Multistage LSCMA Beamforming Algorithm for Smart Antenna with SMI initialization

A. BOUACHA and F.T. BENDIMERAD

Abstract—**The multistage LSCMA beamforming algorithm is capable of detecting multiple input signals sources without pilot or training signals. it is comprised of acascade of LSCM array subsections, eash of which captures one of the signals impinging on the array. An adaptative signal canceller folows each LSCM array to remove captured signal from the input before processing by subsequent section. We also propose in this paper new method for blind algorithm initialization. The SMI is used to estimate initial weights of the LSCMA for a few samples.**

Keywords—**Smart antenna, beamforming algorithm, constant modulus algorithm (CMA), direct matrix inversion (DMI), normalized constant modulus algorithm (NCMA),**

I. Introduction

IN cellular radio systems, spectral crowding and cochannel interference are becoming increasingly important issues as the number of subscribers grows. Cochannel interference results from frequency reusage whereby multiple ce Ils operate on the same carrier frequency [1]. Depending on geographic considerations and environmental conditions, cochannel interference can be severe. It would be desirable to incorporate "smart" directional antennas into the cellular system that are capable of reducing the effects of cochannel interference and in turn allow greater frequency reusage. These antennas should be capable of simultaneously estimating the angles of arrival (AOAs) of several cochannel sources, as well as demodulating the signals themselves .

In recent years, there has been much interest in developing cochannel signal demodulation algorithms for systems having a single antenna as weil for systems using multiple antennas. For example, techniques based on maximum likelihood sequence estimation and maximum a posteriori symbol detection were presented in [2] for the joint demodulation of cochannel data signals using a single antenna. Signal copy algorithms for multiple antenna systems have also been proposed. One such technique is based on a two-step procedure incorporating a high-resolution direction-finding algorithm followed by a signal estimation algorithm that demodulates the sources using a maximum likelihood criterion [3], [4].

In this paper, we analyze a blind adaptive antenna technique called the multistage LSCMA adaptive beamformer. It consists of a cascade of several CM array subsections adapted by the least-square constant modulus algorithm (LSCMA). Section 2 of this paper is devoted to adaptive beamforming principals for antenna array. Section 3 presents and discusses the new proposed algorithm, the SMI-LSCMA adaptive beamforming algorithm. Section 4 gives the simulations results, and finally section 5 concludes the paper.

Manuscript received February 21, 2012.

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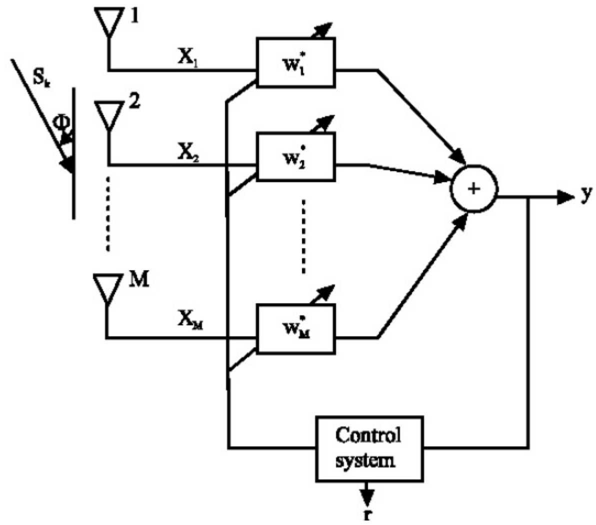

Fig. 1. Simple smart antenna.

II. Smart antenna system

An adaptive antenna array is the one that continuously adjusts its own pattern by means of feedback control. The principal purpose of an adaptive array sensor system is to enhance the detection and reception of certain desired signals while nulling interferes at same time, [5]. This intelligent antenna array (adaptive antenna) which requires a reference signal can be presented by the following figure (2):

In this system the received signal $x(n)$ is multiplied with the complex weight vector w and summed up resulting in array output $y(n)$. An adaptive algorithm is then employed to minimize the error $e(n)$ between a desired signal $d(n)$ and the array output $y(n)$. The output of beamformer at time n $(y(n))$ is represented by :

$$y(n) = w^H x(n) \tag{1}$$

where

$$w = [w_1, w_2, \ldots, w_k] \;\text{ and }\; x(n) = [x_1, x_2, \ldots, x_k],$$

k: indicates each of the array elements.

H: denotes Hermitian (complex conjugate) transpose.

The signal processor of the array automatically adjusts, from the collected information, the weight vector w which corresponds to the complex amplitude excitation along each antenna element. Typically, various adaptive algorithms have already been developed to calculate the optimal weight coefficients that satisfy several criteria or constraints. The most frequently used performance criteria include MMSE, maximum signal-to-interference-and-noise-ratio (SINR), maximum likelihood (ML), minimum noise variance, minimum output power and maximum gain,. . . etc.

