Effect of Normalized Scale on Design of Rectangular Microstrip Antenna by using FFBP

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Abstract— **Nonlinear neural optimization networks are used for the designing of MSA. The paper presents NN model for computing resonant frequency of RMSA with normalized scale. NN model with normalised scale computes very fast. The normalized data has been applied to NN to get more efficient NN model. This model is compared with the NN model without normalized scale which gives very accurate result.**

Keywords- NN (Neural Network), ANN (Artificial Neural Network), FFBP (Feed Forward Back Propogation), RMSA (Rectangular Microstrip Antenna), EM. (Electromagnetic).

I. Introduction

Microstrip Antenna has wide range of applications from communication systems to biomedical systems. MSA consists of a metallic radiating patch on one side of thin dielectric substrate and the other side is ground plane. The resonant frequency of MSA needs to be determined accurately as these MSAs have narrow BW and can operate effectively in the vicinity of resonant frequency [1]. Various methods are available to calculate patch dimensions and resonant frequencies of different geometries of MSA. Mainly two approaches are available for calculation, namely: analytical and numerical methods. The main objective of the present paper is to develop a simple NN model using FFBP algorithm to calculate resonant frequency of RMSA with normalized scale. Once the model is developed, it can be used in place of computationally intensive physics or EM models [2].

II. Neural network development

Neural network technology is an emerging technology in the microwave area for microwave modeling, simulation, optimization and design [5].

Multilayer Perceptron (MLP), Radial Basis Function (RBF), Knowledge Based Neural Network (KBNN), Wavelet network & Recurrent Neural Network (RNN) are commonly used NN structures. Selection of NN structure and training algorithm are two major issues in developing NN model. The most important and time consuming step in model development is NN training. The microwave behavior is learned through this process. The NN model uses the measured or simulated data for training. Training is an optimization process in the weight space and is often done using optimization –based training algorithm such as backpropogation (BP).

Training algorithms are an internal part of neural n/w model development. Any alternative structure may still fail to give a better model, unless trained by a suitable training algorithm [3]. The proper training algorithm manages to reduce the training time by achieving better accuracy.

A distinct advantage of neural computation is that, after proper training, it completely bypasses the repeated use of complex iterative processes for new design presented to it.

III. Neural Network model

i) For design of RMSA a FFBP algorithm is used which consists of three layers: input, hidden & output layer.
ii) The input and output must be selected which best suits the requirement of the job.
iii) Sufficient amount of data must be generated for training either by measurement, simulation or calculation using equations.
iv) Execution of algorithm starts the training process of NN model.
v) After executing the algorithm the output is compared with the required target. If the outcome of algorithm gives better result then the NN model is tested with new data to calculate the accuracy of the NN model
vi) The selection of number of neurons used for hidden layers and value of moment count (mc) in algorithm plays very important role in providing higher accuracy for the developed NN model.
vii) If the accuracy is not achieved then by changing the number of neurons for hidden layers and or changing number of epochs, appropriate NN model can be developed as explained in fig.4.
viii) If NN model outcome shows over learning/ under learning of target data then the neurons are deleted, or else they are added. In this way by trial and error method the accurate NN model can be developed.

IV. Design problem for MSA

In the paper [6], the analysis design by FFBP has been presented by considering the ANN model with inputs as width (W), length (L), height (h) and permittivity constant (εr) and output parameter as resonant frequency (fr).

This model was developed by considering scale without normalization. It gives accuracy up to 99.78% for training and 99.858% for testing. The NN Model has 4 inputs and 1 output as given in fig 1.

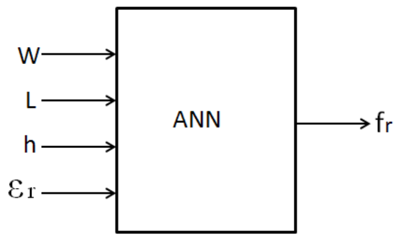

Fig.1: Four input & one output ANN Model

The rectangular patch is the most widely used configuration. It can be analyzed using transmission line or cavity based model. For NN model, the data has been generated by using transmission line model.

The resonant frequency of RMSA is given by equation (1)

$$fmn = \frac{c}{2\sqrt{\varepsilon_{eff}}}\left[\left(\frac{m}{L_e}\right)^2 + \left(\frac{n}{W_e}\right)^2\right]^{1/2} \qquad \ldots\ldots (1)$$

where ε_{eff}, Le & We are the effective permittivity constant, effective length and effective width, respectively.

