Empirical Study of ANN Based Prediction of Resonant Frequency and Bandwidth of Circular Slot Loaded Polygon FSS

M. Panda, Md Rabiul Hossain, Md Ehtesham Hussain, Samriddha Samanta, Rubaba Rahman
Electrical Engineering Department
CAMELLIA SCHOOL OF ENGINEERING & TECHNOLOGY
Barasat, Kazipara, Kol-700124

Abstract— An unit cell of frequency selective surface is designed in order to control the transmission characteristic and reflection characteristic of electromagnetic wave for different application like Biomedical application, Waveguide Modulator, Ultra wide Band application, etc**.** Here a new FSS is proposed that consists of Polygon structure with circular slot loaded centrally. Polygon structure is used in order to increase the Bandwidth. This manuscript presents a comparative study of simulation oriented from ANSOFT based result and the result obtained from the Artificial Neural Network (ANN)**.** To obtain good result proper training of neural network is required. Back Propagation Algorithm based on Gradient Decent (GD) method is used here for training of ANN. The result is in good agreement within the accepted error value.

Index Terms— FSS, ANN, Bandwidth, Resonant frequency , Back propagation, slot, ANSOFT

1 INTRODUCTION

ONE of the fundamental components of electrical circuit is filter. For communication engineering, counter part of filter circuit is Frequency Selective Surface (FSS) especially in microwave engineering. Depending upon their physical construction, material and geometry, they are divided into Low Pass (LP), High Pass (HP), Band Pass (BP) and Band Stop (BS) filters. Structurally it is any thin, respective surface [such as the screen on a microwave oven] designed to reflect, transmit or absorb electromagnetic field based on frequency "[1],[2],[3],[4]". A detailed study on FSS is done in "[5]". For increasing the Bandwidth of FSS in case of wide band application it consists of typical layers as described in "[6]". FSS characteristic depends on its geometry structure, periodicity, and width of the dielectric. This paper deals with the theoretical study of FSS property of Polygon with centrally circular slot loaded patch with fixed dimension and varying periodicity.

2 PROPOSED STRUCTURE OF FSS

The geometry of the single layer FSS unit cell structure shown in Fig.-1 which consists of polygon with centrally circular slot loaded. The dimension of unit cell structure is clearly mentioned in the said figure. For x, y direction periodicity the length is 11mm & 16mm respectively. The unit cells are placed in repeated structure in 2D Array form.

3 SIMULATION RESULT USING ANSOFT

Computer based extensive numerical method is used for designing the parameter of FSS by using different commercial software. Numerical methods are Finite Element Method (FEM), Method of Moment (MOM), Finite Difference Time Domain (FDTD) method etc. For extensive simulation ANSOFT simulation tool is adopted here. It is based on MOM and it operates in frequency range of 1 GHz to 25 GHz with 0.01 GHz frequency interval. Fig.-2 respectively shows the Band Width (BW) variation (fig2-a) and Resonant Frequency (RF) (Fig2-b) for different y direction periodicity with fixed x-direction periodicity in the proposed structure.

4 ARTIFICIAL NEURAL NETWORK (ANN)

Multilayer conception is used for designing Artificial Neural Network (ANN). Multilayer Neural Network (MNN) "[7],[8],[9]" contains one input layer, one output layer and one or more hidden layers. In each layer a set of neuron is present and every adjacent layer is connected by weight. Two phases are present for the training of the neural network. First phase is intended for feed forward operation and second phase is for Back Propagation. First phase calculates the output in response to corresponding input and fixed weight configuration. In the second phase weight is modified and error signal is calculated with comparing the calculated output and desired output value. The error signal propagates backward in the network by adjacent weight. Most popular Error function is Mean Square Error (MSE) function. MSE is defined by (eq-1)

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

Where notation are

m= output vector dimension
n= No. of training sample
y_{ki}= network output of the ith neuron for pattern k.
t_{ki}= target value of ith component for pattern k.
Back propagation (BP) uses gradient decent method to minimize the error function as follows (eq-2)

$$W_{ij} = -\eta \frac{\delta MSE}{\delta W_{ij}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

η= learning rate

w_{IJ} = connecting weight between neurons i & j

Sigmoid Activation function (SAF) is used for the activation function of Back Propagation algorithm. SAF is in the form

$$Y = \frac{1}{1+e^{-\lambda}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Derivative SAF is $Y' = Y(1-Y)$, $Y \approx 0$ or 1, the $Y' \approx 0$. It means no weight can be updated when y value arises at that plane. This problem is controlled when Y=1 and then it is replaced by Y=0.95, Y=0 and by Y=0.05.

5 Proposed Artificial ANN for Prediction of BW and RF

BP is best on MLN perception. Four layer architecture is used here. One input layer, one output layer and two hidden layer is used for the proposed ANN model. The said model is shown in Fig.-3. For input layer of ANN model the periodicity in x-direction and y-direction are taken. The output of ANN model is the bandwidth and resonating frequency "[10],[11]". Total 600 data is generated from the MOM based ANSOFT tool for training the proposed ANN model. Minimum 5 set of data are tabulated in the Table 1, 2 & 3.

