A Dual Resonance Three Segment Rectangular Dielectric Resonator Antenna

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Abstract— A three-segment rectangular dielectric resonator antenna with equal segment dimensions and different dielectric constants is investigated. The dielectric constant of each segment is optimized with two different optimization algorithms, genetic algorithm and an optimization algorithm inspired from weed colonization in order to improve bandwidth. A dual resonance frequency response with improved bandwidth is obtained.

1. INTRODUCTION

Dielectric resonator antennas are suitable for a variety of applications. DRAs have small size and low cost. They can be easily coupled to almost all types of transmission lines [1]. DRAs have high radiation efficiency, since the only loss for a DRA is that due to the imperfect material of the DRA which can be very small in practice [2]. They have wider impedance bandwidth in comparison to microstrip antennas. For a typical DRA with dielectric constant of 10 the impedance bandwidth of 10% can be achieved. Avoidance of surface waves is another attractive advantage of DRAs over microstrip antennas.

There are a variety of feed configurations, which electromagnetic fields can be coupled to DRAs. Most common feed arrangements are microstrip aperture coupling, direct microstrip coupling, probe coupling and conformal strip coupling. Among these feed configurations, aperture coupling is more suitable for MMW applications. In aperture coupling configuration, since the DRA is placed on the ground plane of the microstrip feed, parasitic radiation from the microstrip line is avoided. Isolation of the feed network from the radiating element is another advantage of the aperture coupling method.

In DRAs bandwidth is a challenge. Several works have been done on improving bandwidth of DRAs. In this paper a three segment rectangular DRA with the help of genetic algorithm is designed to improve bandwidth.

2. ANTENNA STRUCTURE

The antenna structure is shown in Figure 1. A dielectric resonator is placed on the ground side of a microstrip line. The feed applied to the microstrip line and electromagnetic energy is coupled to the DRA via an aperture which is etched on the ground plane.

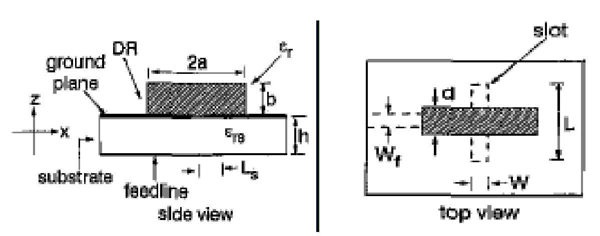

Figure 1: Single DRA [3].

There isn't any analytical formula for computing bandwidth of DRAs and numerical techniques should be employed. In this work for investigating DRAs, CST Microwave Studio is used. CST is based on the finite difference time domain method. The CST package has this advantage that, with a VBA editor its environment can be controlled and in this paper for optimizing purposes, optimization programs are developed in VBA in order to have direct access to the CST simulation environment.

Rectangular DRAs with aperture coupling have been commonly studied in literature [4]. Rectangular DRA with parameters: $\varepsilon_{rs} = 10.2$, $\varepsilon_r = 10.8$, $2a = 15\,\text{mm}$, $b = 7.5\,\text{mm}$, $d = 3\,\text{mm}$, $L = 6.1\,\text{mm}$, $L_s = 2.2\,\text{mm}$, $w = 1.2\,\text{mm}$, $w_f = 0.64\,\text{mm}$ and $h = 0.64\,\text{mm}$ is simulated in [5] with FDTD method and the resultant frequency response is shown in Figure 2. This antenna is also simulated here with CST and the frequency response is plotted in Figure 3. agreement between two figures is good and the bandwidth is 9%.

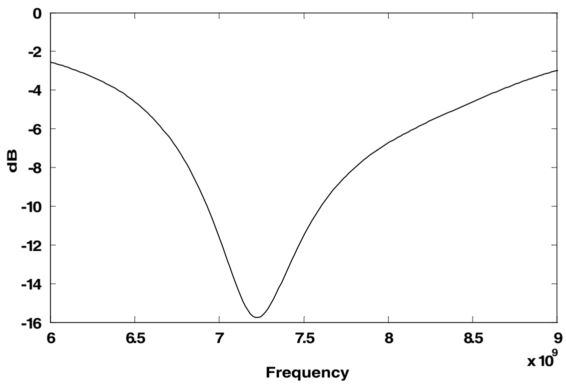

Figure 2: Return loss of the single DRA [5].

