Artificial Neural Model for a Dipole Antenna's Feed Balun*

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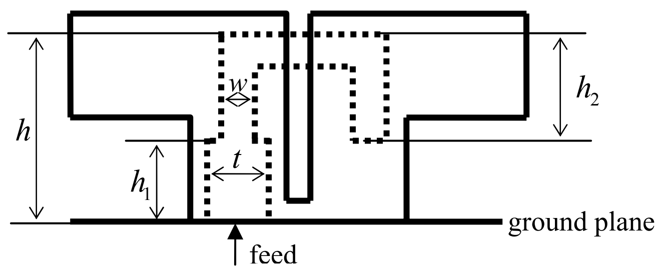
Abstract Artificial neural network (ANN) models of microwave devices or circuits can be created through measuring or simulating data. Once the model is developed it can be used in the design of microwave circuits and can provides fast answers of the tasks. In this paper an ANN model is applied to construct a model of a printed dipole antenna's feed balun.

I. Introduction

Phased array often adopts waveguide with the shortcoming of big bulk. If we adopt microstrip unit we can get over this deficiency but can't achieve wide band. Multilayer microstrip with a probe in the shape of L coupling feed structure can increase the bandwidth, but the structure is complex. Literature [1] provided a wideband conformal phased array structure. The printed dipole antenna provided in the literature used an integrated balun for feeding in order to solve the dipole arm's current balance problem. And this antenna structure can achieve a wide bandwidth. Commercial softwares such as Ansoft 9.0 and CST can be used to accurately model the electrical properties of the printed dipole antenna. However, they will expend tremendous efforts and are not practicable for interactive CAD. The ability and adaptability to learn, generalizability, smaller information requirement, fast real-time operation, and ease of implementation features, have made ANN models popular in the last few years. Literature [2] gave an ANN model for the antenna's feed balun. Now we put forward some improvements on the printed dipole antenna's feed balun to achieve some better performance, and construct an ANN model for the improved dipole antenna's feed balun.

II. Dipole Antenna's Feed Balun Model

The problem used to construct a neural network is a printed dipole antenna with an integrated balun. The geometry diagram is featured in Fgure1. In literature [2] the balun's width has the same value i.e., $w = t$. In our paper we give some improvements that the two parameters do not have the same value. Through such improvement we can achieve a wider bandwidth. The figure shows that the dipole antenna is printed on one side of the dielectric substrate and the balun feed is located on the other side of the substrate. A SMA f_0 connector is connected to the balun and microwave signal is coupled to the dipole antenna through the balun. In addition the balun is centered between the two-dipole arms. The dielectric constant of the substrate is 2.65. The thickness of the substrate is 1mm. The operating frequency of the printed dipole antenna is f_0, and the corresponding space wavelength is λ_0. The size of the antenna is $0.7\lambda_0 \times 0.4\lambda_0$. The size of the ground plane is $3.25\lambda_0 \times 2.0\lambda_0$.



Fgure1 The geometry of the dipole antenna and feed balun

The geometrical parameters of the balun are shown in Figure 1. The CST software is used to produce the voltage standing-wave ratio (VSWR) over a frequency band of 8 to 12 GHz. In order to avoid the conflicts between each parameters when we analyse the antenna and balun with CST we define five model parameters. The defined model parameters are show in Table I.

Table I. Model parameters of the balun (in cm)

Model prameter	$a_1 = h_1/(h-w)$	$a_2 = h_2/h$	$a_3 = w/h$	$h = h$	$t = t$
Ranges of model parameters	$(0,1]$	$(0,1]$	$(0,0.3651]$	$(0,0.784]$	$(0,0.3045]$

For the model parameters in Table I and the frequency parameter we define the input $\mathbf{X}$ of the neural network,

$$\mathbf{X} = (a_1, a_2, a_3, w, t, f) \tag{1}$$

and output of the network ,

$$Y=F(\mathbf{X}) \tag{2}$$

where Y is the VSWR (ρ) of the antenna, $Y = \rho$ (3)

Two layer perception neural network is implemented to model the input-output mapping defined in (2). The hidden neuron of the ANN has a sigmoidal nonlinear activation function in the form of a *hyperbolic tangent*, defined by $F_1(v) = \tanh(v)$ (4)

The output neuron has a linear activation function

$$F_2(v) = v \tag{5}$$

Mapping of the input-output relationship can be represented by

$$Y = F_2[\mathbf{W_2} \bullet F_1(\mathbf{W}_1 \bullet \mathbf{X} + \mathbf{B_1}) + \mathbf{B_2}] \tag{6}$$

Where $\mathbf{W_1}$ and $\mathbf{W_2}$ are the weight matrices between the input and hidden layers, respectively $\mathbf{B_1}$ and $\mathbf{B_2}$ are the bias matrices of the hidden and output layers respectively.

