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A Neural Adaptive Circular Array for Enhancing SNR and Reducing Interference

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***Abstract*—** In today's mobile communication world, desired as well as interfering signals are mobile. Therefore, a fast tracking system is needed to constantly estimate the directions of those users and then adapt the radiation pattern of the antenna to direct multiple beams to desired users and nulls to sources of interference so that desired users get better quality signal with high SNR and to achieve this Artificial Neural Networks come to rescue to precisely predict which antenna element and the number of antenna elements in circular array to be activated to form better combined radiation pattern to be directed to user.

***Keywords*—**Circular Array, Neural Network, SNR

I. INTRODUCTION

Wireless mobile communication involves the transmission of information over a distance without the help of wires, cables or any other forms of electrical conductors. The transmitted distance can be anywhere between a few meters (for example, a television's remote control) and thousands of kilometres (for example, radio communication).

A wireless mobile can ensure you a constant connectivity though you move from place to place or while you travel, whereas in wired land line it is not possible. Constant connectivity also ensures that people can respond to emergencies relatively quickly.

The wireless channel is susceptible to a variety of transmission impediments such as path loss, interference and blockage. These factors restrict the range, data rate, and the reliability of the wireless transmission.

This paper analyses the radiation patterns of the circular array of antenna elements with MATLAB and Artificial Neural Networks are used for selection of the antenna elements from circular array having better main lobe radiation pattern in the target direction to have overall better combined radiation pattern of array and as a result there is enhancement in SNR

II. RELATED WORK

Signal to Noise Ratio

A signal-to-noise ratio [1] compares a level of signal power versus a level of noise power and is most often expressed in decibels (dB).

$$SNR=20 \log_{10} (V_s / V_n) \quad (1)$$

Higher numbers generally mean a better specification, since there is more useful information (the signal) than there is unwanted data (the noise). For example, when an audio component lists a signal-to-noise ratio of 100 dB, it means that the level of the audio signal is 100 dB higher than the level of the noise. Artificial Neural Network (ANN) control system is proposed in this paper to reduce or eliminate interfering signals in mobile communication and improve signal to noise ratio (SNR).

Artificial Neural Network

The human brain is composed of nerve cells called neurons. They are connected to other thousand cells by Axons. Stimuli from external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to other neuron to handle the issue. Natural Neural Network has been sown as in Figure1.

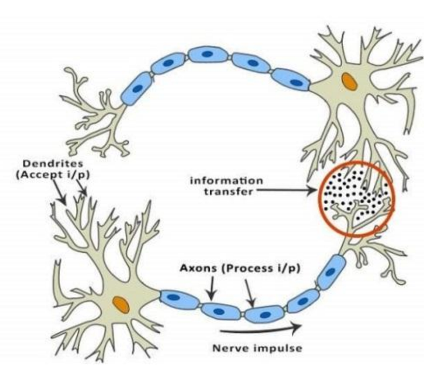

Figure 1. Natural Neural Network

The idea of ANNs is based on the belief that working of human brain can be imitated using silicon and wires as living neurons and dendrites.

ANNs are composed of multiple nodes, which imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation or node value.

Each link is associated with weight. ANNs [2] are capable of learning, which takes place by altering weight values. The following illustration in Figure 2 shows a simple ANN

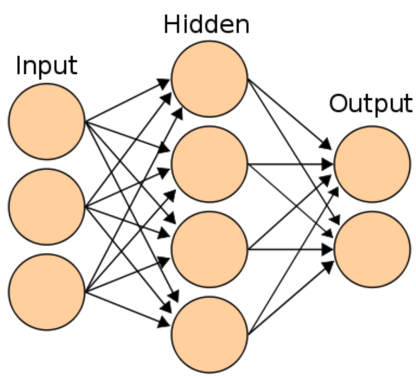

Figure 2. A simple Artificial Neural Network

Learning in ANN

ANNs are capable of learning and they need to be trained. For example, the teacher feeds some example data set about which the teacher already knows the answers. The ANN comes up with guesses while recognizing desired signal or interfering signal. Then the teacher provides the ANN with the answers. The network then compares it guesses with the teacher's "correct" answers and makes adjustments according to errors.

