Design a low mutual coupling microstrip array antenna with non regular polygonal patches

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Abstract: This paper presents a new method to design microstrip array antennas. In this method, non-regular polygonal patches are used and their shapes are determined by genetic algorithm (GA) depending on the design needs. The positions of patch vertexes are optimized by GA. Connecting the vertexes with an incorrect order yields to an invalid patch which its edges intersect themselves. So, ant colony optimization (ACO) is used to find correct connection order of vertexes. This method is used to design an array antenna with low amount of return loss and mutual coupling. Finally, design procedure is verified by simulation.

Keywords: microstrip array antenna, mutual coupling, polygonal patch, genetic algorithm, ant colony optimization

Classification: Microwave and millimeter wave devices, circuits, and systems

References

1 Introduction

The idea of microstrip antenna was introduced in 1953 and it was developed in 1970 by Howell and Munson [1, 2]. Due to fast development of wireless communications, design of a small, low cost, simple manufacturing, light weight and conformable antenna is very important. So microstrip antenna, which has these properties, is a good choice [3, 4, 5, 6, 7, 8, 9, 10]. Also, they are widely used in array antennas. In array antenna, the mutual coupling effect is caused by coupling the current of one element on the other elements. This effect consumes input power and decreases the efficiency of the array. Also, it degrades the beam forming and steering. Many methods are presented in lit-
temperatures for decreasing or compensating this effect such as modifying antenna substrate, changing patch shape and so on [11, 12, 13, 14, 15, 16, 17, 18, 19]. A new design method is presented in this paper in which a non-regular polygonal patch is used instead of ordinary patches and the shape of patch is determined according to the design constraints. This method is used to design an array antenna with low amount of return loss and mutual coupling. In the next section, the design procedure is studied. Then this method is verified by simulation.

2 Design procedure

In this section, a microstrip array antenna with two elements is designed. The antenna has three conductive layers which are patch layer, feed line layer and infinite ground layer. Thicknesses of the both dielectric layers are the same and equal to 0.76 mm. Also their relative permittivity ($\epsilon_r$) are the same i.e. 2.2. Since the dielectrics are non magnetic their relative permabilities ($\mu_r$) are 1. The patches are fed by proximity coupled mechanism by 50$\Omega$ feed lines.

The patch is considered as a polygon with 28 vertexes. Depending on the application needs, the number of vertexes can be decreased or increased. To simplify design procedure, the patches are considered to have vertical and horizontal symmetry. Figure 1 (a) shows a typical polygonal patch. To apply patch symmetry, positions of vertexes must satisfy the following relations.

$$P_{1n}(x) = P_{2n}(-x), \quad P_{1n}(x) = -P_{3n}(-x), \quad P_{1n}(x) = -P_{4n}(x)$$

The $x$ and $y$ values of vertexes, feed line width and length and amount of patch and feed line intersection are variables which must be optimized by enhanced genetic algorithm [20] to achieve an optimal array antenna with the least amount of mutual coupling and return loss. The $x$ and $y$ values vary without any constrains. So if they are connected together with a constant order, an invalid patch, that their edges intersect each other, will be made as shown in Figure 1 (b). Enhanced ACO [20] is used to solve this problem and find the correct order of vertexes connection.

Some artificial ants are generated and placed on vertexes randomly. Ants move from one vertex to another, randomly and deposit trail of pheromone on their path. The ants’ goal is to find the shortest path without intersection between all vertexes. In many cases, the shortest path is the path without intersection, so finding shortest path is a good help to find the path without intersection. The ants move between vertexes with these simple rules:

- Each ant moves only once through each vertex.
- Each ant must travel through all vertexes.
- Ant deposits more pheromone on shorter paths.
- Ant deposits less pheromone on the paths which have intersection with traveled paths.
Fig. 1. A typical polygon patch (a) and some invalid (b) and validated (c) patches.

- Ant prefers to travel through the path with more pheromone.

Figure 1 (c) illustrates validated patches by ACO. This method was run to design an array antenna with two elements at resonant frequency 8.5 GHz. Distance between elements in array is 14.5 mm (\(<\lambda/2\)). The fitness of GA members, which are antenna arrays, is calculated by simulation that is based on the method of moments (MOM) [21]. The genetic algorithm results are listed in Table I and Figure 2 (a) shows obtained patch.

**Table I.** Optimization results (all units are mm).

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<tbody>
<tr>
<td>x1, y1</td>
<td>x2, y2</td>
<td>x3, y3</td>
<td>x4, y4</td>
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<tr>
<td>0.4, 4.58</td>
<td>0, 5.82</td>
<td>1.08, 6.11</td>
<td>1.37, 7.16</td>
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<tr>
<td>x5, y5</td>
<td>x6, y6</td>
<td>x7, y7</td>
<td>x8, y8</td>
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<tr>
<td>3.41, 3.74</td>
<td>4.2, 3.97</td>
<td>4.15, 3.52</td>
<td>6.85, 0.0</td>
<td></td>
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<tr>
<td>Feed Line upper width</td>
<td>Feed Line lower width</td>
<td></td>
<td></td>
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<tr>
<td>2.39</td>
<td>1.24</td>
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<tr>
<td>Feed Line Length</td>
<td>FL and Patch overlapping</td>
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<tr>
<td>9.74</td>
<td>1.64</td>
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Fig. 2. Optimal array antenna (a) and its reflection coefficient (b) and mutual coupling (c) in comparison to array antenna with conventional rectangular patches.

The reflection coefficient and mutual coupling of the proposed antenna are illustrated in Figures 2 (b) and (c) respectively and are compared with reflection coefficient and mutual coupling of array antenna with conventional rectangle patch which shows that the proposed structure has better VSWR and mutual coupling.

3 Conclusion

A novel design procedure has been proposed to improve the characteristics of microstrip arrays antenna using an irregular polygonal patch. The main challenge which is finding the patch shape which satisfies designer needs has been solved by enhanced genetic algorithm. GA was used to optimum patch and feed line parameters and achieved an optimal array antenna. Also enhanced ACO was used to make valid the patches which are generated by GA. Simulation results show that this method acts as expected.