Investigation of Switching Behavior of Microstrip Triangular Patch Antenna through Neural Network

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Abstract: *Switching behavior of microstrip equilateral triangular patch antenna printed on ferrite substrate is investigated using general artificial neural network (ANN) analysis. Using ferrite as substrate with applied external magnetic field perpendicularly, microstrip antennas offered switchable behavior due to negative permeability constant which causes extraordinary wave decaying or attenuating. In this communication the study of negative permeability and external magnetic field which are only responsible for this switching behavior is done with help of ANN. Both synthesis and analysis are mainly focused on the switchabilty of antenna. In this work Radial Basis Function (RBF) networks is used in ANN models. Synthesis is defined as the forward side and then analysis as the reverse side of the problem. Here the analysis is considered as a final stage of the design procedure, therefore the parameters of the analysis ANN network are determined by the data obtained reversing the input-output data of the synthesis network. In the RBF network, the spread value was chosen as 0.01, which gives the best accuracy. RBF is trained with 100 samples but tested only for particular cutoff 15 samples.*

Key Words: *Microstrip antennas, switchability, ferrite material, artificial neural networks, reverse modeling.*

I. Introduction

Ferrite as a substrate offered numbers of novel magnetic and electrical characteristics including switchability from microstrip antennas with DC magnetic biasing. On applying magnetic biasing ferrite substrate generate ordinary and extraordinary wave propagation due to nonreciprocal behavior of ferrite substrate. For particular external dc magnetic field, most of the power in the form of extraordinary wave resonance with lattice magnetic vibrations and converted into mechanical waves and little radiates into air. Under such condition the antenna becomes switch off, in the sense of effectively absence as radiator [1] – [3].

In the literature, artificial neural network (ANN) models have been built usually for the analysis of microstrip antennas in various forms such as rectangular, circular, and equilateral triangle patch antennas. In these works, the analysis problem can be defined as to obtain resonant frequency for a given dielectric material and geometric structure.

However, in the present work, for the synthesis we include desired cutoff frequency (w), applied magnetic frequency (w_o), and internal magnetic frequency (w_m) as input parameters to get the effective permeability constant (μ_{eff}) which is mainly responsible for the switchabilty of antenna. For analysis we include effective permeability constant (μ_{eff}), desired cutoff frequency (w), internal magnetic frequency (w_m) as input parameters to get the applied external magnetic field frequency (w_o), which is very desirable and should be very precise to control the switching condition of antenna system [4] – [6].

II. Microstrip Antenna

The equilateral triangular microstrip antennas are made of a triangular patch with side length ‘a’ over a ground plane with a substrate thickness h and dielectric constants ε_r as given in Fig.1. Dielectric constants are most desirable ones of the high dielectric constant for low profile, surface wave reduction etc [7].

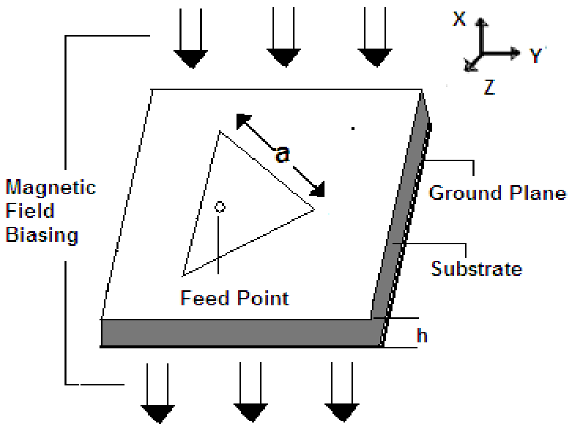

Fig.1 Equilateral triangular microstrip antenna

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 K_e [8]. It is observed from eqn (1) that when effective permeability constant μ_{eff} is negative for microwave propagation through a biased ferrite substrate the extraordinary wave is decaying even if the material is lossless.

$$\mu_{eff} = \frac{\mu^2 - k^2}{\mu} \quad (1)$$

where

$$\mu = 1 + \frac{w_o w_m}{w_o^2 - w^2}$$

$$k = \frac{w w_m}{w_o^2 - w^2}$$

$$w = 2\pi f \, , w_o = \gamma H_o \; and \; w_m = \gamma 4\pi M_s$$

where H_o is the bias field, $4\pi M_s$ is the saturation magnetization, γ is the gyromagnetic ratio as $\gamma = 2.8 \; MHz./Oe$. Polycrystalline LiTiMg ferrite has been synthesized by the solid state reaction technique (SSRT). Lithium ferrite is one of the most versatile magnetic materials. It is generally useful for microwave devices, memory-core, power-transformers in electronics, antennas, read/write heads for high speed digital tapes. This material is strategically important due to its high resistivity, low electric losses, high Curie temperature. The electrical and magnetic properties of LiTiMg ferrite substrate has been experimentally calculated in laboratory which is listed in table 1.

