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GA Analysis of Switchability of Ferrite Rectangular Patch Antenna

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Abstract: *The application of Genetic Algorithm (GA) to analyze / optimize the switching behavior of magnetically biased switchable microstrip antenna, fabricated on ferrite substrate, is reported. In this work, GA has been applied to optimize extraordinary wave propagation constant (K_e) which is mainly responsible for the switchability of antenna. The wave propagation constant becomes zero or negative under proper magnetic biasing which resist the antenna as radiator without a mechanical maneuvering. The fitness functions for the GA program have been developed using mathematical formulation based on nonreciprocal approach of ferrite substrate under external magnetic field. The computed results are in good agreement with the results obtained experimentally and trained artificial neural network analysis. In this ANN training Radial Basis Function (RBF) networks is used. All programming related to genetic algorithm and ANN analysis performed by MatLab 7.1.*

Keywords: *Microstrip rectangular patch antenna, genetic algorithm, fitness function, ferrite substrate, magnetic biasing, ANN analysis training, etc.*

I. Introduction

In recent years there are lots of works exercised in the microwave field with the help of artificial intelligence tool. The substituted polycrystalline ferrite with DC magnetic biasing is offers number of novel magnetic and electrical characteristics including switchable and polarized radiations from a microstrip antenna. In such a case of antenna radiation, most of the power will be converted into mechanical waves and little radiates into air. Under such condition the antenna become switch off, in the sense of effectively absence as radiator. It is well known that the search technique genetic algorithm is a parallel, robust and probabilistic which can easily implemented without gradient calculation, compare with the conventional gradient base search procedure. Most important of all, the GA proposed also provides a mechanism for global search that is not easily trapped in local optima. The GA proposed here an adaptive mutation rate strategy. Although some work [1-6, 32-33] have been performed for microstrip antenna with GA approach for the patch antennas without magnetic biasing but analysis of switchability of antenna printed on ferrite substrate under magnetic biasing for rectangular patch antenna is new one. Present analysis also incorporate the dispersion effects due to magnetic field biasing in the form of effective propagation constant (Ke) which is not discussed in the referenced articles. Some similar referenced works [7-11] also have done mathematically or by conventional methods for optimization but this technique is rather precise, accurate and sensitive to optimize parameters of patch antenna as well as other type of antenna also. There are many optimization techniques frequently using for the same work. GA's were introduced by Holland [24] and were applied to many practical problems by Goldberg [25, 26]. It is well known that search technique, the genetic algorithm is a parallel, robust and probabilistic search technique that is simply and easily implemented without gradient calculation, compare with the conventional gradient base search procedure. Most important of all, the GA proposed also provides a mechanism for global search that is not easily trapped in local optima. The GA proposed here an adaptive mutation rate strategy.

II. Structure & Theory of Antenna:

Structure of microstrip rectangular patch antenna is depicted in fig. 1. Here 'L' and 'W' are the length and width of microstrip patch respectively. Patch is modeled on LiTiZn ferrite substrate of thickness 'h'. The dielectric constant and saturation magnetization ($4\pi M_s$) of substrate is 15 and 2200 Gauss respectively.

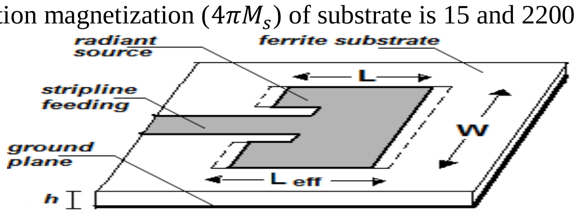

Figure 1: Schematic Diagram of Microstrip Rectangular Patch Antenna

It has been established that, for a biased ferrite slab, a normal incident plane wave may excite two types of waves (ordinary and extraordinary wave). In the case of normal incident magnetic field biasing ordinary wave is same as the plane wave in the dielectric slab. On the other hand, the extraordinary wave is a TE mode polarized parallel to the biasing direction with its phase propagation constant Ke [12-15].

$$K_e = \frac{w}{c}\sqrt{\epsilon_{eff} \times \mu_{eff}} \qquad (1)$$

$$K_d = \frac{w}{c}\sqrt{\epsilon_{eff}} \qquad (2)$$

$$\mu_{eff} = \frac{\mu^2 - k^2}{\mu} \qquad (3)$$

$$\mu = 1 + \frac{w_o w_m}{w_o^2 - w^2} \qquad (4)$$

$$k = \frac{w w_m}{w_o^2 - w^2} \qquad (5)$$

with

$$w_o = \gamma H_o \;\; and \;\; w_m = \gamma 4\pi M_s$$

Where H_o is the bias field, $4\pi M_s$ is the saturation magnetization, γ is the gyromagnetic ratio as $\gamma = 2.8\ MHz./Oe$.

