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Convergence Rate Improvement and Interference Reduction in Smart Antenna System

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ABSTRACT: The adaptive beamforming algorithms are used for producing a maximum narrow beam in the desired direction and at the same time nulls in other directions. This paper mainly focuses on the existing adaptive beamforming algorithm that is Variable Step Size – Normalized Least Mean Square (VSS – NLMS) algorithm and a new proposed adaptive beamforming algorithm in which the updated weight equations of two adaptive beamforming algorithms Least Mean Square (LMS) and Constant Modulus Algorithm(CMA) are used for the weight updation of the smart antenna. This proposed adaptive beamforming algorithm improves the convergence rate and reduces the interference by forming a maximum narrow beam in desired direction and nulls at other directions. The above two algorithms (VSS – NLMS and the new proposed algorithms) are simulated using MATLAB for uniform linear array.

KEYWORDS: Smart antenna, Adaptive beamforming, LMS, CMA, VSS-NLMS, MSE.

I.INTRODUCTION

A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source (transmitter), the destination (receiver), or both. The diversity effect involves the transmission and/or reception of multiple radio frequency waves to increase the data speed and reduce the error rate. The core of the smart antenna is the selection of smart algorithms at the antenna array. The word smart refers to the signal processing. In general, the antennas are not smart. in order to make the antennas smart, we need to use the signal processing algorithms. The smart antenna consists of a number of antenna elements whose weights are controlled by the signal processing algorithm called adaptive beamforming algorithm.

The steps in adaptive beamforming algorithm are,

1. Initialize the weights of the antenna elements.
2. Calculate the output which is nothing but the sum of multiplication of the input signal with the weights of each element.
3. Calculate the error which is nothing but the difference between a reference signal and the output signal. The reference signal that estimates the desired signal and previous weights.
4. Update the weights and repeat these steps to minimize the error.

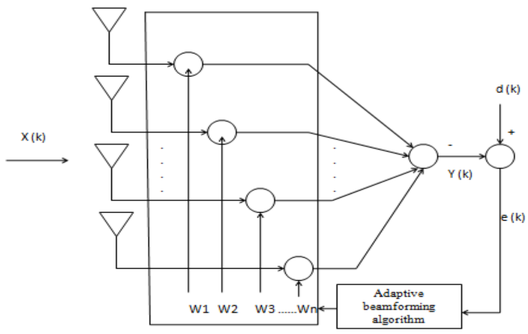

Figure 1: Functionality of adaptive beamforming algorithm

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The Figure.1 shows the functionality of the adaptive beamforming algorithm. Where $x(k)$ is the input signal, where as $y(k)$ is the output signal that is the sum of the multiplication of $x(k)$ and the corresponding weights of the antenna array. Then the output signal is subtracted from the reference signal $d(k)$. The reference signal estimates the desired signal and previous weights [13]. The adaptive beamforming algorithm updates the weights of the antenna array to reduce the Mean Square Error (MSE). This process is repeated for the number of times until the steady state error reached.
In this paper, section II presents a Variable step size NLMS algorithm and the new proposed algorithm, where as in section III, simulation results which present MSE and output beampattern of the antenna array are discussed. Finally, our observations are summarized in section IV.

II. ADAPTIVE BEAMFORMING ALGORITHMS

A.VSS-NLMS Algorithm

The fixed step size is replaced by a variable one. The variable step size is developed by multiplying the fixed step size parameter with *P(k)* which is randomly chosen and then it is multiplied by a curve function in order to control the variable step size [1]. The curve function is as follows,

$$\varsigma(k) = \begin{cases} \left(\left(\frac{6}{N}\right)^2 \left(k - \left(\frac{N}{6}\right)\right)^2\right) + 0.001, & 1 \le k \le \frac{N}{6} \\ 0.001, & \frac{N}{6} \le k \le N \end{cases}$$

Then, the variable step size is,

$$\mu(k) = P(k)\,\varsigma(k)\,\mu$$

The updated weight equation of the VSS – NLMS algorithm [1] as follows,

$$W(k+1) = W(k) + \frac{\mu(k)\, e(k)\, x(k)}{\sigma + ||x(k)||^2}$$

W(k) is the old weight vector at iteration k and W(k+1) is the updated weight vector at iteration k+1. e(k) is the error and x(k) is the signal to be received by the antenna elements. σ is a constant.