For all MSA h<<L & h<<W, the mode with lowest frequency (dominant mode) is TM010 whose resonant frequency is given by equation (2).

$$f_{10} = \frac{c}{2Leff\sqrt{\varepsilon eff}} \qquad \ldots\ldots.. (2)$$

$$c = 3 * 10^8 \ m/s$$

A practical approximate relation for normalized extension of the length is given by ΔL/h and can be written as

$$\Delta L = 0.412\, h\, \frac{(\varepsilon_{eff}+0.3)}{(\varepsilon_{eff}-0.258)}\, \frac{\left(\frac{W}{h}+0.264\right)}{\left(\frac{W}{h}+0.8\right)} \qquad \ldots\ldots. (3)$$

As the length of the patch has been extended by ΔL on each side, the effective length of the patch is given by

$$L_e = L + 2\Delta L \qquad \ldots\ldots\ldots. (4)$$

And the effective permittivity constant is given by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\,\frac{h}{W}\right]^{-1/2} \qquad \ldots\ldots\ldots (5)$$

By using these equations 55 sets of data have been generated, out of which 40 sets of data have been used for training and 15 fresh sets of data have been used to test the trained model.

V. Proposed Technique - Normalised Scaled ANN Model

In this work, instead of four inputs as explained in [6], three inputs have been considered. For this design, normalized scale has been used which changes 4 inputs into 3 inputs. Here width W, length L, and height h, is divided by permittivity constant εr to get three inputs and the output remains the same as resonant frequency fr. The ANN model is as shown in fig. 2.

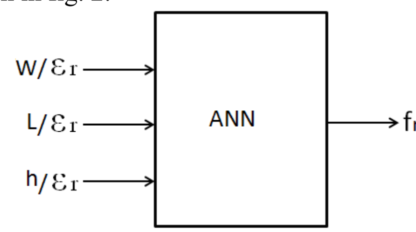

Fig.2. Three input & one output ANN Model
(By using normalized scale)

For ANN model with normalized scale the same algorithm has been used to get the better accuracy. For training, the flow chart given in fig 3 has been used and by changing the values of S1 & S3 (hidden layer neurons) the 99.98 % accuracy has been achieved. Immediately after training, the ANN model was tested for 15 fresh data and this model attained 99.017 % of average of accuracy in testing results.

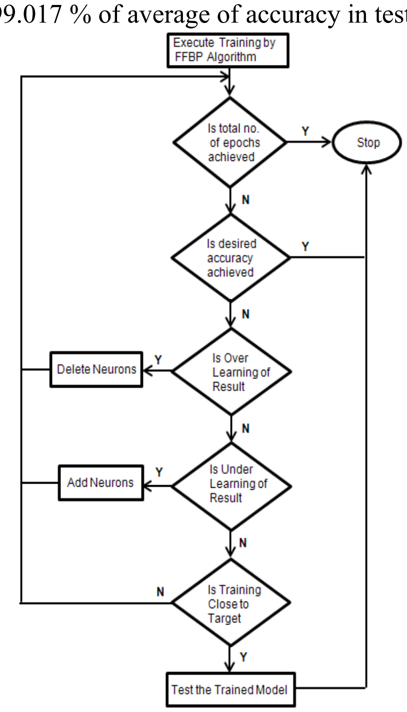

Fig3: flow chart for attaining higher accuracy through developed NN model

For this design five models have been developed by considering different values of S1 & S3. All the five models have been trained and tested to get maximum accuracy as shown in table 3.

Table1: Comparison of Performance of NN models based on the scales used

ANN Model	Details of Algorithm	Average of Accuracy % In Training (40 samples)	Average of Accuracy % in Testing (15 Samples)
Without Normalized scale- Input: W,L,h,ε_r Output: fr	S1=30,S2=40,S3=80 Epochs=1,32,500 Goal=0 mc=0.8 TrainingTime=28 min.	99.782%	99.858%
With Normalized Scale- Input: W/ε_r , L/ε_r , h/ε_r Output: fr	S1=60,S2=40,S3=60 Epochs=35000 Goal=0 mc=0.99 TrainingTime= 11 min.	99.98%	99.017%

Practically, analysis with the normalized scale helps to reduce the number of epochs in analysis model of ANN if FFBP algorithm is used. The comparative analysis of results of different scales used is shown in table1. The normalized model is finalized after getting the maximum accuracy by changing the neurons of three hidden layers as shown in table2.

Table2: Analysis of Five different models for normalized scaled ANN Model.

