간섭신호 환경에서 교대 주빔 제거 알고리듬을 위한 반복 기법

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An Iterative Approach for Alternate Mainbeam Nulling Algorithm in Coherent Environment

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Abstract

This paper concerns an efficient iterative approach for eliminating coherent interference signals in linearly constrained adaptive arrays. The Alternate Mainbeam Nulling Algorithm[1] is implemented iteratively to find an optimum weight vector. The convergence parameters in the unit gain and null constraints are calculated using steepest descent method with gradient estimation. The nulling performance of the proposed method is compared with that of conventional ones. It is shown that the proposed method performs better than conventional ones when the power of the coherent signals is large compared with a desired signal. Also, it performs consistently well for more number of interferences.

Key words : iterative, linear array, AMN, coherent, convergence parameter.

I. Introduction

If incoming interferences are correlated with the desired signal in Frost beamformer[2], the desired signal is partly or totally cancelled in the array output depending on the extent of correlation. As a result, Frost beamformer is incompetent in nulling out coherent interference signals. A variety of methods has been proposed to improve the nulling performance of the linearly constrained adaptive arrays in coherent interference environment[3-6]. A master-slave type array processor proposed by Duvall[3] employs a subtractive preprocessing to eliminate signal cancellation during adaptive process. The shortcoming of this method is that it needs an additional processor to the Frost beamformer. A spatial smoothing approach proposed by Shan and Kailath[4] employs subarray preprocessing to decorrelate input correlation matrix. In this approach, subarrays need to be increased as the number of interferences increases. Su and Widrow[5] proposed parallel processing method which uses a subarray structure similar to the spatial smoothing approach. Processing time is much reduced due to parallel processing of input signals while proper number of subarrays are required to reject coherent interferences.

In this paper, an iterative approach for the Alternate Mainbeam Nulling(AMN) algorithm[1] is proposed to deal with coherent interferences efficiently in linearly constrained adaptive arrays. The steepest descent method is employed in estimating convergence parameters in the unit gain and null constraints in the look direction (the direction of the desired signal). It is demonstrated that the AMN algorithm is more robust to the number of interferences than the conventional methods.

Ⅱ. Alternate Mainbeam Nulling Algorithm

Alternate Mainbeam Nulling algorithm is based on the fact that If a null constraint is employed in the look direction, the resulting weight vector in the subspace parallel to the constrained hyperplane is orthogonal to the steering vector in the look direction and thus is not affected by the desired signal.

Consider a narrowband linear array with N equispaced isotropic antenna elements. Each element is followed by a complex weight. An iterative way to find a suboptimum solution is a linearly constrained LMS algorithm given by

$$w_{k+1}=\left[I-\frac{cc^H}{N} \right]\left[w_k-\mu_u y_k x_k \right]+\frac{c}{k} \tag{1}$$

where w_k is weight vector, x_k is input signal vector, y_k is array output, μ_u is convergence parameter, and k is iteration index.

The problem of the adaptive arrays implemented by (1) is that it may not estimate the desired signal when the desired signal is correlated with incoming interferences, the main cause of which is signal cancellation. A simple way of reducing the signal cancellation phenomenon is to use a null constraint at the look direction. The corresponding adaptive algorithm is represented by

$$w_{k+1}=\left[I-\frac{cc^H}{N} \right]\left[w_k-\mu_u y_k x_k \right] \tag{2}$$

It is to be noted that the convergence parameters for (1) and (2) are different in general, which are expressed as μ_u and μ_n , respectively. The iterative approach for the AMN algorithm consists of two steps. In the first step, the array weights are updated alternately with a null and a unit gain constraint by (1) and (2) with iteratively estimated convergence parameters. The iterative equation for estimating the convergence parameters is given by

$$\mu_{k+1}=\mu_k-\eta \widehat{\nabla_k} \tag{3}$$

When η is convegence parameter for μ and $\widehat{\nabla_k}$ is estimatied gradient in the μ_u and μ_n domain.

In the second step, the resulting array output is interpolated in the unit gain constraint to generate a final output signal. First-order linear interpolation is employed to estimate the desired signal. In the null constraint, the desired signal is not involved in the weight update or the weight vector is orthogonal to the look direction steering vector, thus the signal cancellation is prevented. Also, the sidelobe is formed alternately between the unit gain and the null constraint patterns, which results in powerful nulling performance as shown in the computer simulation.

Ⅲ. Simulation Results

A 7-element linear array is employed to examine the performance of the iterative approach for the AMN algorithm. It is assumed that interelement spacing is a half wavelength. A desired signal of magnitude 0.1 is assumed to be incident at the array normal. Coherent interferences with magnitude 0.1 and 1.0 are simulated respectively. In FIgs 1 and 2, the amount of delay of the output signal with respect to the desired signal for the proposed and two conventional methods, which are Duvall beamformer and spatial smooth approach, are displayed, when up to 12 coherent interferences of magnitude 0.1 are assumed to incident at 69.6°, 54.3°, 43.4°, 34.2°, 25.9°, 18.2°, -14.4°, -22.0°, -30.0°, -38.6°, -48.5°, -61.0°.

The simulation results for the cases for coherent interferences of magnitude 1.0 are desplay in Figs. 3 and 4. In FIg. 5. the trajectory of the MSE in the 2-dimensional convergence parameter domain for unit gain and null constraints are displayed with an optimum MSE.

The beam patterns for the conventional methods and the proposed one with 10 interferences involved are displayed in Fig. 6. The corresponding output and error signals are shown in Figs. 7 and 8, respectively.

Ⅳ. Conclusion

An iterative approach is implemented with the Alternate Mainbeam Algorithm. The nulling performance of the proposed method is compared with that of conventional methods in coherent environment. It is shown that except for the case of less number of interferences, the proposed method performs better than the conventional methods. Especially, the proposed method performs significantly well compared to the conventional methods as the number of interferences increases.