B. New proposed algorithm

The important step in the adaptive beamforming algorithm is the weight updation of the antenna array. By updating the weights of the array we can generate the maximum narrow beam in the desire direction. The updated weight equation is changed from one adaptive beamforming algorithm to another adaptive beamforming algorithm. Updated weight equations of the two adaptive beamforming algorithms LMS and CMA are used here. At each time, the output signal is calculated and then the error is calculated. Next the weights of the array are updated. The weights of the antenna array are updated by using the previous weights. The LMS and CMA adaptive beamforming algorithms are fixed step size algorithms. In the step of weight updation, first we have calculated the updated weights using the equation of updated weight of the LMS and then we have placed this weight equation in the place of previous weight vector of the CMA adaptive beamforming algorithm.
The LMS is a non-blind algorithm, this algorithm requires the reference signal and uses the estimate of the gradient vector from the available data. This algorithm makes successive corrections to the weight vector in the direction of the negative of the gradient vector which finally concludes to minimum MSE.
The updated weight equation of LMS [12] adaptive beamforming algorithm is,

$$W(k+1) = W(k) + \mu\, e(k)x(k)$$

CMA is a blind algorithm, it does not require the reference signal This algorithm seeks for a signal with a constant magnitude i.e. modulus within the received data vector and is only applicable for modulation scheme which uses symbol of equal power includes phase and frequency modulated signals.
The updated weight equation of the CMA [11] is

$$W(k+1) = W(k) - 2\,\mu\left[y - \frac{y}{|y|}\right] x(k)$$

The updated weight equation of the new proposed algorithm in which the combination of both LMS and CMA algorithms are used is as follows,

$$W(k+1) = \underbrace{W(k) + \mu\, e(k)x(k)}_{\text{LMS}} - \underbrace{2\mu\left[y - \frac{y}{|y|}\right] x(k)}_{\text{CMA}}$$

The VSS-NLMS algorithm uses the step size as variable, that is µ is multiplied by a random number and a curve function. In the new proposed algorithm we use the fixed step size parameter that is µ as 0.05.

III. RESULTS AND DISCUSSION

A. Comparison of MSE for VSS-NLMS and new proposed algorithm

The error is calculated for 30 iterations. In figure 2 and 3, the x-axis is represented by the iterations and y-axis is represented by the error (dB).

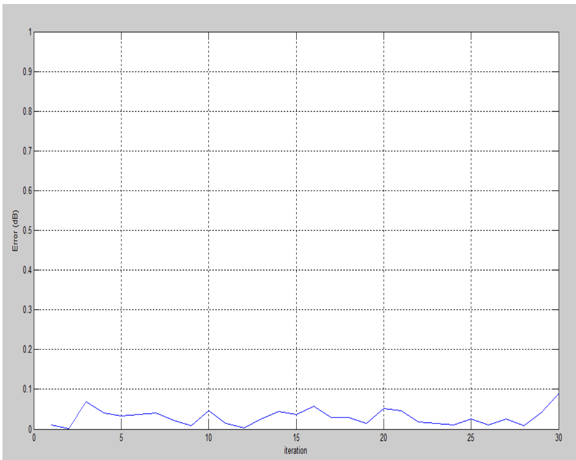

Figure 2: Error signal using the VSS-NLMS algorithm

Figure 2 shows the error signal which is obtained by the VSS-NLMS algorithm. The error obtained from the VSS –NLMS algorithm is 0.09dB for 30 iterations.

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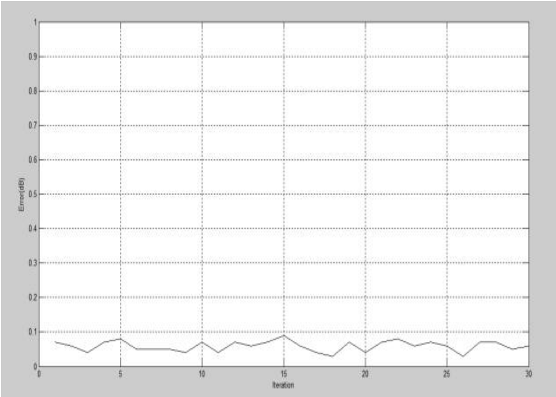

Figure 3: Error signal using the new proposed algorithm

Figure 3 shows the error signal which is obtained by the new proposed algorithm. The error obtained from the new proposed algorithm is 0.07dB for 30 iterations.

The VSS – NLMS algorithm is simulated with 12 number of antenna elements using the user signal at an angle 40 degrees and the interferer at the angle of -60 degrees. The spacing between them is chosen as 0.5λ. The step size parameter μ is chosen here as 0.05 that is multiplied by the curve function and a random number. The number of iterations are 30. The new proposed algorithm is also simulated with same parameters but the step size μ is fixed that is μ=0.05. Finally, the error signal and the beampattern of the antenna array are plotted.

