A FREQUENCY RECONFIGURABLE ANTENNA DESIGN USING NEURAL NETWOKS

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Abstract - **In this work, design aspects of a frequency reconfigurable antenna are handled using neural networks. The job of the neural network is to determine the switches that are to be made ON for the structure to resonate at specific bands. This task is handled as a classification type of problem and is accomplished by a self-organizing map neural network (SOM NN).**

I. INTRODUCTION

In response to the ever-increasing needs of antenna bandwidth, considerable amount of effort is currently underway to develop multiband antennas. Reconfigurable multiband antennas are attractive for many applications where it is desirable to have a single antenna that can be dynamically reconfigured to transmit and/or receive on multiple frequency bands. Mostly planar designs are preferred for these structures due to their added advantage of small size, low manufacturing cost and conformability. The technology of design and fabrication of microelectromechanical (MEMS) for RF circuits has put a major positive impact on reconfigurable antennas [1]. For a frequency reconfigurable antenna [2], the challenging task is, how to connect the radiating elements together, such that the resulting module will have desired frequency bands of operation, or in other words to determine which switches to turn ON, so that a specific set of elements will be active to make the structure to operate at desired frequency bands. In this paper, an effort has been made using neural networks, to determine the switches to be made ON, in order to make the antenna to resonate at specified frequencies. The developed formulation is tested on a laboratory prototype antenna.

II. PROBLEM FORMULATION

The structure under investigation is shown in Figure 1. The antenna was fabricated on a Duroid substrate (ε_r = 2.2) with no radiating element touching its adjacent elements. In the absence of actual MEMS switches, their electromagnetic performance was considered ideal and their placement was accomplished by small physical connections of the antenna's adjacent conducting parts. Our aim in this paper is to show the feasibility of use of NNs as a design tool for multiband reconfigurable antennas. With the use of actual MEMS switches, the same technique is equally applicable.

The purpose here is to correlate any frequency response, within the operational range of the antenna, with a reconfigurable structure as closely as possible. We approached the design procedure as a clustering problem and used a SOM NN for classification of the frequency

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response plots. Based on the shape of the frequency response plots, the SOM NN classifies the responses into different clusters. The Clusters so formed are then related with their corresponding antenna structure.

III. ANN IMPLEMENTATION

The SOM NN consists of an input layer of nodes, where the inputs to the NN are applied, and an output layer of nodes, where the categorization (grouping/clustering) of the inputs are formed. Training is performed in an unsupervised way using Kohonen learning algorithm [3]. The training can be viewed as a procedure that learns to group input patterns in Clusters in a way inherent to the data

In the present problem the inputs to the SOM NN is the frequency responses ($|S_{11}|$) fed through 40 nodes (sampled frequency points). In the output layer, we took four neurons, because it was observed that classifying the response plots into four groups marks each Cluster with distinguished features. The adaptive process for SOM used in this work is as described in [4]. In this, the weights of a two dimensional SOM network is updated according to:

$$\mathbf{w}_j(t+1) = \mathbf{w}_j(t) + \eta(t) h_{j,i(\mathbf{x})}(t)(\mathbf{x} - \mathbf{w}_j(t)) \tag{1}$$

where $\eta(t)$ is the time varying learning parameter given by $\eta(t) = \eta_0 \exp(-t/\tau_2)$, $t = 0, 1, 2, \ldots$; η_0 ($\approx$0.1), τ_2 ($\approx$1000) are constants. $h_{j,i(\mathbf{x})}(t)$ is the neighbourhood function given by:

$$h_{j,i(x)}(t) = \exp\left(\frac{-d_{j,i}^2}{2\sigma^2(t)}\right), \quad t = 0, 1, 2, \ldots; \tag{2}$$

where σ is the 'effective width' of the topological neighbourhood given by $\sigma(t) = \sigma_0 \exp(-t/\tau_1)$, $t = 0, 1, 2, \ldots$; τ_1 = (1000/log σ_0), σ_0 ($\approx$1) a constant. $d_{j,i}$ is the lateral distance between winning neuron i and excited neuron j. The four Clusters of frequency responses formed by the trained NN are shown in Fig. 2. (a-d).

III. DESIGN PROCESS

The typical structures corresponding to the Clusters so formed are shown is Figure 3.(a-d) (Figure 3 shows only the paths of the active elements in the reconfigurable structure and the inset picture shows the formation of paths for a typical configuration). The developed SOM network now can be used for design purposes. The paradigm of the design process is as described below.
Step 1: Give the network the desired frequency response (input)
Step 2: SOM NN matches the frequency response to the closest Cluster
Step 3: The antenna configuration can be chosen from the set of structures corresponding to that Cluster, starting with a simple structure with minimum number of switches
Step 4: Depending on requirement, more elements can be excited over the original structure.