Back Propagation Algorithm

It is the training or learning algorithm. It learns by example. If you submit to the algorithm the example of what you want the network to do, it changes the network's weights so that it can produce desired output for a particular input on finishing the training.

Antenna Arrays:

A set of antennas working together to produce certain radiation pattern. Each antenna in an array is called an element antenna (or simply an element).
For array made up of identical elements,

(Array pattern) = (Array factor) X (element pattern)

Radiation Pattern

The energy radiated by an antenna is represented by the Radiation pattern of the antenna. Radiation Patterns are diagrammatical representations of the distribution of radiated energy into space, as a function of direction. The power when radiated from the antenna has its effect in the near and far field regions. Graphically, radiation can be plotted as a function of angular position and radial distance from the antenna.

Lobe Formation

In the representation of radiation pattern, we often come across different shapes, which indicate the major and minor radiation areas, by which the radiation efficiency of the antenna is known.To have a better understanding, consider the following figure 3, which represents the radiation pattern of a dipole antenna.

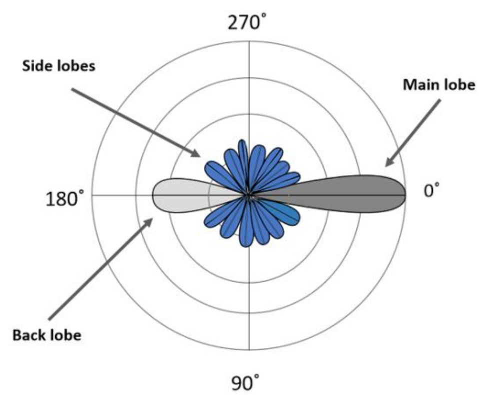

Figure 3. Radiation pattern of dipole showing various lobes
Here, the radiation pattern has main lobe, side lobes and back lobe.

The major part of the radiated field, which covers a larger area, is the main lobe or major lobe. This is the portion where maximum radiated energy exists. The direction of this lobe indicates the directivity of the antenna.

The other parts of the pattern where the radiation is distributed side wards are known as side lobes or minor lobes. These are the areas where the power is wasted.

There is other lobe, which is exactly opposite to the direction of main lobe. It is known as back lobe, which is also a minor lobe. A considerable amount of energy is wasted even here.

If the antennas used in radar systems produce side lobes, target tracing becomes very difficult. This is because, false targets are indicated by these side lobes. It is messy to trace out the real ones and to identify the fake ones.

Hence, elimination of these side lobes is must, in order to improve the performance and save the energy.

The radiated energy, which is being wasted in such forms needs to be utilized. If these minor lobes are eliminated and this energy is diverted into one direction (that is towards the major lobe), then the directivity of the antenna gets increased which leads to antenna's better performance.

III. METHODOLOGY

It is very much essential to identify the desired signals and interfering signals so that only desired signals are directed to the receiving antenna or destination. For this circular arrays of antennas [3] are analyzed and only that individual antenna from the arrays having maximum desired signal and minimum interfering signal are activated to transmit signals. ANN will be used to identify and activate such antennas from the arrays by training the neural network from the set of inputs and desired output. On the input layer of the neural network, two variables i.e desired and interfering signal are used and on the output layer exist the number of antenna elements selected for activation with desired radiation pattern resulting in circular array optimisation [4] and to have max SNR. To achieve this

a. Firstly circular array is designed with equally spaced n antenna elements with radius r.
b. Find the radiation pattern with different sets of angles of desired and interference signals in MATLAB
c. Find the output parameter SNR
d. Then Neural network is trained with Radial Basis Function Neural Network (RBFNN)
e. Results of predicted values of antenna elements are compared with actual values and calculate the percentage error to determine the accuracy of the neural network.

