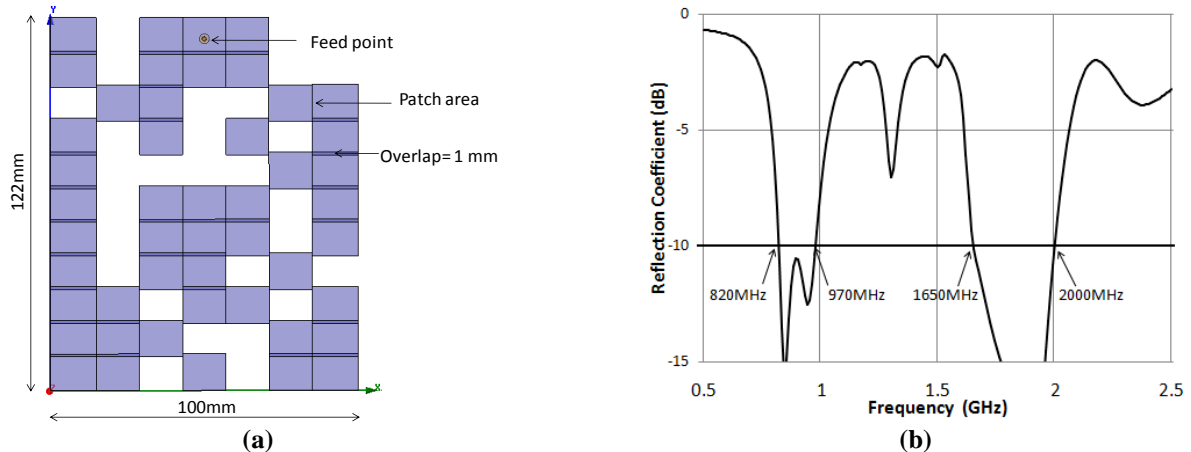


Fig. 2: Simulation Results of the Optimized MPA. (A) Patch Geometry. (B) Reflection Coefficient.

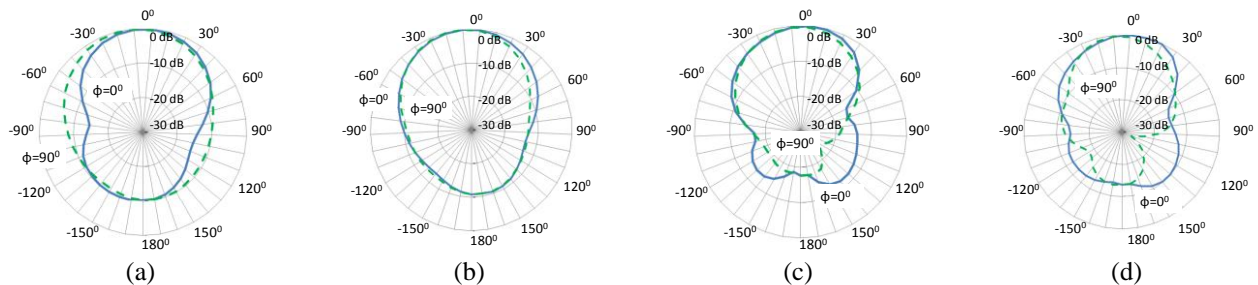


Fig. 3: Radiation Patterns at Center Frequency of Each Band. (A) GSM850 (B) GSM900 (C) GSM1800 (D) GSM1900

## 4. Conclusions

It is impossible to obtain multiband performance, while maintaining broadside radiation patterns in each band, using conventional rectangular shaped MPAs since bands are dictated by the mode distribution. To overcome this problem, a patch (100 mm  $\times$  122 mm) over a dielectric substrate of  $\epsilon_r = 3.2$  and  $h=0.72$  mm suspended on air (10 mm height) has been optimized with GA to obtain a dual-band MPA having a reflection coefficient less than -10dB in GSM850, GSM900, GSM1800 and GSM1900 frequency bands. It shows broadside radiation patterns at all bands. Due to multiband behavior and broadside radiation patterns, these designs can be useful as base station antennas.

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