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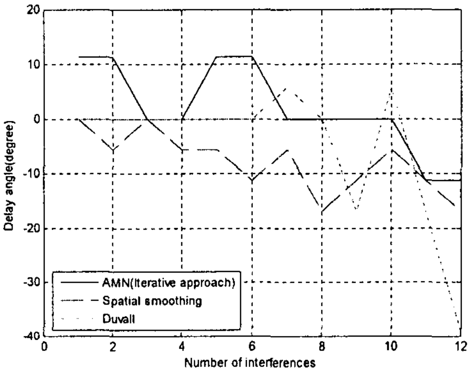

Fig 1. Comparison of delay angles in terms of number of interferences with magnitude 0.1.

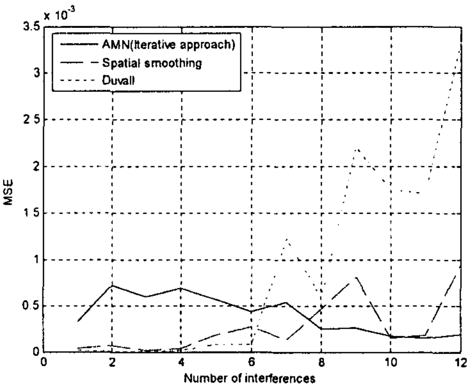

Fig 2. Comparison of mean square errors in terms of number of interferences with magnitude 0.1.

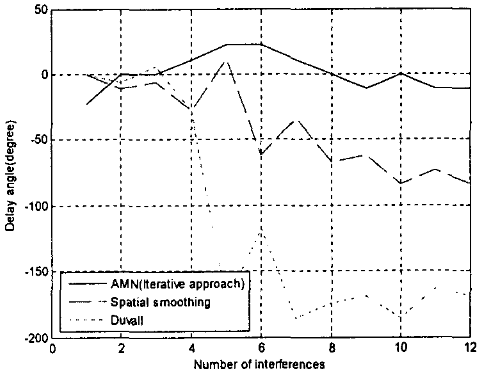

Fig 3. Comparison of delay angles in terms of number of interferences with magnitude 1.0.

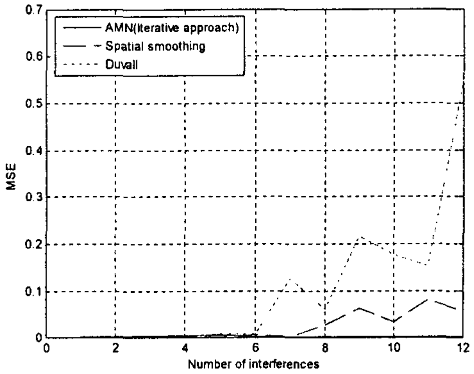

Fig 4. Comparison of mean square errors in terms of number of interferences with magnitude 1.0.

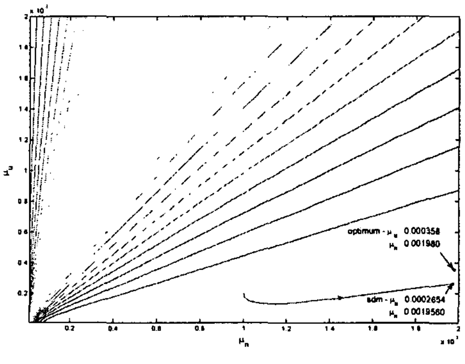

Fig 5. The trajectory of the MSE for 6 interferences with an optimum MSE in MSE level curves.

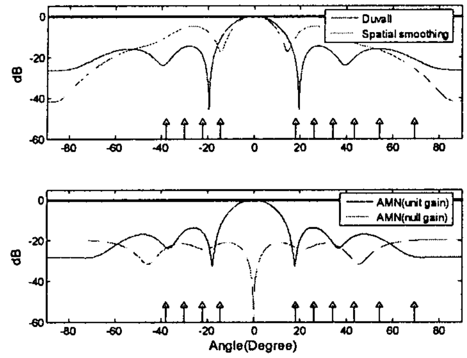

Fig 6. Beampatterns for 10 interferences with magnitude 1.0.

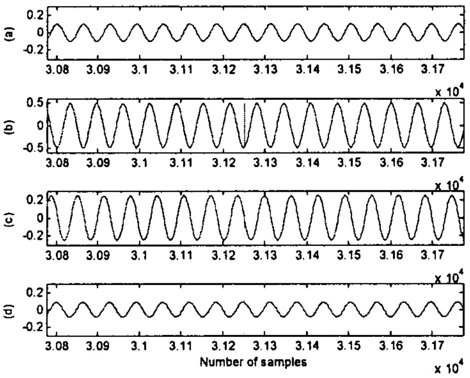

Fig 7. Output signals for 10 interferences with magnitude 1.0; (a) Desired signal (b) Duvall (c) Spatial smoothing (d) AMN.

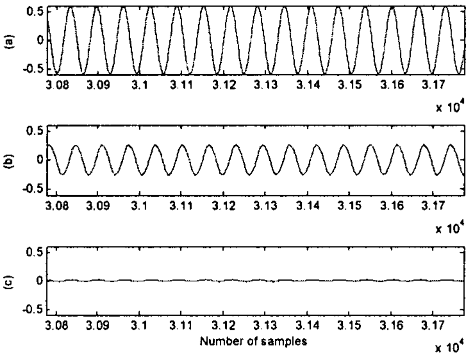

Fig 8. Error signals for 10 interferences with magnitude 1.0; (a) Duvall (b) Spatial smoothing (c) AMN.