The error plot is drawn by subtracting original signal from output signal.

Figure: 2 shows the error vs. iterations for VSS-NLMS algorithm and the figure: 3 shows the error vs. iterations for the new proposed algorithm.

The error obtained from the VSS – NLMS algorithm is 0.09dB. The error obtained from the new proposed algorithm is 0.07dB. So, minimum error has been obtained from the new proposed algorithm

B. Comparison of beampattern for VSS-NLMS and the new proposed algorithm

The response of input user signal and interfering signal for VSS-NLMS and the new proposed algorithm are shown in figure 4 and figure 5.In Figure 4 and 5, the y-axis is represented with Normalized power (dB) and the x-axis is represented with angle of arrival (deg). It can be seen that main lobe is formed towards user at angle 40 degrees as it has maximum signal strength in the user direction and interfering signal at -60 degrees is being rejected as null is placed at the interferer angle -60. By giving different angles to user signal and interference the beampattern changes accordingly.

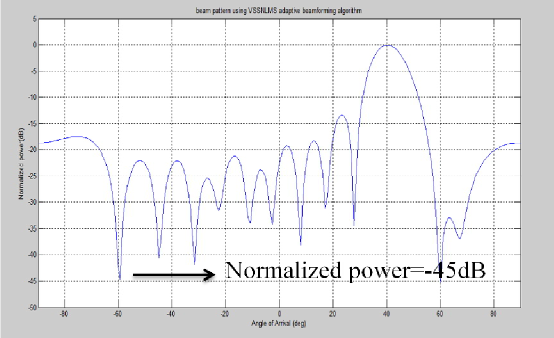

Figure 4: Array beam pattern using VSS-NLMS algorithm

Figure 4 shows the array beam pattern using the VSS-NLMS algorithm, where the normalized power obtained at -60 deg angle of arrival (angle of arrival of interferer) by the VSS-NLMS algorithm is -45dB.

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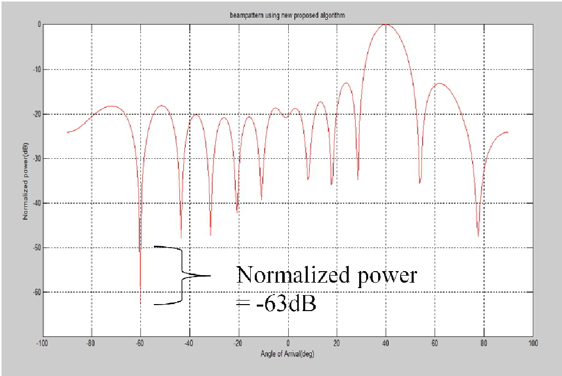

Figure 5: Array beam pattern using the new proposed algorithm

Figure 5 shows the array beam pattern using the new proposed algorithm, where the normalized power obtained at -60 deg angle of arrival (angle of arrival of the interferer) by the new proposed algorithm is -63dB.
The two algorithms are simulated with same parameters which are used in section-A. We can see that the normalized power at -60 deg is -45 dB by using VSS-NLMS and from the new proposed algorithm the normalized power is -63 dB. The difference between the existing and the new proposed algorithm is 18dB. The new proposed algorithm produces deeper null at the angle of arrival of interferer when compared to the VSS-NLMS algorithm. The new proposed algorithm results in the better interference suppression due to deeper nulls produced in the direction of interfering signal.

We have also simulated the algorithms for different number of iterations from 10 to 50.

Number of iterations	Mean Square Error from VSS-NLMS algorithm (dB)	Mean Square Error from the proposed algorithm (dB)	Improvement in error reduction by the new proposed algorithm
10	0.1	0.1	None
20	0.1	0.1	None
30	0.09	0.07	0.02
40	0.08	0.07	0.01
50	0.05	0.04	0.01

Table 1: Comparison of Error for VSS – NLMS and the new proposed algorithm

Table 1 shows the comparison of Error for VSS – NLMS and the new proposed algorithm. From this table, we can observe that the error is minimized by the new proposed algorithm than the VSS-NLMS algorithm.

IV. CONCLUSION

The VSS-NLMS adaptive beamforming algorithm and the new proposed algorithm are compared on the basis of beam pattern and Mean Square Error (MSE) and the beampattern for the Uniform Linear Array. The error is minimized by the new proposed algorithm than the VSS-NLMS algorithm. The new proposed algorithm provides better interference suppression due to deeper nulls produced in the direction of interference signal.

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