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Determination of Radius of Circular Microstrip Antenna Using Clonal Selection Algorithm

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Abstract: *A method based on clonal selection algorithm (CSA) for computing the radius of circular microstrip antennas (MSAs) is presented. The CSA is a stochastic method which has the capability of optimizing multimodal problems. The method gives the radius as output for given values of resonant frequency (f_r), height (h), dielectric constant (ε_r) of the circular MSAs. Results obtained for the radius of circular MSAs are in good agreement with the experimental results reported by several authors.*
Keywords: *clonal selection algorithm, circular microstrip antenna, resonant frequency, stochastic methods;*

I. Introduction

Microstrip antennas have extensively been used in commercial and military communication systems due to their simplicity, conformability, low manufacturing cost, light weight, low profile, reproducibility, reliability, and ease in fabrication and integration with solid-state devices [1-6]. Several methods [7-9] are available to calculate the resonant frequency of circular microstrip patch antenna, as this is one of the most popular and convenient shapes. However, it would be more useful if we would calculate the value of radius for a desired value of resonant frequencies as well as dielectric constant and height. In this proposed work, a method to calculate the radius of circular microstrip antenna for the desired values of above mentioned antenna parameters is presented.

As an essential part of Artificial Immune System (AIS), clonal selection algorithm has drawn attentions of researchers in different fields [10-12]. CSA is biologically inspired search technique introduced by Burnet F.M. in 1958 [13].The performance of CSA involves basic three steps: cloning, mutation and evaluation. The main features CSA are [14]:

a) maintenance of memory cells functionally disconnected from the larger antibody set;
b) selection and cloning of most stimulated antibodies;
c) suppression of nonstimulated cells;
d) affinity maturation and reselection of clones with higher affinity;
e) mutation rate proportional to cell affinity;
f) cloning and hypermutation to maintain the diversity of the antibody set. In this paper, CSA based method is used to determine the radius of circular microstrip antenna.

II. Problem Definition

2.1 Design of circular microstrip antenna

The geometry of circular microstrip antenna is shown fig.1. The resonant frequency (f_r) of a circular patch antenna is approximately given without considering the effect of probe radius by [1]:

$$f_r = \frac{K_{nm} * c}{2\pi\ a_e \sqrt{\varepsilon_r}} \tag{1}$$

where a_e = effective radius of the circular patch
c = velocity of light in free space
ε_r = relative permittivity of the medium
K_{nm} = mth zero of the derivative of the Bessel function of order n.

In our application, we have considered the fundamental mode TM_{11} for which the value of K is 1.84118. The expression for a_e is given by [3] as:

$$a_e = a\ \left\{1 + \left(\frac{2h}{\pi a \varepsilon_r}\right) \left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \tag{2}$$

where h = height of the antenna
a = radius of the antenna

2.2 Clonal selection Algorithm

Clonal selection algorithm is a robust, stochastic evolutionary computation technique based on the behavior of adaptive immune system [15]. The adaptive immune system is the most sophisticated system and involves many different types of cells and molecules. It is called “adaptive” because it is responsible for immunity that is adaptively acquired during the lifetime of the organism. This technique has been applied for electromagnetic optimization recently.

In the Clonal selection algorithm, a candidate solution for the specific problem is called an antigen, which is recognized by the antibody. Each antibody represents a possible solution to the problem. A population consists of a restricted number of antibodies. In this algorithm, after recognizing an antigen, immune system reproduces antibodies which are able to identify that particular antigen. Consequently, every antibody is evaluated by the evaluation mechanism to obtain its affinity. In addition, mutation process is also performed on regenerated antibodies causing partial differences between them. These differences make the population able to recognize antigens that were not recognizable for initial antibodies. So we can summarize the steps as:

1. Produce the initial population randomly in the problem space. The number of initial antibodies in the population is “N”.
2. Determine the affinity of each antibodies (evaluating by objective function). In this case, equation (1) is taken as the objective function.
3. Select “n” antibodies which have the higher affinity.
4. Improve new population which has “n” antibodies. Improvement is in proportion to each antibody’s affinity. In other words, an antibody with higher affinity will be copied more than other antibodies with lower affinity.

