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Parametric Optimization of Wired Bowtie Antenna Using Artificial Neural Networks

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Abstract: In this paper a novel technique is proposed to design Bowtie using Artificial Neural Networks (ANN). ANN models are developed to calculate the antenna Gain for the given frequency and dimensions. ANN is designed using Feed forward back propagation neural network (FFBPNN) architecture and trained by Levenberg-Marquardt training algorithm. ANN can be trained to provide the best and worst case precisions of an antenna design problem defined by these parameters. We have trained the network using 400 MHz frequency with different values of length and width. The results obtained by FFBPNN are compared with the results of 4NEC-2 simulation and the errors founds by these are of very low order 5.4266E-06.

Keywords: Artificial Neural Network, Bowtie antenna, Feed forward back propagation, Levenberg-Marquardt training *algorithm*.

Introduction

A bowtie antenna is made from a bi-triangular sheet or wire of metal with the feed at its vertex [1]. It is used extensively in many applications such as ground penetrating radars [2]–[4] and mobile stations [5]. Modified dipole-shapes are often used to obtain wideband operation without increasing the complexity of the antenna. The wire bow-tie antenna represents a fairly simple dipole variation, and provides good wideband performance in spite of its simplicity. This antenna is popular for frequencies ranging from VHF up to the millimeter wave range, and has also found application in arrays. The wire bow-tie is closely related to the rounded (planar) bow-tie; the multiple wires can be seen as a wire simulation of the planar shape. The wire construction makes the wire bow-tie more practical at lower frequencies than planar bow-ties. While the wire bow-tie approximates the performance of the rounded (planar) bow-tie for the most part, its performance is somewhat degraded by higher order resonances that are supported between the wire arms. The wire bow-tie antenna performance is not sensitive to small parameter variations, improving robustness to manufacturing tolerances.

In this paper, the frequency and corresponding dimensions of bowtie antenna computed using 4NEC2 package. For training the BPNN a database is created for different bowtie antenna geometry. The database contains geometry parameters and value of frequency and corresponding dimension. Using this database BPNN is trained with input as frequencies and dimension (dx & dy) and output as gain of the bowtie antenna. Once the network is trained this BPNN can be used for designing the antenna for a given specification. The simulated results show good agreement with desired specification.

Antenna Structure

A horizontally-polarized triangular wire-structured HF antenna is depicted in Fig. 1. Its radiation arm is in the shape of a vertically arranged bilateral triangle which is made of wire. End points of these wires are attached to a Vertex serving as feeding point. The arm length of the antenna is 2.4196 meter and the angle between the arms is about 25^0.

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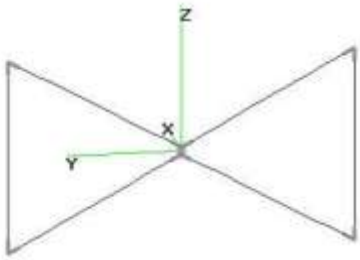

Fig. 1: Structure of Bow-tie antenna

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ANN Modeling

A neural network is a massively parallel distributed processor made up from simple processing units, which has a natural propensity for storing experiential knowledge and making it available for use. The use of neural networks offers the input-output mapping property and capability. There are two groups of ANNs learning algorithm, Supervised and unsupervised. Supervised learning learns based on the target value or the desired output. During the training the networks tries to match the output with the desired target values. ANN design aims at utmost simplicity and self-organization. In the present paper feed forward back propagation neural network (FFBPNN) are used and the Levenberg-Marquardt training algorithm is used to train the feed-forward Back Propagation (FFBP) network. The FFBPNN train with Levenberg-Marquardt (L-M) training algorithm is one of the approaches which show a great promise in this sort of problems because of its faster learning capacity. The multilayer perception (MLP) model with input, hidden and output three layer structure is used.

In order to design FFBPNN, network weights are to be found. Finding the weights is called network training. The Levenberg-Marquardt training algorithm is used to train the feed-forward Back Propagation (FFBP) network. The training process requires a set of examples of proper network behaviour network inputs P and target outputs T. The FFBPNN has to be trained with the input data P = (X1, X2… XN) and the targets T = (t1, t2… tN). During training the weights and biases of the network are iteratively adjusted to minimize the network performance function (i.e. mean squared error). By using set of input-output pairs, called training set, the network parameters are optimized in order to fit the network targets to the given inputs. After training, the FFBP network can be used with data whose underlying statistics is similar to that of the training set, known as testing set. A trained neural network can be used for high-level design, providing fast and accurate answers to the task it has learned.

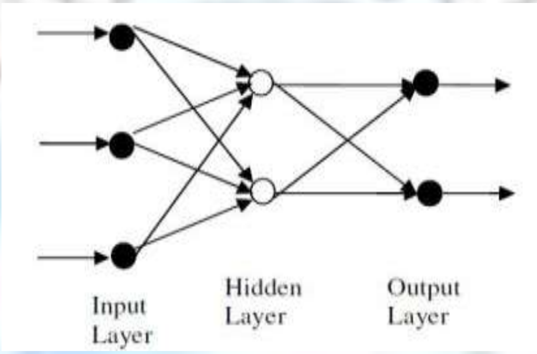

Fig. 2: An ANN based model

he use of neural networks offers the input-output mapping property and capability. One of the most commonly used supervised ANN model is back propagation network that uses back propagation learning algorithm. Back propagation is a systematic method of training multilayer ANNs. Even though it has its own limitations, it is applicable to wide range practical problems [6].

