An Artificial Neural Network Model for Feed Position of the Microstrip Antenna

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Introduction

Fig. 1 shows a microstrip antenna, which consists of a very thin metallic patch placed a small fraction of a wavelength above a conducting ground plane. The patch and ground are separated by a dielectric. The patch conductor is copper and can assume any shape [1-2]. The patches are usually photo etched on the dielectric substrate. The simplest method of feeding is through coaxial lines. The inner conductor of coaxial (probe) is connected to the radiating patch and outer conductor to the ground plane. Microstrip antennas have become very popular due to their several advantages such as simplicity, conformability, low manufacturing cost, lightweight, low profile, reproducibility, ease in fabrication and integration with solid-state devices. Microstrip antennas are used in a broad range of application from communication systems to biomedical systems. However, the analysis of microstrip antennas are complicated and exhaustive. To optimize the antenna efficiency for transmitting and receiving the patch impedance should match with the feed. The patch impedance depends upon the feed position; hence it becomes very necessary to optimize the feed position.

Training Data and Generation

The network is trained with the data obtained from the mathematical formulation and PCAAD software [5]. The whole work has been divided into two phases. In first phase patch size (patch length and patch width) is varied for a fixed frequency and a neural network is trained for the feed position. In the second phase, resonant frequency and hence patch sizes are changed to develop a trained neural network (Fig. 2).

Phase I. First, the patch dimensions for resonant frequency $f_0 = 2.45$ GHz, dielectric permittivity $\varepsilon_r = 2.33$, dielectric thickness $h = 3.18$ mm were calculated as follows.

The initial value of length

$$L = \frac{c}{2(\sqrt{\varepsilon_r})} = 40.1\,\text{mm.}$$

The effective permittivity is given by

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2 \left(1 + \frac{h}{W}\right)^{1/2}}.$$  

Fig. 2. Feed forward Network

Fig. 1. A microstrip Patch Antenna
The fringe factor $\Delta L$

$$\Delta L = 0.412h \left[ \frac{c_{\text{eff}} + 0.300 \left( \frac{W}{h} + 0.264 \right)}{c_{\text{eff}} - 0.258 \left( \frac{W}{h} + 0.813 \right)} \right]. \quad (3)$$

The physical or actual length of the path is given by

$$L = \frac{c}{2 \sqrt{f_0 \varepsilon_{\text{eff}}}} - 2\Delta L. \quad (4)$$

By using equations (1–4), lengths of patch were calculated for different values of width. Then for all the sets of lengths and widths, edge impedances (input impedance at the edge of patch) were calculated using PCAAD software. The distance $x$ of feed position from the radiating edge of the patch was found using formula,

$$R(x) = Ro \cos^2(\pi x/L), \quad (5)$$

where $Ro$ is the impedance at the edge of the patch; $x$ is the distance of feed position from the radiating edge of the patch; $L$ is the length of the patch.

The width $w$ was varied from 10 mm to 55 mm to generate training data $x$.

**Phase II.** The frequency range is taken from 0.8 to 2.5 GHz with width ranging from 10 mm to 52.5 mm. Using equations (1-4) length of patch was calculated for different values of frequencies and widths. Training data for feed position were obtained using PCAAD and equation (5).

**Results and discussion**

Artificial neural network based on back propagation method using feed forward network was trained with the 91 sets of training data. The input vector has 2 rows containing the values of width and length. The target vector has single row of feed position. The parameters for the network training are: 1) the learning rate = 0.0128, 2) the number of epochs for training = 40,000 and 3) the performance goal $= 1e^{-5}$.

The network parameters are: the number of hidden layers = 1 with 500 neurons and single neuron in the output layer. After training, network was used to calculate feed position for arbitrary value of width and length and result was compared with the value calculated from PCAAD. The result is shown in the Table 1.