$$n_c = round\left(\beta.\frac{N}{i}\right), \qquad i = 1,2,...... \tag{3}$$

where “n_c” is the number of offspring antibodies from i[th] antibody (parent) and β is a constant coefficient which indicates the rate of copy. At the end of this step, the number of antibodies in the refreshed population would be “N_c” as follows:

$$N_c = round\left(\beta.\frac{N}{i}\right), \tag{4}$$

Mutate N_c antibodies of the population in proportion to their affinities. It means that antibodies with higher affinity should be mutated less than those with lower affinity.

5. Determine the affinity of each mutated antibodies and select “m” antibodies with higher affinity. Therefore, the population consists of “m” antibodies which enter the next generation directly.
6. Generate “p” new antibodies randomly and add them to the population. These new antibodies increase the solution diversity and consequently the optimization process is able to escape from the local optima. This step causes the number of antibodies in the final population to reach (m + p).
7. Return to step 2 and repeat this cycle until the termination criteria are met.

III. Results and Discussions

In order to demonstrate the performance of the proposed method, it is compared with the existing experimental values of radius from previous papers which are reported here [16-22]. The population size is taken to be 20 individuals and 20000 generations are produced. The probability of mutation is equal to 0.01. In this approach, the clone size is taken as a constant value [11]. TABLE.1 depicts the comparison between the calculated and experimental values for different sets of antenna parameters.

It is observed from the TABLE.1 that the values obtained from the proposed method are in very good agreement with experimental results. For further verification, the circular MSAs given in TABLE.1 are designed with the value of radius obtained from the proposed code and simulated using Ansoft HFSS-13 version. The simulated return loss plots of three antennas with serial no.4, no.17, no.24 are shown here in fig.2, fig.3 and fig.4 respectively. It is found that the resonant frequencies are approximately same with the desired values. Therefore, we can compute the value of radius of the circular patch by using the proposed method for a desired resonant frequency. Thus the CSA model given in this work can be used for circular microstrip antenna design for various applications.