TABLE 1: Input data sequence for ANN

Sl no.	Periodicity in x-direction (mm)	Periodicity in y-direction (mm)
1	11	18.5
2	11.5	17
3	12.5	17
4	13.5	18
5	14.5	19.5

TABLE 2: Output data sequence for BW

Sl No.	ANSOFT simulation B.W (GHz)	ANN B.W(GHz)
1	4.63	4.75
2	5.49	5.38
3	5.28	5.4
4	4.38	4.28
5	3.53	3.66

TABLE 3: Output data sequence for RF

Sl No.	ANSOFT Simulation RF (GHz)	ANN RF (GHz)
1	10.35	10.43
2	10.17	10.27
3	9.98	10.1
4	9.88	9.76
5	9.62	9.57

Table-1 shows the input sequence of data and table 2 and 3 shows the corresponding output sequence of proposed ANN model. For example periodicity in x-direction is 11 mm and periodicity in y-direction is 18.5 mm as shown in Table 1. The same are the parameters for calculating MOM-based ANSOFT and ANN model for BW result of the value 4.63GHz and 4.75GHz for Sl. no. 1 in Table 2 specifically. Subsequently the same technique was followed for RF calculation in Table 3.

6. Conclusion

All results are quite satisfactory. Results obtained by proposed ANN structure are compared with ANSOFT simulation tool results. In both cases result are quite identical and error value is in acceptance range. For further future study authors intend to take new model with solid or slit loaded structure with different dimensions.

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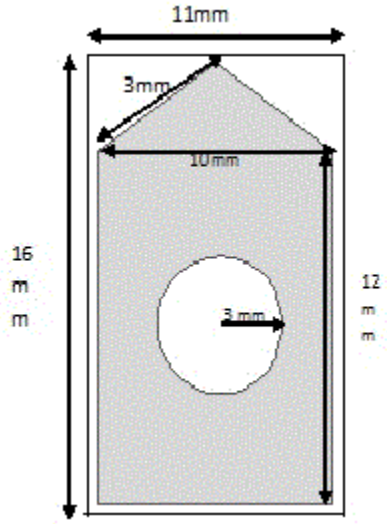
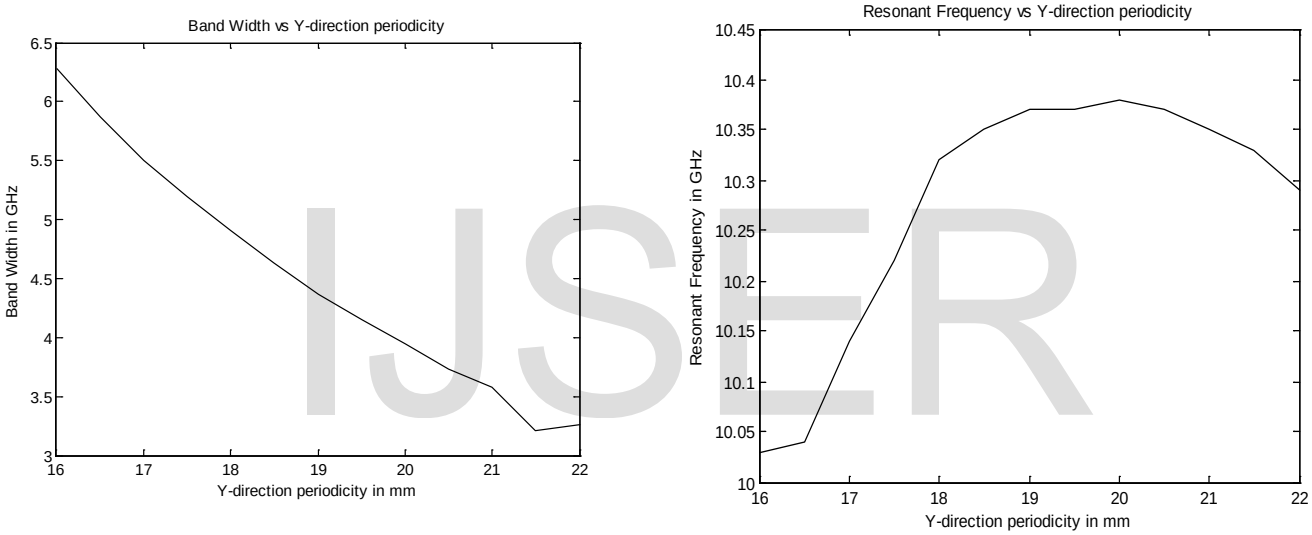


Fig1: Proposed Unit Cell diagram for one specific dimension



(a) (b)

Fig2: Variation of band width and resonant frequency in Y direction periodicity for one fixed X direction periodicity

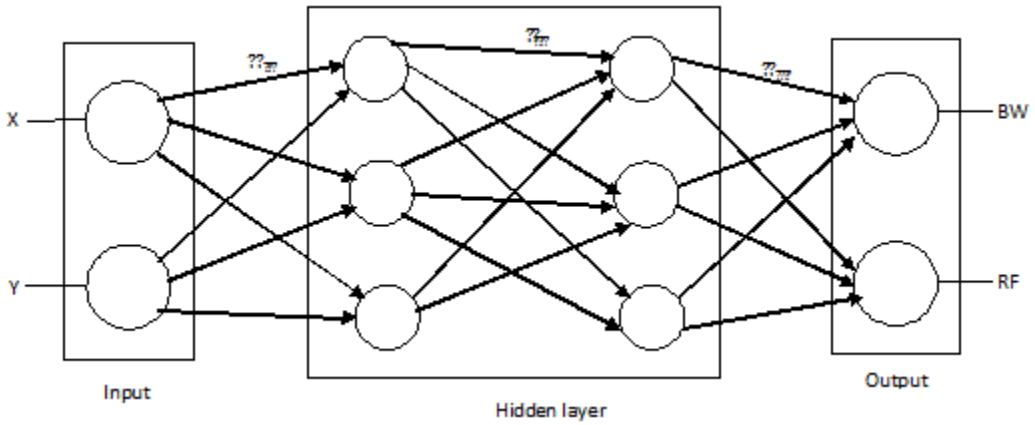


Fig3: Propose ANN model for estimation of Band Width and Resonant frequency