III. CONCLUSION

Design aspects of a frequency reconfigurable antenna are handled using a SOM NN. The developed neurocomputational methodology can be extended for characterizing any reconfigurable electromagnetic structure.

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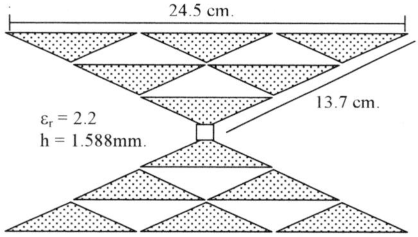
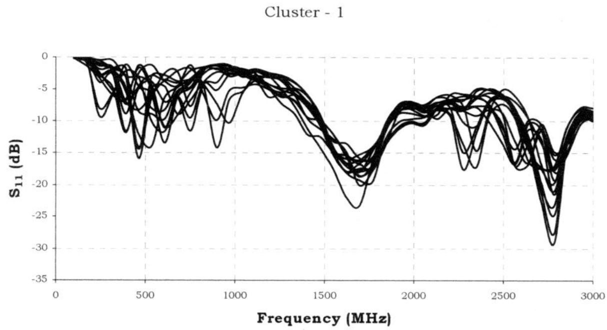
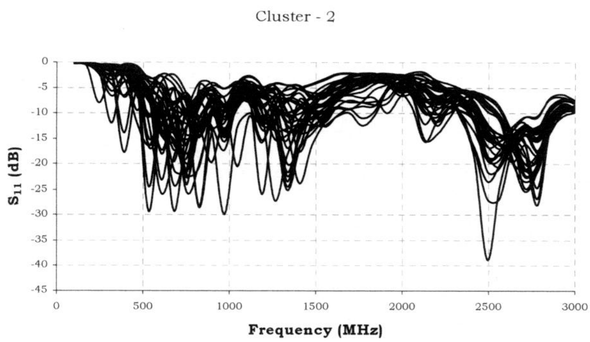
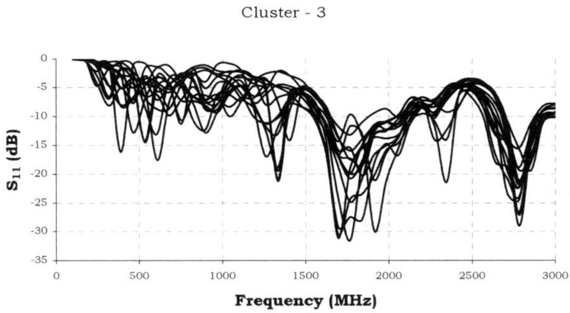


Fig. 1. Multiband antenna under investigation







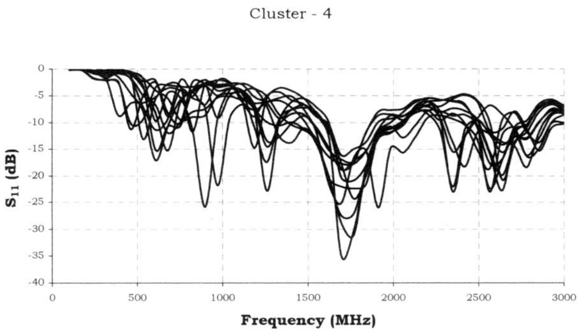


Fig. 2. (a-d). Clusters of the frequency responses of the reconfigurable structure as made by the SOM NN

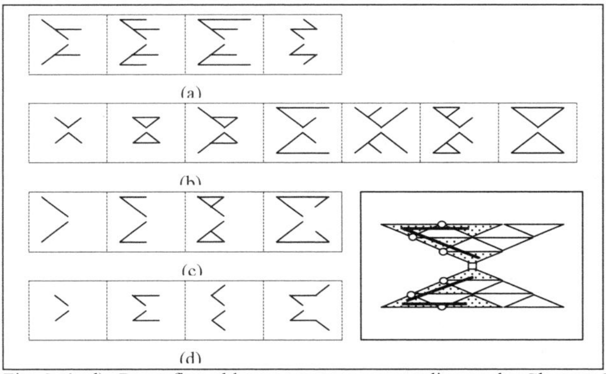


Fig. 3. (a-d) Reconfigurable structures corresponding to the Clusters 1-4 as shown in fig. 6. a-d respectively.