III. Application of Genetic Algorithm to the Microstrip Antenna and Computed Results:

All the basic parameters, that is, ordinary wave propagation constant (Kd), Applied magnetic frequency (wo), Internal magnetic frequency (wm) and cutoff frequency (w) are coded into 5 bit scaled binary coding. Hence the total length of the chromosome was 20 bits. The Roulette wheel selection was used for GA population. The genetic algorithm was run for 50 generations.

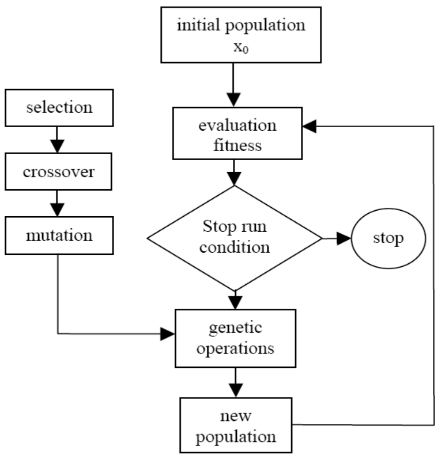

Figure 2: Flow Chart of Genetic Algorithm

The probability of crossover was varied from 0.7 to 0.85 and the probability of mutation was varied from 0.001 to 0.002. The fitness function expression of antenna used for optimization is:

$$\left(\frac{K_e}{K_d}\right)^2 = \frac{(w_o + w_m)^2 - w^2}{w_o(w_o + w_m) - w^2} \qquad (6)$$

The GA consists of five components. These are the random number generator, a fitness evaluation unit and genetic operators for reproduction, crossover and mutation operations. The flow chart, for optimization of microstrip antenna, using GA, is shown in fig. 2.

IV. Results and Calculations:

Obtained results (table 1 and fig. 3) show the variation of best, mean and expected values of extraordinary wave propagation constant (Ke) of antenna.

Table 1: Generation of fittest value through genetic algorithm

Pop. No.	K_d	w_o	w_m	w	K_e
1	12.0299	5.1611	7.0000	7.1377	0.5013
2	12.0299	5.1611	7.0000	7.1377	0.0513
3	12.0299	5.1611	7.0000	7.1377	0.5130
4	12.0299	5.1611	7.0313	7.1377	0.3513
5	12.0299	5.1611	7.0000	7.1377	0.3513
6	12.0299	5.1611	7.0000	7.1377	0.0883
7	12.0299	5.1611	7.0000	7.1377	0.2774
8	12.0299	5.1611	7.0000	7.1377	0.1142
9	12.0299	5.1611	7.0000	7.1377	0.3513
10	12.0299	5.1611	7.0000	7.1377	0.3513
11	12.2799	5.1611	7.0000	7.1377	0.2513
12	12.0299	5.1611	7.0000	7.1377	0.3513
13	12.0143	5.1611	7.0000	7.1377	0.3513
14	12.0299	5.1611	7.0000	7.1377	0.3513
15	12.0299	5.1611	7.0000	7.1377	0.1118
16	12.0299	5.1611	7.0000	7.1377	0.3513
17	12.0299	5.1611	7.0000	7.1220	0.2644
18	12.2799	5.1611	7.0000	7.0908	0.2647
19	12.0143	5.1611	7.0000	7.0629	0.2248
20	12.0299	5.1611	7.0002	7.0752	0.5130

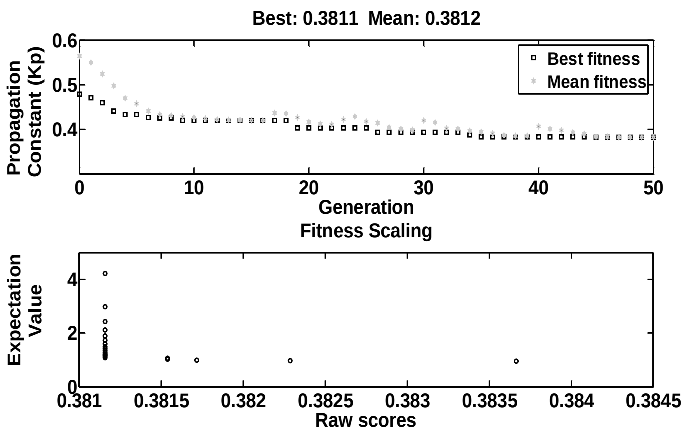

Fig. 3: Variation of Best, Mean and Expected value of Cutoff Frequency of Biased Rectangular Patch Antenna

The artificial neural network training program (based on RBF) also runs to optimize the cutoff frequency. In this RBF network, the spread value was chosen as 0.01, which gives the best accuracy. RBF is tested with 100 samples frequencies but trained only for particular 20 samples frequencies. For ANN calculation by RBF, differ-differ values arrange as target from literature and experimental data [6-9].