**Table 1. The obtained results**

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Width (W in mm)</th>
<th>Length (L in mm)</th>
<th>Feed position obtained from trained network (mm)</th>
<th>Feed position Obtained from PCAAD software (mm)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.5</td>
<td>38.9365</td>
<td>10.2376</td>
<td>10.2358</td>
<td>0.0018</td>
</tr>
<tr>
<td>2</td>
<td>36.5</td>
<td>38.7017</td>
<td>8.7654</td>
<td>8.7642</td>
<td>0.0012</td>
</tr>
<tr>
<td>3</td>
<td>43</td>
<td>38.501</td>
<td>6.9810</td>
<td>6.9833</td>
<td>-0.0023</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>38.4223</td>
<td>6.0261</td>
<td>6.0269</td>
<td>-0.0008</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>38.3064</td>
<td>4.2810</td>
<td>4.2821</td>
<td>-0.0011</td>
</tr>
</tbody>
</table>

Then another network with frequency, length and width as input vector and feed position was as target vector was trained with 86 different sets of data. The network has one hidden layer containing 500 neurons and output layer containing single neuron. The performance goal was taken $1e^{-5}$ and number of epochs 55,000 during training. After training it was tested and compared with data calculated using PCAAD [5], which is shown in the Table 2.

**Table 2. The obtained results**

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Frequency (f in GHz)</th>
<th>Width (W in mm)</th>
<th>Length (L in mm)</th>
<th>Feed position Obtained from trained network (mm)</th>
<th>Feed position Obtained from PCAAD software (mm)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.12</td>
<td>18.0</td>
<td>90.5874</td>
<td>34.9935</td>
<td>34.9935</td>
<td>0.000</td>
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<td>25.0</td>
<td>71.0259</td>
<td>25.1727</td>
<td>25.1722</td>
<td>0.0005</td>
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<tr>
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<td>1.58</td>
<td>29.5</td>
<td>62.2277</td>
<td>20.4933</td>
<td>20.4963</td>
<td>-0.003</td>
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<tr>
<td>4</td>
<td>1.86</td>
<td>36.5</td>
<td>52.0086</td>
<td>14.6711</td>
<td>14.6601</td>
<td>0.011</td>
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<td>5</td>
<td>2.16</td>
<td>44.0</td>
<td>44.0777</td>
<td>9.4065</td>
<td>9.4069</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

**Conclusion**

The neural model presented in this work gives almost accurate results and, requires no tremendous computational efforts. A distinct advantage of neural computation is that, after proper training, a neural network completely bypasses repeated use of complex iterative processes for new design presented to it. For engineering applications, this simple model is very useful. The neural models used in this work can further be extended to include other parameters like shape of the patch, choice of dielectric constant, its thickness, etc.

**References**


Nagrinėjamas dirbtinio neuroninio tinklo, skirto mikrojuostelinei antenai pozicionuoti tobulinimas, pateikiami tokių pageidaujamų parametrų, kaip rezonansinio dažnio $f_0$ substrato storis ir sąlyginė dielektrinė skvarba $\varepsilon_r$. Tinklas pirmiausia yra treniruojamas keičiant fragmentų matmenis esant fiksuotam dažniui. Vėliau jis treniruojamas taikant visus tris kintamus parametrus, fragmentų matmenis (W and L) kartu su dažniu, siekiant tinkamai pozicionuoti tiesiogją. Il. 2, bibl. 5 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).


The current work deals with the development of an artificial neural network for fixing the feed position of a microstrip antenna, given the desired parameters like resonant frequency $f_0$, substrate thickness, and relative permittivity $\varepsilon_r$. The network is first trained by varying patch dimensions at a fixed frequency. Next it is trained with all the three varying parameters, the patch dimensions (W and L) together with the frequency, to obtain the suitable position of the feed. Ill. 2, bibl. 5 (in English; summaries in Lithuanian, English and Russian).


Описывается развитие искусственной нейронной сети для позиционирования микрополосковой антенны. Представлены такие желаемые параметры, как толщина субстрата частоты $f_0$ и относительная диэлектрическая проницаемость $\varepsilon_r$. Вначале сеть тренируется меняя измерения фрагментов при фиксированной частоте. После ее тренируют применяя все три изменяющиеся параметры, также измерения фрагменты (W and L) вместе с частотой с целью получить нужное позиционирование снабжения. Ил. 2, библ. 5 (на английском языке; рефераты на литовском, английском и русском яз.).