Design of Circular Array

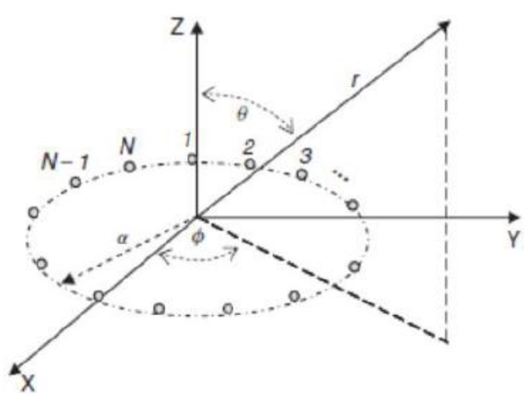

Figure 4. Geometry of N-element circular array of antennas

Total field/radiation pattern [5] from an array can be found by multiplying the element factor (the pattern produced by a single element) by the array factor.
The array factor for circular array is given as:

$$AF(\theta,\emptyset) = \sum_{n=1}^{N} I_n e^{j[kaSin\theta\, Cos(\emptyset-\emptyset_n)+\alpha_n]} \quad (2)$$

Where I_n is the amplitude term,

α_n is the phase of the excitation of the n-th element relative to a chosen array element of zero phase.

$\emptyset_n$ is the angular position of the n-th element

$a = I_n e^{j\alpha_n}$ is the excitation coefficient
MATLAB code for radiation pattern of Uniform Circular Array is written as below and the resulting figures of radiation pattern are below the code.

```
% Radiation pattern of UCA
clear all
clc
% define parameters
lambda=1;          % wavelength
k=2*pi/lambda;     % propagation constant
N=15;              % number of antenna elements
delta=0.4*lambda;  % spacing between antenna
%elements
alpha=2*pi/N;            % alpha for array
theta_o=[0:pi/20:2*pi];     % phase  difference for input % in
antenna elements
theta=[-pi:pi/200:2*pi];    % vary theta in xz plane

% calculate antenna factor (AF) for uniform circular   %array
(UCA) and plot
for n=1:length(theta_o)
   AFUCA=zeros(N,length(theta));
   for m=1:N
      AFUCA(m,:)=
exp((j*k*delta/alpha).*(sin(m*alpha+theta)-...
          sin(m*alpha+theta_o(n))));
   end
   AFUCA(n,:)=real(sum(AFUCA,1));  % sum for each
%thetas
   absAFUCA(n,:)=abs(AFUCA(n,:));
end
figure(1)
for i=1:length(theta_o)
clf
polar(theta,absAFUCA(i,:),'b')
hold on
legend('UCA')
display(theta_o(i)*180/pi)
pause(0.2)
```

end

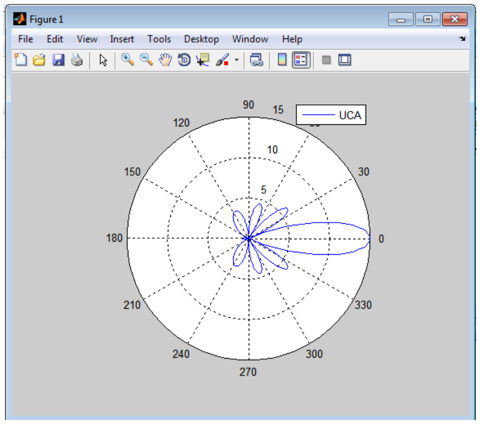

Figure 5.a. Radiation pattern of UCA of 15 antenna elements with main beam at 0 degree

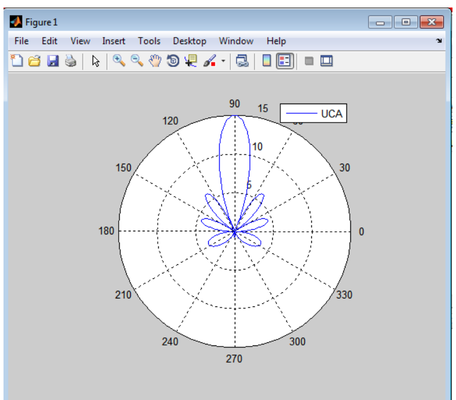

Figure 5.b. Radiation pattern of UCA of 15 antenna elements with main beam at 90 degree.