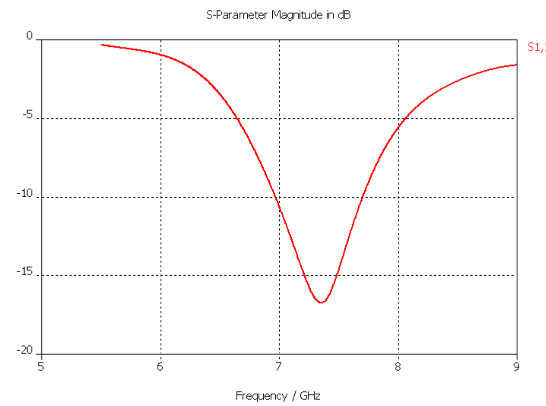

Figure 3: Return loss of the single DRA simulated with CST.

In order to obtain improved bandwidth, the DRA is subdivided into three segments with equal dimensions and different dielectric constants. The structure of the three-segment DRA is shown in Figure 4. This structure is optimized with two methods, genetic algorithm and an optimization algorithm inspired from weed colonization which is recently developed in [6] and the results of both methods are compared.

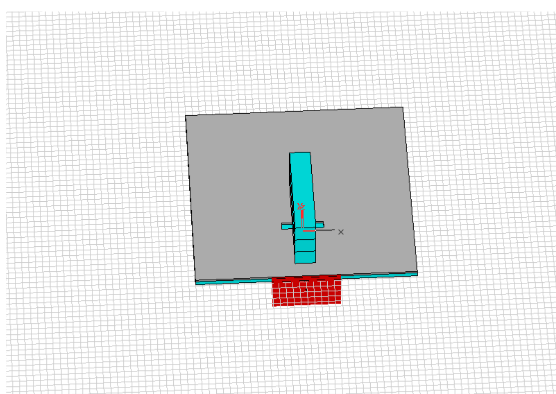

Figure 4: Three segment DRA.

3. OPTIMIZATION ALGORITHMS

As stated in previous paragraphs the antenna structure is optimized with two different methods.

3.1. Genetic Algorithm

To implement genetic algorithm binary coding was chosen and number of individuals in each population was selected to be 20.

Firstly the whole population was initialized randomly. Then fitness function, which is the DRA bandwidth, was evaluated for each individual in the population, and the population was sorted in the order of better fitness. Then 50% better individuals were selected as parents and the other 50% of parents were obtained with a 2-element tournament selection applied on whole population. Afterwards one-point cross-over and mutation algorithms with probabilities of 0.7 and 0.05, respectively, were applied on whole parents in order to produce new generations. After 9 generations, the GA converged to an acceptable answer. The plot of mean bandwidth of each generation is shown in Figure 5. This figure shows acceptable convergence of GA for the three-segment DRA problem. Parameters of the best individual in 15th generation are: $\varepsilon_{r1} = 18.7451$, $\varepsilon_{r2} = 10.5098$ and $\varepsilon_{r3} = 15.41176$. With these parameters the DRA is simulated with CST Microwave Studio and the resultant frequency response is shown in Figure 6. A dual resonance is observed in Figure 6, which is a technique commonly used in antennas to improve bandwidth, and the improved bandwidth is 1.085 GHz which is 16.5%.

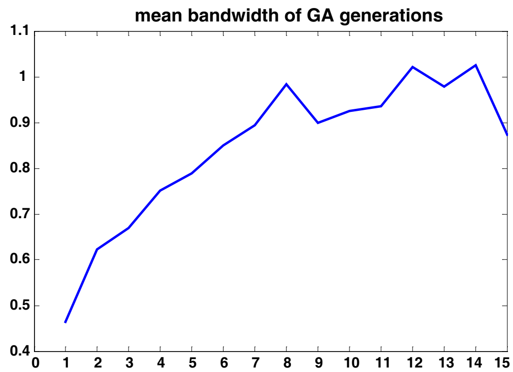

Figure 5: Mean bandwidth of generations for GA algorithm.

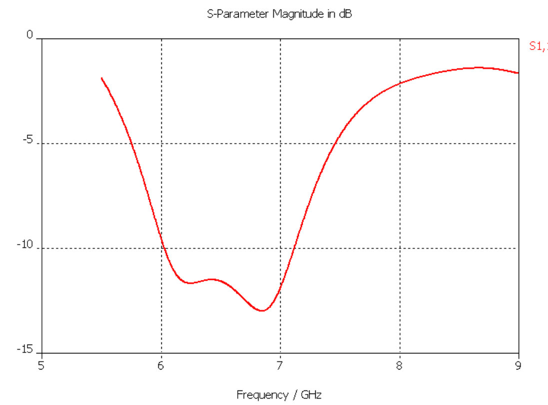

Figure 6: Three segment DRA optimized with GA.

3.2. An Optimization Algorithm Inspired from Weed Colonization

An optimization algorithm inspired from weed colonization has been proposed in [6]. For the antenna problem three dimensional search space which consists of three dielectric constants exists.