Table 1: The electrical and magnetic properties of LiTiMg ferrite substrate

LiTiMg Ferrite Characteristics	Values
Magnetic Saturation ($4\pi M_s$)	2200 Gauss
Curie Temperature (T_c)	325 K
Density (ρ)	4.21 grams/cm^3
Remanence	0.90
Coercivity	2.54 Oe.
Dielectric Constant (ε)	15
Resonance Line Width (ΔH)	290 Oersteds
Loss Tangent ($\tan\delta$)	< 0.0009

III. Neural Network Analysis

In this work Radial Basis Function (RBF) networks is used in ANN models. The input/output quantities to the ANN synthesis and ANN analysis are shown in fig. 2 and 3 respectively.

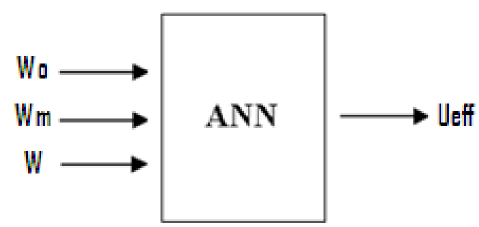

Fig. 2 Forward side ANN model.

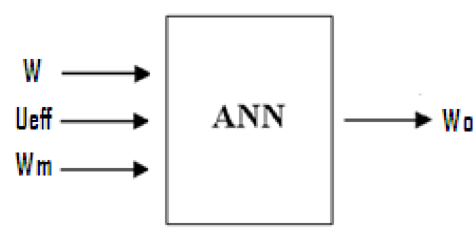

Fig. 3 Reverse side ANN model.

In the RBF network, the spread value was chosen as 0.01, which gives the best accuracy. RBF is trained with 100 samples but tested only for particular cutoff 15 samples. 3 inputs and 1 output were used for both the analysis ANN the synthesis ANN. The training and test data of the synthesis and analysis ANN were obtained from both experimental results given in previous works and a computer program using formulae given in previous section [9-11].

1.1 The Forward and Reverse Side of the Problem: In the analysis side of the problem, terminology similar to that in the synthesis mechanism is used, but the cutoff frequency of antenna is obtained from the output for a optimize extraordinary propagation constant, ordinary wave propagation constant (K_d), applied magnetic frequency (w_o), and internal magnetic frequency (w_m).

1.2 RBF Networks: Feed forward neural networks with a single hidden layer that use radial basis activation functions for hidden neurons are called radial basis function networks. RBF networks are applied for various microwave modeling purposes. The parameters c_{ij} and λ_{ij} are centers and standard deviations of radial basis activation functions. Commonly used radial basis activation functions are Gaussian and multi-quadratic. Given the inputs x, the total input to the ith hidden neuron Υ_i is given by

$$\gamma_i = \sqrt{\sum_{j=1}^{n}\left(\frac{x_j - c_{ij}}{\lambda_{ij}}\right)^2}\ , i = 1,2,3 \ldots \ldots N \qquad (2)$$

where N is the number of hidden neurons. The output value of the ith hidden neuron is $z_{ij} = \sigma(\gamma_i)$ where σ(γ) is a radial basis function. Finally, the outputs of the RBF network are computed from hidden neurons as:

$$y_k = \sum_{i=0}^{N} w_{ki} z_{ki} \qquad (3)$$

where w_{ki} is the weight of the link between the ith neuron of the hidden layer and the kth neuron of the output layer. Training parameters w of the RBF network include w_{k0}, w_{ki}, c_{ij}, λ_{ij}, k = 1 ,2, . . . m, i= 1 ,2, ...N, j = 1,2, . . . n.

1.3 Structures of the Neural Networks: In the RBF network, the spread value was chosen as 0.01, which gives the best accuracy. RBF is trained with 100 samples frequencies but tested only for particular cutoff 15 samples frequencies. 4 inputs and 1 output were used for both the analysis ANN the synthesis ANN. The training and test data of the synthesis and analysis ANN were obtained from both experimental results given in previous works and a computer program using formulae given in previous section.

IV. PERFORMANCE AND RESULT

As can be seen from Tables 2 and 3, in synthesis and analysis, RBF network giving the best approximation to the target values. Figures 4 and 5 depict the performance of both synthesis and analysis respectively when Goal is 0.001.

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

w_o(GHz)	w_m(GHz)	w(GHz)	μ_{eff} - target	μ_{eff} - RBF
4.2000	6.1575	6.4277	-3.98449	-3.98378
4.3400	5.9816	6.2392	-3.47929	-3.47876
4.3680	6.0168	6.1764	-3.41234	-3.41117
4.2896	6.0520	6.5973	-3.84902	-3.84986
4.2560	5.8408	5.2150	-2.88108	-2.88050
4.2280	6.2279	5.7994	-3.53699	-3.53626
4.3120	6.3335	5.8622	-3.49104	-3.48812
4.3120	6.2631	6.4277	-3.83087	-3.84007
4.2616	6.2983	6.7419	-4.17094	-4.16548
4.2308	5.8408	5.8308	-3.32101	-3.32107
4.2336	5.9464	5.7994	-3.35875	-3.36015

4.2364	6.1223	6.9304	-4.22992	-4.22944
4.2700	6.0871	7.0372	-4.20468	-4.20637
4.3848	6.3335	4.9826	-2.78592	-2.78874
4.3540	6.1927	4.5742	-2.49648	-2.49667
4.6368	6.3335	6.2832	-3.22205	-3.22104