Simulation & Results

For the simulation of work the geometrical modeling of bow tie antenna have been developed in 4NEC2 package. 4 NEC2 is a antenna package which can be simulate a wide range of antennas. Matlab simulation have also been developed for training the Back Propagation Neural Network (BPNN)the BPNN is trained using the database containing input output pattern, where inputs are frequency, length and width of antenna and the output is gain of the antenna. In this work we use 3 inputs layers, one output layer and 25 hidden layers. The training function is TRAINLM, performance function is Mean Square Error and transfer function is TANSING. Here we use 1000 epochs and the simulation have done in 19 iterations. Learning of neural network is shown in Fig. 5.

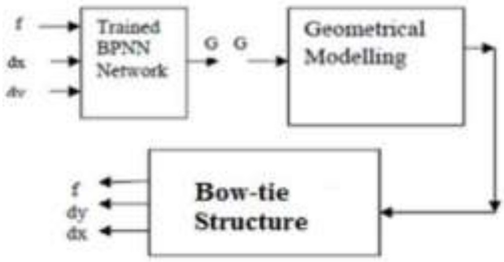

Fig. 3: Layout of the working model

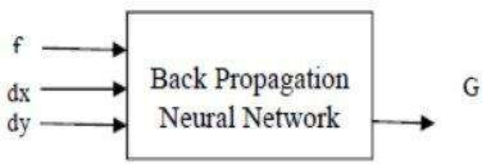

Fig. 4: Structure of BPNN Training

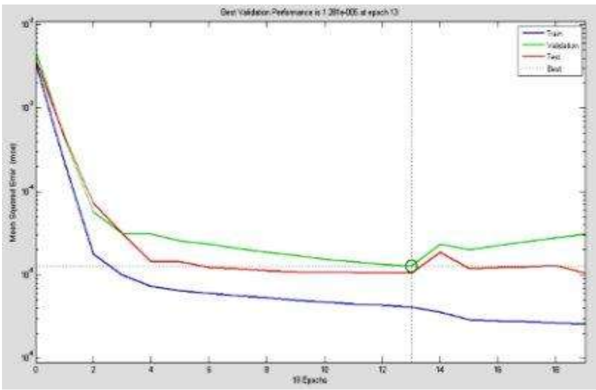

Fig. 5: Learning of ANN network

For testing our model we have given following input parameters f=400 MHz and dx (height) = 0.1325 meter and dy (width) = 0.3050 meter to the neural networks. These values are selected outside the database. The corresponding outputs gain of BPNN is 6.48dBi. Using these values a bowtie antenna is modeled and simulated using 4NEC2 package. The resulting gain is the 6.96 dBi. The corresponding antenna model, input standing wave ratio (SWR) graph and radiation pattern are shown in Fig. 6, Fig.7 and Fig.8 respectively. The simulated results shows results are very close to our specification.

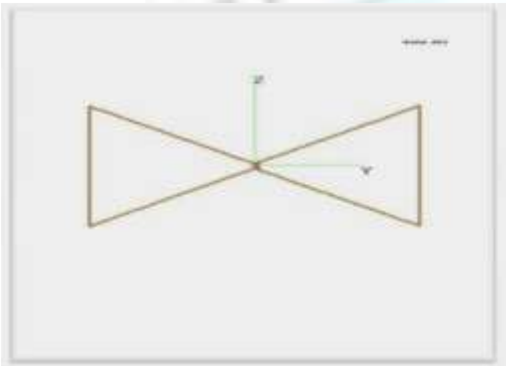

Fig. 6: The antenna mode

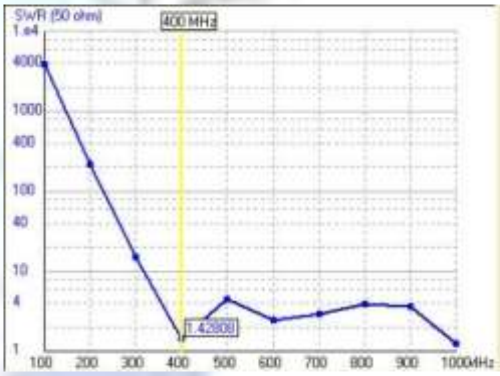

Fig. 7: Input reflection coefficient for the simulated Bowtie antenna

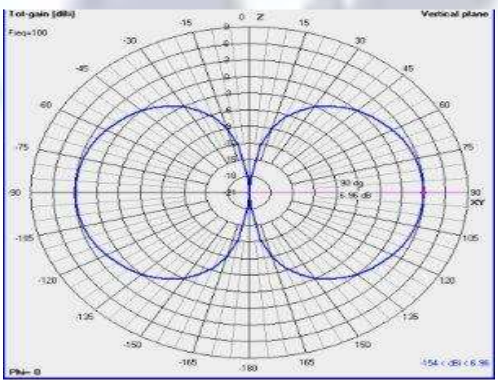

Fig. 8: Radiation pattern

Conclusion

This paper presents a novel design of Bowtie antenna based on wired structure and neural networks. Simulation results have shown good agreement with the desired specification. Future work involves actual physical modeling and antenna parameter estimation for performance evaluation.

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