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Accuracy of Perceptron Based Beamforming for Embedded Smart and MIMO Antennas

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***Abstract*—Array antennas have a nonlinear, complex relationship between the antenna beams generated and the array input functions that generate the steerable beams. In this paper we demonstrate the use of a simple, computationally less intensive Perceptron Neural Network with non-linear sigmoid activation function to do the synthesis of the desired antenna beam. The single neuron is used, where its optimized weights will yield the beam shape required. This paper presents a successfully implemented Perceptron and discusses the error between the desired and Perceptron generated beams The successful beam control gives high accuracy in the maximum radiation direction of the desired beam, as well as optimization in the direction of null points. Moreover, a comparison between the array antenna beams obtained using the Perceptron Single Neuron Weight Optimization method (SNWOM) and the optimized beams obtained using the Least Mean Square (LMS) method, further demonstrates the reliability and accuracy of the Perceptron based beamformer. The tests were performed for two different desired antenna beams: one braod side beam and the other with the antenna radiating in four different desired directions. The Perceptron based antenna may be embedded in the Arduino microcontroller used. It is also shown why it is not possible to get a single beam, linear array antenna with the Perceptron based array reported herein.**

***Index Terms*—Smart Antenna, Adaptive Array, Adaptive Beamforming, Artificial Neural Network.**

I. Introduction

The Long Term Evolutionary (LTE) communication system is the latest wireless communication technology in use which provides high speed and high capacity wireless communication when compared to the 3G wireless systems. However, what is referred to as the LTE 4G systems is still limited in many areas Smart antennas and the MIMO system are one of the available ways to increase the rapidly increasing demand on capacity. The peak data rate is proportional to the number of antennas at the sending and receiving ends. This paper specifically focuses on beam steering using a fast neural network adaptation to direct the beam towards particular users and/or to steer nulls to reduce interference. This is a crucial role of a smart antenna which is able to provide electrical tilt, beam width and azimuth control suitable for handling moving traffic patterns. The smart antenna solution is far more versatile, and cheaper provided low memory, fast beam steering techniques such as that reported in this paper are used at the base stations. In parallel, the development of cost effective fast cell site addition, increasing the number of cell sectors and bandwidth, and better air interface capabilities will be critical to moving into the proper 4G systems of the future.

Artificial Neural Networks (ANN) are powerful techniques to be used where the mathematical relationship between input and out can be reliably established [1], [2]. The ANN is able to approximately model the input-out relationship by optimizing the weights through using known input-output training pairs. Once the training is done, it is able to obtain the needed antenna radiation beam for a given set of inputs by adaptive signal processing [3-6]. In this paper is presented a simple Perceptron that is able to rapidly adjust the weights by adaptive signal processing for given input-put pairs, and then generate a desired radiation beam using the converged weights. This paper considers the accuracy of a simple, fast perceptron Neural Network to form beams using linear arrays to generate beams that may communicate at a traffic junction along all four roads that meet at the junction, or a single long tunnel in underground communication where the beams need to be generated by the linear array of antennas [7, 8].

II. Single Neuron Weight Optimization Model (SNWOM)

In this section we briefly describe the single neuron modal to optimize the weights which will be used in adaptive beamforming. In the perceptron model as shown in Fig.1, a single neuron with a linear weighted net function and a threshold activation function also known as transfer functions are employed. The model has three parts and at the first part inputs (x_1, x_2 ...., x_n) are multiplied with individual weights (w_1, w_2 ...w_n). In the second part of a simple perceptron is the net function that sums all weighted inputs and bias as in

$$z = b + \sum_{k=1}^{n} w_k x_k \tag{1}$$

In the final part of a simple perceptron, the sum of previously weighted inputs and bias is passing through a transfer function to get the output. In case of the linear activation function, the artificial neuron is doing simple linear transformation over the sum of weighted inputs and bias b. There is no single best method for nonlinear optimization and it is based on the characteristics of the problem to be solved.

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