Artificial Neural Network for the Analysis and Design of a Frequency Selective Surface with SLITS

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Abstract- **This paper presents on designing and analysis of frequency selected surface with slit loaded on it. An artificial neural network has been used to train a network to establish the relation between the dimensions of slit with patches of FSS and the lower cut off, upper cut off, resonant frequency etc. The results obtained from artificial neural network have been compared with the result obtained from the ANSOFT software based on method of momentum. The two results are in good agreement.**

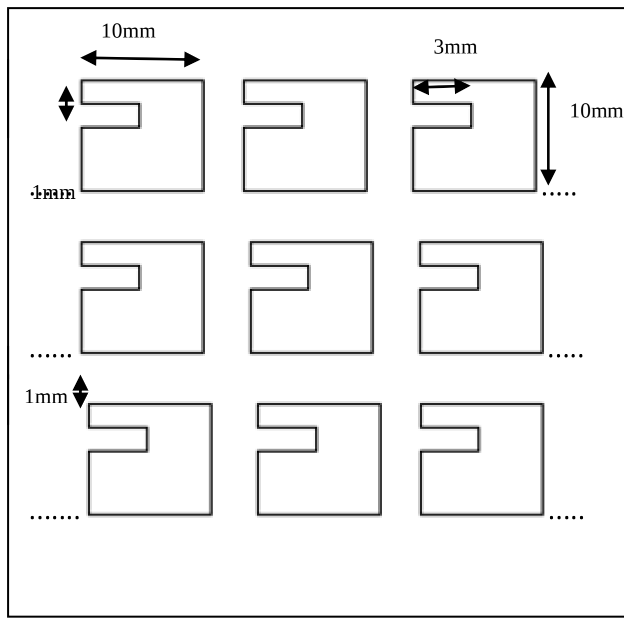
Keywords: **Frequency Selective surface, artificial neural network slit, Back Propagation, resonant frequency.**

I. INTRODUCTION

Filters are one of the fundamental devices in electric circuits. In microwave engineering, the counterpart of a filter is a frequency selective surface (FSS). FSSs have often been considered for the reflector-antenna system [1– 4] in multi frequency operations. The FSS can be modelled as either an infinite or finite array of identical unit cells, whose shape can typically be a dipole, square, ring, and so forth [5–7]. They exhibit total reflection (patches) or transmission (apertures) in the neighbourhood of the element resonance. The FSS characteristics depend upon the element shape and dimensions, as well as upon the thickness and permittivity of the dielectric layers. This paper deals with the theoretical investigations on the frequency-selective property of a square patch with same periodicity with different dimensions of slit.

II. DESIGN OF FSS

The design of the slit loaded FSS using a dipole type patch element is described in this section. The dimensions of each element of the FSS are chosen to be 10 mm X 10 mm and width of slit varies from 1mm to 8mm and with periodicity value 12mm. The elements are spaced horizontally one by one in consecutive rows and these rows are repeated to form the 2D array.



III. SIMULATION OF FSS

The designing parameters can be determined by using different commercial software which uses computer based intensive numerical methods such as, Finite Element Method (FEM), Method of Moment (MoM), Finite Difference Time Domain (FDTD) method etc. The simulation of slit loaded FSS was performed in ansoft software based on method of moment in frequency range of 1 GHz to 25 GHz with 0.01 GHz frequency interval. Figure -2 shows relation between The lower cut off, resonant and uppercut off frequency with one specific slit width.

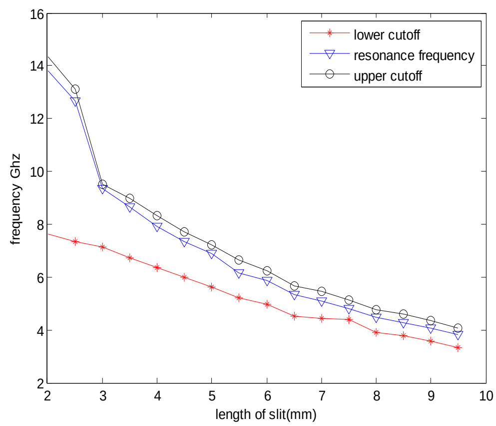


Fig.2 Frequency Vs Slit Length

IV. BASIC THEORY OF BACK PROPAGATION

Multilayer neural networks (MLN) [8] consist of one input layer, one output layer, and one or more hidden layers. Each layer contains a set of neurons and is fully connected with an adjacent layer by a weight. Network outputs and target values are minimized by adjusting weight. This process is called supervised learning. The MLN Learning consists of two phases. First phase is basically the feed-forward stage and second phase is back propagation phase. First phase calculates the network outputs in response to the corresponding inputs. In this phase the connection weights are fixed. The input signals pass on through the network's layer during the first phase. Each neuron performs a transfer function which is differentiable and no decreasing. The second phase modifies the connection weights. In this phase error signal is calculated by comparing the network output with the target values. Then, the error signal propagates backward in the network layers with adjusted weight. For adjusting the weight, the most popularly used error function is the mean squared error (MSE) that is given by:

$$MSE = \frac{1}{n}\sum_{k=1}^{n}\sum_{i=1}^{m}(y_{ki} - t_{ki})^2$$

Where the Notation are :

m output vector dimension

n number of training samples

y_{ki} Network output of i-th neuron for Pattern k

t_{ki} Target value of *i*-th component for Pattern k

BP applies a gradient descent procedure to minimize the error function E as follows,

$$W_{ij} = -\eta \frac{\partial MSE}{\partial W_{ij}}$$

Where the notations are

W_{ij} Connection weight between neurons i and j

η learning rate

Two phases perform alternatively till the output can be approximated with the smallest error. Sigmoid activation function (SAF) is most useful activation function(AF) in BP learning, although it creates few difficulties in the training. The weight update is negligible at near the target. The SAF is of the form

$$Y = \frac{1}{1 + e^{-x}}$$

The derivatives of SAF is Y'=Y(1-Y) and When Y≅ 0 or 1 then Y'(x) ≅ 0. This means that there is no update of weights if this condition happens. This is a major problem while training with standard BP algorithm with SAF. To overcome this problem when Y=1 comes at output side replaced by 0.95 and when Y=0, it will be Y=0.05.

V. RESULT

A. *Artificial Neural Networks for the Lower Cut Off Frequency (LCF), Upper Cut Off Frequency (UCF) and Resonant Frequency (RF) Calculation*

In this work, the BP algorithm is used for training MLN. This MLN consists of three layers: an input layer, an output layer and one hidden layer, as shown in fig.3.

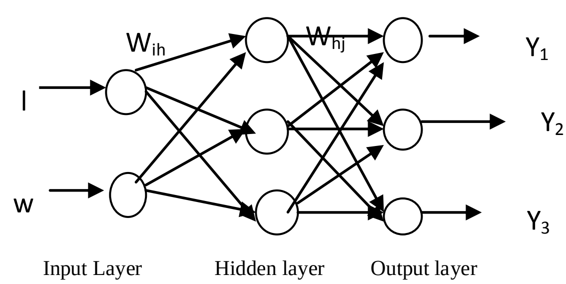


Fig.3 Proposed Neural Network Model

Hidden layer has three neurons. It is well known that the FSS characteristics depend upon the element's shape and dimensions, as well as upon the thickness and permittivity of the dielectric layers. Here slit loaded FSS is used. Neural network inputs are slit length (l) and slit width (w) of the square patch and outputs are LCF(Y_1), RF(Y_2) and UCF(Y_3).For generating the training set ansoft designer software is used. Ansoft designer software uses the MoM method for simulation study. The length of the slit is varied from 2mm to 9.5mm with fixed width of slit. For all the cases the dielectric constant (ε = 4.4) and plane wave excitation are used. Total design of slit loaded FSS is shown in fig-1.

TABLE I

LCF CALCULATION FROM NN AND ANSOFT

Slit Length	Slit width	LCF from Ansoft	LCF from NN
9.5	2	3.17	3.11
9	4	3.11	3.10

TABLE II

RF CALCULATION FROM NN AND ANSOFT

Slit Length	Slit width	RF from Ansoft	RF from NN
9.5	2	3.61	3.13
9	4	3.65	3.44

TABLE III

UCF CALCULATION FROM NN AND ANSOFT

Slit Length	Slit width	UCF from Ansoft	UCF from NN
9.5	2	3.93	3.82
9	4	4.08	4.07

B. *Artificial Neural Networks for the Slit Width Calculation*

Here we study the reverse case of the neural network. We also get satisfactory result. Lower cut off frequency, Resonance frequency and upper cut off frequency are taken as a input and slit width is output of the network.

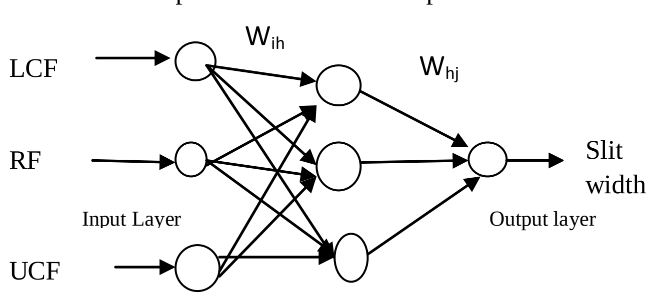


Fig.4 Proposed Neural Network Model for Reverse Calculation

TABLE IV

SLIT WIDTH CALCULATION FROM NN AND ANSOFT

LCF	RF	UCF	Slit width from Ansoft	Slit width from NN
6.1	7.92	8.34	3	2.76
3.11	3.65	4.08	4	3.75

VI. CONCLUSION

For determining the LCF, RF and UCF from different dimensions of slit loaded FSS the network has been trained for the slit length 2 to 9.5 mm and width 1mm to 8mm. With this dimensions, required width may be also determined if LCF, RF and UCF are given as input. After training the output for both the cases compared with the results obtained by Ansoft software based on method of moment. In both cases results are comparatively same. The method may be further extended in case of different dimension with slot loaded FSS.

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