Firstly the population was initialized randomly. The number of individuals in initial population was selected to be 30. The initial population was sorted in order of better fitness, which is a higher bandwidth for the antenna problem. In this population the first 5 individuals produce 3 seeds, the second 5 individuals produce 2 seeds, the third 5 individuals produce 1 seed and the other individuals produce no seeds. The seeds are generated with a Gaussian distribution function with standard deviation (SD), σ and mean, μ. Where μ is the dielectric constant of parent plant. In each iteration, the standard deviation has been calculated with the following nonlinear equation [6]:

$$\sigma_{iter} = \frac{(iter_{\max} - iter)^n}{(iter_{msx})^n} (\sigma_{initial} - \sigma_{final}) + \sigma_{final} \tag{1}$$

Table 1: Setup of Weed Colonization algorithm.

Symbol	Quantity	Value
N_0	Number of initial population	30
$\text{it}_{\max}$	Maximum number of iterations	6
dim	Problem dimension	3
$\text{P}_{\max}$	Maximum number of plant population	30
$\text{s}_{\max}$	Maximum number of seeds	3
$\text{s}_{\min}$	Minimum number of seeds	0
n	Nonlinear modulation index	2
σ_{initial}	Initial value of standard deviation	3
σ_{final}	Final value of standard deviation	0.01
x_{ini}	Initial search area	$10 < x < 20$

where $iter_{\max}$ is the maximum number of iterations, σ_{iter} is the SD at the present time step and n is the nonlinear modulation index. For the antenna problem n is selected to be 2. Parameters of this algorithm are summarized in Table 1.

After 15 generations the algorithm converged to an acceptable solution. The final dielectric constants are $\varepsilon_{r1} = 18.64311$, $\varepsilon_{r2} = 11.52842$ and $\varepsilon_{r3} = 14.07712$ with the bandwidth of 1.092 GHz, which is 16.6%. The frequency response is shown in Figure 7. A dual resonance is obtained.

The plot of mean bandwidth in each population is shown in Figure 8. This figure describes a reasonable convergence. In this algorithm, modulation index and initial and final values of standard deviation was selected without any further investigations. With an optimum choice of these parameters, the performance of the algorithm can be improved.

The two methods discussed above are compared in Table 2 and the results of both optimization methods are summarized in Table 3.

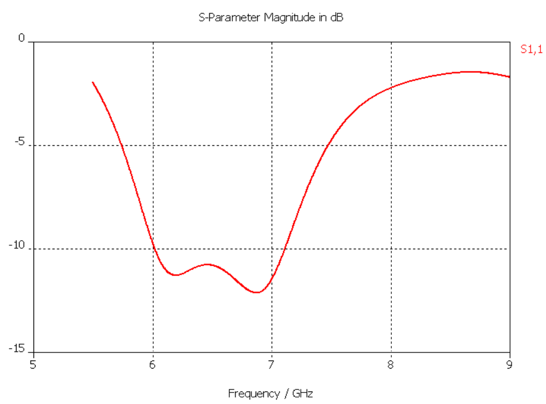

Figure 7: Three segment DRA optimized with weed colonization algorithm.

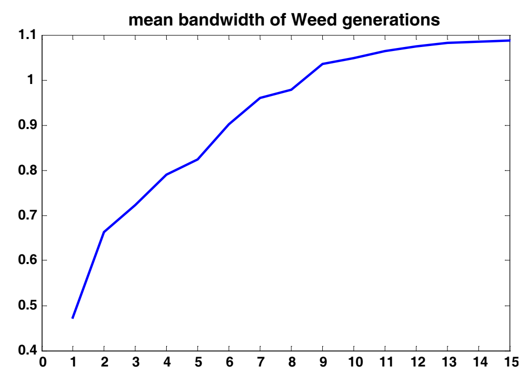

Figure 8: Mean bandwidth of generations for weed colonization algorithm.

Table 2: Comparison of GA and weed colonization.

	Number of individuals	**Number of iterations**	**Number of fitness evaluation**	**bandwidth**
GA	20	15	300	16.5%
Weed colonization	30	15	450	16.6%

Table 3: Results of GA and weed colonization algorithms.

	Bandwidth	**Number of resonances**
Single DRA	9%	1
GA optim.	16.5%	2
Weed colonization optim.	16.6%	2

4. CONCLUSION

A three segment rectangular dielectric resonator antenna with equal segments and different dielectric constants was investigated. Dielectric constant of each segment was optimized with two optimization algorithms, genetic algorithm and an optimization algorithm inspired from weed colonization. A dual resonance with improved bandwidth was obtained with both methods.

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