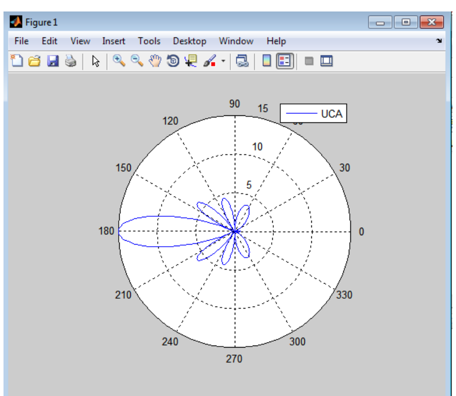

Figure 5.c. Radiation pattern of UCA of 15 antenna elements with main beam at 180 degree.

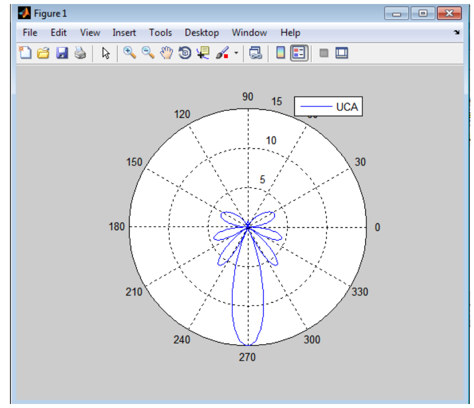

Figure 5.d. Radiation pattern of UCA of 15 antenna elements with main beam at 270 degree.

Once these radiation pattern are developed, neural network is used to optimise performance of circular array i.e. to enhance SNR in desired direction

Artificial Neural network alters certain variables in response to a set of corresponding input and output patterns. Beginning with an initial set of internal random values, the network modifies these quantities in order to find a position of "best fit," thereby generating from the input patterns their expected results. The ability of these networks to generalize relationships between inputs and outputs is a key to their effectiveness.

Radial Basis Function Neural Network RBFNN [6] has three layers of neurons, namely input, hidden and output, which are fully interconnected.

The first layer is composed of input nodes. The number of nodes, n, is equal to the dimension of input vector. The second layer is a hidden layer composed of multivariate Gaussian nonlinear units that are connected directly to all of the input layer nodes. Each neuron in the hidden layer operates at the Gaussian transfer function. RBF network with a sufficiently large number of nodes can approximate any real multivariate continuous function on a compact set.

IV RESULTS AND DISCUSSION

Consider a circular array with 5, 10, 15 and 20 elements and respective output parameters SNR [7]. Figures 5.a to 5.d show the radiation pattern for 15-element circular array generated using MATLAB simulation. To establish the validity of the procedure, a circular array with isotropic elements with uniform excitation and uniform spacing is considered. Table I gives the list of simulated output parameters of this circular array using MATLAB.

Table 1 Parameters and Measured Error of Circular array

Input Parameters: a: Number of elements b: Radius c: angle of desired signal d: angle of interfering signal				Output Parameters		
a	B	c	d	SNR (in db)	Predicted Number Of Elements activated using RBFNN	% error
5	0.5	0	30	6.06	5.06	1.20
5	0.5	0	60	6.09	5.03	0.60
5	0.5	0	90	6.11	5.01	0.20
10	0.5	0	30	6.14	10.24	2.40
10	0.5	0	60	6.15	10.05	0.50
10	0.5	0	90	6.16	10.01	0.10
15	0.5	0	30	6.16	15.18	1.20
15	0.5	0	60	6.2	15.16	1.07
15	0.5	0	90	6.8	15.04	0.27
20	0.5	0	30	7.6	20.25	1.25
20	0.5	0	60	7.9	20.23	1.15
20	0.5	0	90	8.1	20.21	1.05