NN Model	Details of Algorithm	Average of Accuracy %
Model 1	S1=80,S2=40,S3=80 Epochs=35000 Goal=0 mom=0.8	99.78%
Model 2	S1=60,S2=40,S3=60 Epochs=35000 Goal=0 mom=0.9	99.90%
Model 3	S1=60,S2=40,S3=60 Epochs=35000 Goal=0 mom=0.89	99.91%
Model 4	S1=60,S2=40,S3=60 Epochs=35000 Goal=0 mom=0.8	99.93%
Model 5	S1=60,S2=40,S3=60 Epochs=35000 Goal=0 mom=0.99	**99.98%**

CONCLUSION

The ANN model with normalized scale presented in this paper allows the designer to obtain accurate results. A brief overview of the NN based nonlinear device modeling has been presented with comparative study of normalized scale and scale without normalization. The major advantage of normalized scaled ANN modelisation is that, after proper training, NN model completely bypasses the repeated use of complex iterative processes resulting as a fast output approacher with high accuracy.

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Table3: Results of Five different ANN models by using normalized scale.

Models	fr	Model-1	Model-2	Model-3	Model-4	Model-5
Sr. No.	Target	Error-1	Error-2	Error-3	Error-4	Error-5
1	17.619	0.0049	-0.0007	0.0037	0.0019	-1.00E-04
2	8.809	-0.0043	0.0013	0.0053	0	0
3	4.541	-0.005	0	0.0051	0.0011	0
4	3.611	-0.005	0.0007	0.0036	0.0011	0.0001
5	3.019	-0.005	-0.0008	0.0035	0.0012	0.0002
6	2.597	-0.0046	0.0004	0.003	0.0002	-0.0001
7	2.282	-0.004	0.0006	0.0035	0.0014	0.0001
8	10.572	-0.0564	-0.0101	-0.106	0.0018	-0.0069
9	9.057	-0.0269	0.0092	-0.087	0.0078	-0.0033
10	7.816	-0.0032	-0.0057	0.0099	-0.0018	-1.00E-04
11	16.708	-0.0047	-0.0004	0.0021	0.001	1.00E-04
12	3.183	-0.0065	0.0017	0.0014	0.0015	-0.0002
13	2.698	-0.0023	-0.0044	0.0038	0	1.00E-04
14	2.341	-0.0048	0.0028	0.0026	0.0018	-0.0005
15	2.296	-0.0055	0.0008	0.0018	-0.0003	0.0004
16	2.252	-0.0048	-0.0012	0.003	0.0018	-0.0002
17	2.208	-0.0037	0.0005	0.0041	0.0013	0.0001
18	2.166	-0.0055	0	0.0026	0.0003	0
19	10.111	0.0259	-0.0028	0.0942	0.0012	0.0046
20	6.211	-0.0047	0.0008	0.0112	-0.0004	0.0004
21	4.818	-0.0048	-0.0004	0.001	0.0012	-0.0001
22	3.791	-0.0042	0	0.006	0.0006	0.0002
23	3.141	-0.0043	-0.0007	0.0033	0.0008	-1.00E-04
24	2.685	-0.0056	0.0012	0.0032	0.0019	-1.00E-04
25	2.347	-0.004	-0.0014	0.002	0.0007	1.00E-04
26	11.705	-0.0064	0.0047	-0.035	-0.0197	-0.0008
27	10.076	-0.0775	-0.0372	-0.093	0.0444	-0.0142
28	8.738	-0.0273	0.0417	-0.071	0.0005	-0.0047
29	8.039	0.0165	-0.0263	0.0305	-0.0051	0.0009
30	2.72	-0.0041	-1.00E-04	0.0017	0.0011	0
31	2.664	-0.0039	-0.0005	0.0038	0.0009	0
32	2.309	-0.0069	-1.00E-04	0.0033	0.0007	0.0002
33	2.273	-0.004	0.0021	0.0021	0.0022	-0.0003
34	2.233	-0.0052	-0.0011	0.0056	0.0004	0.0004
35	2.193	-0.0036	-0.0008	0.0024	0.0012	-0.0003
36	2.152	-0.0051	0.0008	0.0043	0.0002	0.0001
37	10.819	0.0122	0.0021	0.0625	0.0249	0.0039
38	9.293	0.0891	0.0417	0.1478	-0.0508	0.016
39	8.039	0.0316	-0.0549	0.1163	-0.0049	0.0049
40	7.42	-0.0299	0.0371	-0.038	0.0135	-0.0007