III. Numerical Results

The first step for constructing the model is to generate samples for training and inspecting. CST simulations are used to produce the data. We have six input parameters including five model parameters and one frequency parameter. The first question is the following: how many samples are needed to be chosen so that important input-output relationship is presented and learned by the model. The ranges and sampling levels of the input variables are given in TableII.

TableII.Variable input parameters for the balun

input parameter	Values in sampled levels
$a_1(5-level)$	0.2, 0.4, 0.6, 0.8, 1
$a_2(5-level)$	0.2, 0.4, 0.6, 0.8, 1
$a_3(5-level)$	0.07302, 0.14604, 0.21906, 0.29208, 0.651
$h(5\text{-}level)(cm)$	0.0609, 0.1218, 0.1827, 0.2436, 0.3045
$t(5\text{-}level)\ (cm)$	0.1568, 0.3136, 0.4704,0. 6272, 0.784
$f(10\text{-}level)\ (GHz)$	8.8, 9.2, 9.6, 9.8 10, 10.8, 11.2, 11.6, 11.8, 12

The ANN model is developed using supervised training. For the application in this paper, the Matlab implementation of the Levenberg-Marquardt algorithm is employed for the training. Figure 2 is the detected outcome of the neural network after training. On the top of the figure there is an expression $A = (1.02)T + (0.0977)$. The value $m = 1.02$ stands for the best regress line's slope and $b =$ 0.0997 stands for the line's intercept. When $m = 1$ and $b = 0$, the output of the network is entirely uniform with the goals. R stands for the correlation coefficient of the output of the network and the goals. The smaller the difference between R and 1, the better the performance of the neural network. In Figure 2 the horizontal axe is the goal, the vertical axe is the output of the network. The ideal regress line (the out of the network equals to the goals) is expressed by the real line, the best regress line is denoted by dashed line. From the figure we can see that the neural network has a good performance.

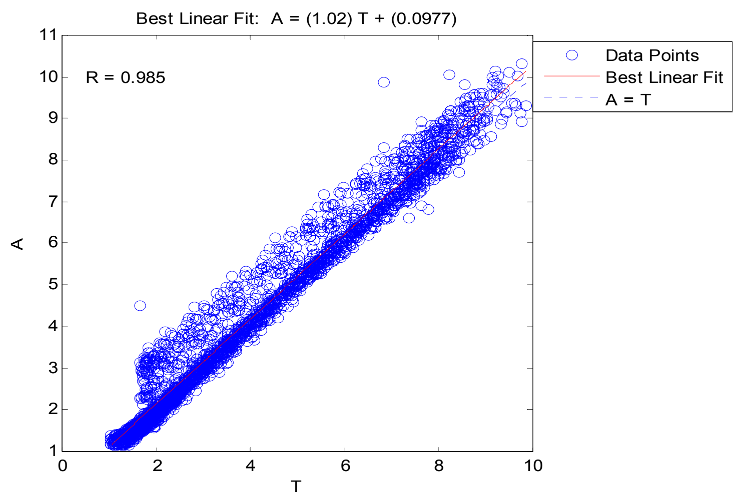


Figure 2. The inspect result of the neural network

IV. Conclusion

An ANN model is constructed for a printed dipole antenna's feed balun. The model is particularly useful in computationally intensive problems. Future work will be done for other integrated antennas.

References

[1] Y. H. Wei, et al., "A wide band antenna unit and it's application in conformal phased array," *Space Electronic Technology. vol. 2, no.1, pp. 32-35, Mar. 2005. (in Chinese)*

[2] J. D. Heriberto, "A novel neural network combined with FDTD for the synthesis of a printed dipole antenna," *IEEE Trans. Antennas Propa. vol. 53, no. 7, pp. 2231-2236, July 2005.*