Then Prepare input model in MATLAB
I= [Number_of_elements; radius; angle_of desired_signal; angle_of_interfering _signal]

and Target model as T=SNR

Then Neural network is created in MATLAB
net=newff(I,T) ;
and network is trained using
net=train(net,I,T);

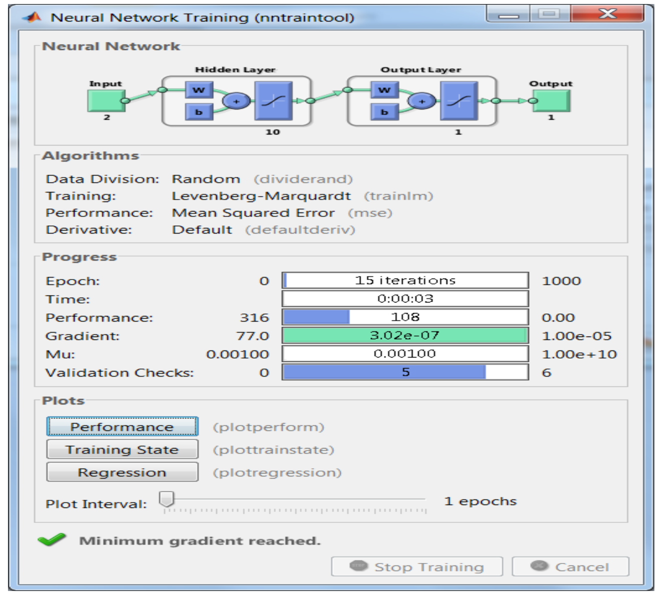

Figure 6. Training of neural network

Now the system is trained, we can test (simulate it) on any input we want. First let's test the model for the same input which we have used for the training, it should give us the same output.

J1=sim(net,I);

Now check the values of J1 and T. These should be same. Now testing the system with some different inputs and observe the output and measure the percentage error.

Percentage error is calculated as (Observed value-Predicted value) / Predicted value, and the measured error calculated for the trained network data is as shown in Table I. Given simulated data is taken as the inputs for the training network and the number of elements are predicted using RBFNN algorithm. The samples are given as inputs to the neural network. Each network [8] is trained with 10 test patterns.

Table 1 shows that SNR increases for a given number of antenna elements as angle between desired signal and interfering signal increases from 30o to 90o and prediction of number of antenna elements selection by ANN for desired SNR using RBFNN converges nearer to the whole number i.e. from 5.06 to 5.01 and 10.24 to 10.01 etc. and percentage error reduces between predicted number of antenna elements and actual number of antenna elements for desired output of SNR.

During the training it is observed that only 20 input nodes are sufficient. Using more input nodes leads to more accurate representation of the pattern but will also require a much larger network and hence the computational time will increase. With the present architecture, the results indicate that for 98% of all cases presented, the network showed the correct result.

V CONCLUSION AND FUTURE SCOPE

In cellular and satellite mobile communications systems, desired as well as interfering signals are mobile. Therefore, a fast tracking system is needed to constantly estimate the directions of those users and then adapt the radiation pattern of the antenna to direct multiple beams to desired users and nulls to sources of interference

Radiation Patterns of circular antenna arrays with different sets of angles of desired and interfering signals have been discussed with the selection of the elements using a Neural Network. Neural Network can be trained for any number of elements, spacing and excitation. Once the network is trained, it can find the parameters with respect to the input. SNR is the output parameter. Number of elements and radius of the circular array are the input parameters for the training network. RBFNN is able to predict the output values with 98% of accuracy. Neural Networks trained by RBFNN can track multiple users by directing desired signals with activated antenna elements predicted by ANN while simultaneously nulling interference caused by co-channel users and enhancing SNR.

In future different geometries of antenna arrays like oval shape can be studied along with optimisation by neural network. Also different shaped antenna arrays can be studied collectively and ANN with back propagation [9] can be used to select the best suited antenna array pattern to increase SNR.

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