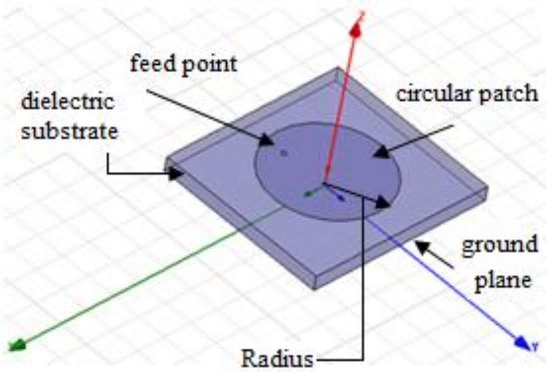

Fig.1: Geometry of Circular Microstrip patch

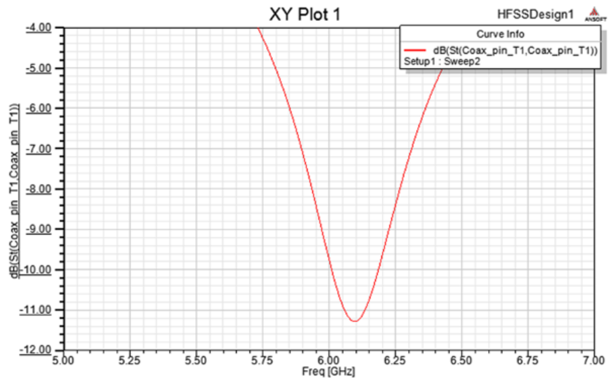

Fig.2: simulated return loss plot for antenna with serial no.4

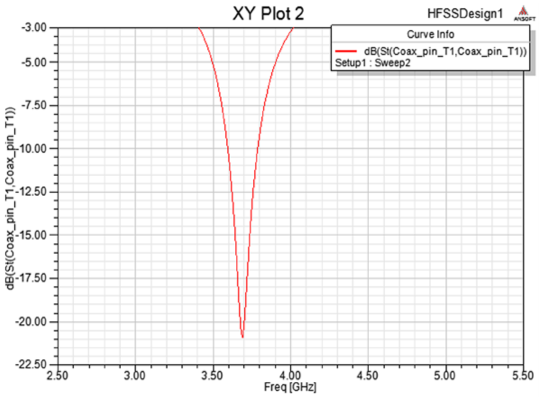

Fig.3: simulated return loss plot for antenna with serial no.17

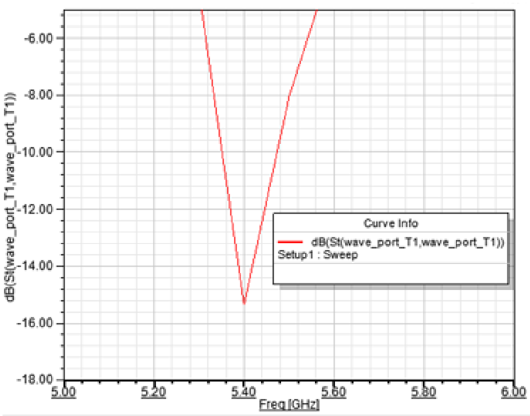

Fig.4: simulated return loss plot for antenna with serial no.24

Table.1: Comparison of experimental and CSA based values of radius of circular microstrip antennas:

Serial no.	Resonant frequency (f_r) (GHz)	Height (h) (mm)	Dielectric constant (ε_r)	CSA value of radius(a) (mm)	Measured value of radius (mm)	Measured by
1	4.425	1.588	2.65	11.67	11.50	[16]
2	4.723	1.588	2.65	10.70	10.9	
3	5.224	1.588	2.65	9.6	9.83	
4	6.074	1.588	2.65	8.2	8.42	
5	1.57	1.588	2.5	34.93	34.64	[17]
6	4.07	0.794	2.59	12.07	12.70	
7	1.51	3.175	2.5	34.93	34.64	
8	2.88	0.35	2.47	18.90	18.61	[18]
9	2.81	1.6	2.47	18.90	19.26	
10	1.443	1.524	2.43	38.00	37.81	[19]
11	1.286	3.175	2.5	41.91	42.55	[20]
12	3.54	1.6	2.62	14.1	14.76	[21]
13	0.8	2.35	4.55	49.5	50.94	
14	1.03	2.35	4.55	39.7	39.487	
15	1.36	2.35	4.55	29.9	29.82	
16	2.00	2.35	4.55	20.00	20.19	
17	3.75	2.35	4.55	10.4	10.68	
18	4.94	2.35	4.55	7.7	8.07	
19	1.09	3.18	2.52	48.5	50.6	
20	28.6	0.49	2.43	1.9	1.53	[22]
21	13.1	0.49	2.43	3.9	3.59	
22	8.9	0.49	2.43	5.8	5.6	
23	6.8	0.49	2.43	8.0	7.54	
24	5.4	0.49	2.43	9.9	9.67	
25	5.45	1.194	10	4.7	4.56	
26	3.65	1.194	10	7.1	7.06	

IV. Conclusion

A code based on clonal selection algorithm is developed here to optimize the radius of circular patch of circular MSAs for the given parameters of the antenna like resonant frequency, height and dielectric constant. The values of radius obtained in this study are compared with the available experimental and theoretical values in the literature. The developed code is also verified here by simulating the designs using Ansoft HFSS and is found to be in good agreement. The advantage of this method is that it determines the optimal value of radius of circular patch for the desired resonant frequency. Therefore, the proposed method is less time consuming and would be more helpful to design circular MSAs. Furthermore, it is not computationally tedious. Thus, CSA approach presented here can be used by a MSA designer practically without any background in sophisticated mathematical techniques.

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