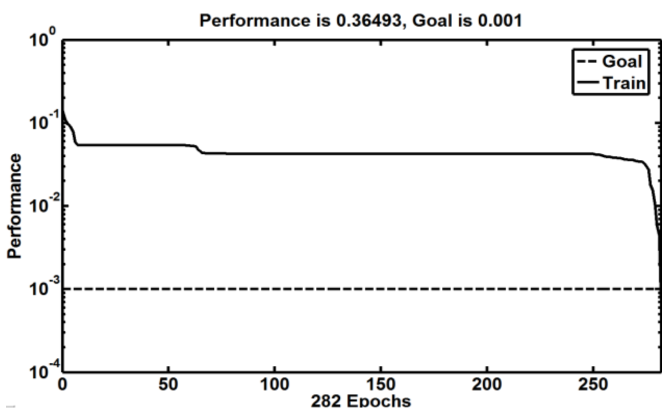

Fig. 4 Training Response of Artificial Neural Network program of Optimization of Cutoff Frequency at 253 Epochs

Calculated values of extra ordinary propagation constant of microstrip rectangular patch antenna with GA program are compared with neural analysis results (fig. 4 and table 2) and experimental dispersion curve (fig. 5) which are in good agreement. This curve is plotted at 1550 Oe for LiTiZn-ferrite slab at SSPL Timarpur Delhi, on which microstrip patch antenna has been designed [6-16].

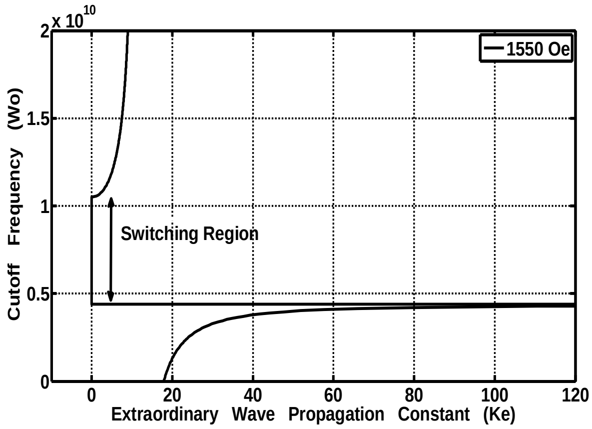

Fig.5. Dispersion curve (w Vs. Ke) for plane wave propagation perpendicular to biasing field

Table 2: Results of the ANN Analysis and comparison with target

Ordinary Wave prop. constant K_d	Applied mag. freq. w_o (GHz)	Internal mag. freq. w_m (GHz)	Cutoff freq. w- RBF (GHz)	Extraordinary wave propag. Constant K_e - target	Extraor-dinary wave propag. Constant K_e- RBF
12.50	4.2000	6.1575	6.4277	0.3221	0.3683
12.50	4.3400	5.9816	6.2392	0.9976	0.9901
11.50	4.3680	6.0168	6.1763	0.9991	0.9671
12.00	4.2896	6.0520	6.5973	0.5475	0.5247
12.50	4.2560	5.8408	5.2150	0.1858	0.1869
11.50	4.2280	6.2279	5.7993	0.4002	0.4133
11.00	4.3120	6.3335	5.8622	0.4010	0.3462
10.55	4.3120	6.2631	6.4277	0.3319	0.3362
10.00	4.2616	6.2983	6.7418	0.3187	0.3168
12.50	4.2308	5.8408	5.8308	0.6718	0.6711
12.50	4.2336	5.9464	5.7993	0.9566	0.9441
11.50	4.2364	6.1223	6.9303	0.3187	0.3222
12.50	4.2700	6.0871	7.0371	0.3190	0.3276
12.50	4.3848	6.3335	4.9825	0.5751	0.5780
11.55	4.3540	6.1927	4.5741	0.9944	0.9892
11.55	4.6068	6.3335	6.2831	0.7059	0.6977
12.55	4.0700	6.0871	7.0571	0.3193	0.3683
11.55	4.3048	6.3035	4.0825	0.5711	0.9901
10.55	4.3500	6.0927	6.5741	0.9949	0.9671
10.00	4.0068	6.3005	6.2031	0.7058	0.5247

Table 3: Results through various techniques and experimental works.

Techniques	wo (GHz)	wm (GHz)	w (GHz)	Kd	Ke
Genetic Algorithm	5.1999	7.0135	7.1265	7.0380	0.3019
Neural Analysis	4.6368	6.3335	6.2912	12.700	0.3333
Experimental Graph	4.2000	6.1600	5.7180	8.4939	0.2853

V. Conclusions

Rather than finding a single solution, optimization implies finding many solutions then selecting the best one. Optimization is an inherently slow, difficult procedure, but it is extremely useful when well done. The difficult problem of optimizing an electromagnetic design has only recently received extensive attention. The computed graphs and results show a good performance in comparison (table 3) of ANN analysis and also have good agreement with the results obtained experimentally. Some other types of problems related to the optimization of biased microstrip antennas can also be sort out by the genetic algorithm for the better performance.

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