Table 3: Results of the analysis ANN and comparison with target

w (GHz)	w_m(GHz)	μ_{eff}	w_o target (GHz)	w_o RBF (GHz)
4.2000	6.1575	-3.98378	4.2000	4.2470
4.3400	5.9816	-3.47876	4.3400	4.3320
4.3680	6.0168	-3.41117	4.3680	4.3752
4.2896	6.0520	-3.84986	4.2896	4.2916
4.2560	5.8408	-2.88050	4.2560	4.2613
4.2280	6.2279	-3.53626	4.2280	4.2584
4.3120	6.3335	-3.48812	4.3120	4.3251
4.3120	6.2631	-3.84007	4.3120	4.3284
4.2616	6.2983	-4.16548	4.2616	4.2505
4.2308	5.8408	-3.32107	4.2308	4.2595
4.2336	5.9464	-3.36015	4.2336	4.2597
4.2364	6.1223	-4.22944	4.2364	4.2471
4.2700	6.0871	-4.20637	4.2700	4.2744
4.3848	6.3335	-2.78874	4.3848	4.3890
4.3540	6.1927	-2.49667	4.3540	4.2997
4.6368	6.3335	-3.22104	4.6368	4.6336

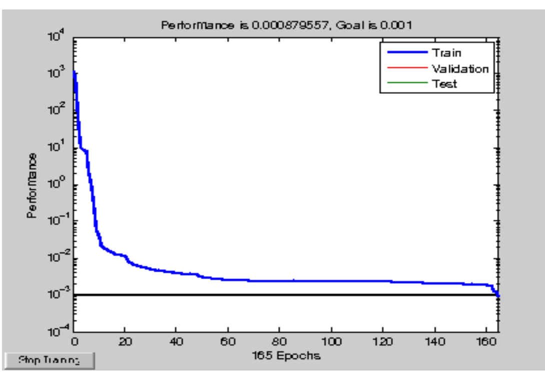

Fig. 5 Training Response at 165 Epochs

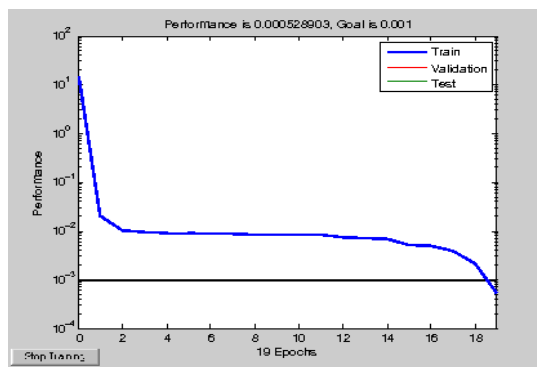

Fig. 6 Training Response at 19 Epochs

The performance, of synthesis ANN is 0.000879557 at 165 epochs and of analysis ANN is 0.0005289035 at 19 epochs. The results of the synthesis and analysis ANN for ferrite material can be compare with dispersion graph (fig. 4) obtained for ferrite material. From the graph $H_o\ (w_o = \gamma H_o)$ and table (w_o) we can conclude and compare the optimal accuracy for the synthesized and optimized cutoff external magnetic field $H_o\ (w_o = \gamma H_o)$.

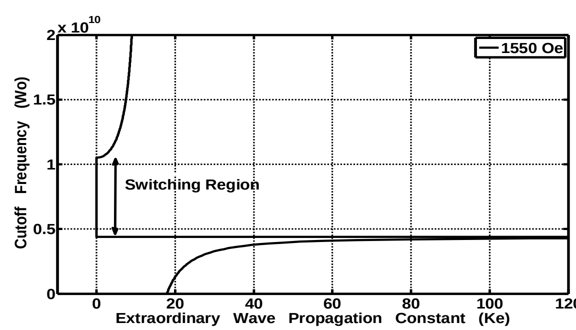

Fig.6. Dispersion curve (f Vs. K) for plane wave propagation perpendicular to biasing field

We have also plotted dispersion curve at 1550 Oe for LiTiMg-ferrite slab as shown in figure 6 at SSPL Timarpur, Delhi, on which circular microstrip patch antenna has been designed. Switchability and tunability regions are clearly shown in the curve. It is pertinent to mention that switchability region is of great concern for the present analysis.

V. CONCLUSION

Investigation of switching behavior of microstrip equilateral triangular patch antenna printed on ferrite substrate is done using general artificial neural network (ANN) analysis. The neural network is employed as a tool to optimize the cutoff external magnetic field $H_o\ (w_o = \gamma H_o)$ of antenna on which effective permeability μ_{eff} become negative and the antenna switch off the radiation. In this design procedure, synthesis is defined as the forward side and then analysis as the reverse side of the problem. Here the analysis is considered as a final stage of the design procedure, therefore the parameters of the analysis ANN network are determined by the data obtained reversing the input-output data of the synthesis network. Thus, the effective permeability resulted from the synthesis ANN is examined against the target in the analysis ANN network.

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