By the estimation of the second order statistics, the adaptive beamforming algorithm, iteratively adjust the weight vector to approaches setting performance criterion. The algorithm is said to be converged when such a performance criterion is met.

Basically there are two major classes of adaptive beamforming algorithms, usually called blind and non-blind algorithms. The letter (i.e. non-blind algorithms) use training sequence $d(n)$ to update its weight vector, this training sequence is received from transmitter during training period. An example of these algorithms is LMS, RLS and DMI [6]-[7]-[8]. On the other hand, Blind algorithms like constant modulus algorithm (CMA)[9], Spectral self-Coherence Restoral (SCORE) [10] and Decision Directed (DD) do not need any training sequence to update its complex vector but use some known proprieties of the desired signal.

III. Multistage Constant Modulus Array

In multistage CM array, each stage consists of two main components an adaptive beamformer to capture a source and an adaptive signal canceller to remove the captured source so that in the next stage a different source can be recovered. Most CM array co-channel separators use stochastic gradient descent (SGD) form [1] to recover each source. The main drawback of SGD method is its slow convergence, a fast convergence version of CMA is Least Square CMA (LS-CMA) [2], since the error criterion is calculated from the average of desired response unlike the SGD methods. In [4] the issue of tracking the captured signal during fading is discussed, where decision direct approach is used to track the fading signal. In this section we analyse the convergence of LS-CMA with SMI initialization for multistage CM array and the tracking of the captured signal during short time fading to reduce error propagation through later stages. In real environment, the signal can't be stable and change continually. Thus, adaptive process must dynamically modify weight vector to meet the new environment requirement. SMI algorithm estimates the covariance matrix R and cross-correlation matrix$r$ in finite observation interval to obtain the optimum weight vectors[11]. R and r can be estimated in (N_2-N_1) block size respectively as follows [12]:

$$R = \sum_{i=N_1}^{N_2} x(n)x^H(n) \tag{2}$$

$$r = \sum_{i=N_1}^{N_2} d^*(n)x^H(n) \tag{3}$$

Where, N_1 and N_2 are the lower and upper limits of observation interval (the bloc size $(N_2 - N_1)$ is taken small)

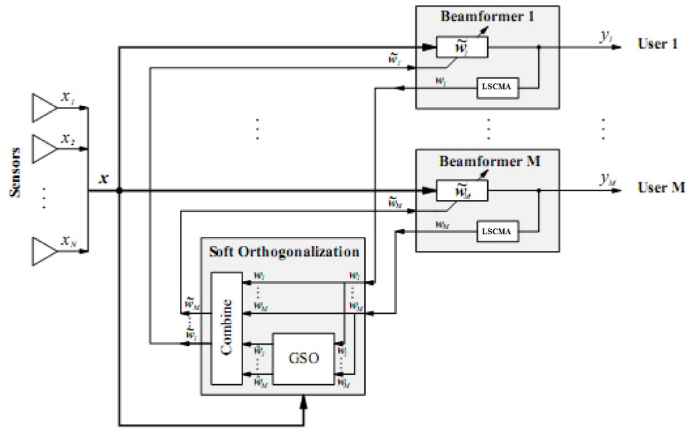

Fig. 2. Multistage Constant Modulus Array.

and n is the sample index. The block acquisition (N_2-N_1) is taken small for two reasons, first to remove signal distortion effect on algorithm performances. Second, DMI calculate the inverse covariance matrix R and large block size increase computational complexity [12].

So the use of SMI for the weight vector updating in real time process is not possible. Thus we use the least-squares constant modulus algorithm to update the weight vector.

When there are several sources received at the antenna array multistage CM array is used to extract each signal in a sequential manner. Each stage of multistage array consists of adaptive beamformer to capture a source, and adaptive signal canceller to remove the captured signal from the array inputs. Figure 2 illustrates a multistage constant modulus array. The received baseband signal assuming sampled at the mth antenna element can be written as :

$$x_m(t) = \sum_{p=1}^{P}\sum_{l=1}^{L} a_{lp}s_{lp} + n(k) \tag{4}$$

Where $a_{lp}(k)$ is the array response matrix corresponding to the l^{th} path of the p^{th} source $s_{lp}(k)$, $n(k)$ is additive white gaussian noise, P is the number of sources and L is the number of multipaths.

The estimate of one source at the beamformer output is given by equation 1. weight vector is calculated as:

$$w(k+1) = R_{xx}^{-1} r_{xd} \tag{5}$$

Given that R_{xx} and r_{xd} are :

$$R_{xx} = \langle x(k)x^H(k)\rangle \tag{6}$$

$$r_{xx} = \langle x(k)d^*(k)\rangle \tag{7}$$

where $< \quad >$ denotes the average over $N > 0$ block size, * denotes complex conjugate and $d(k)$ the instantaneous modulus of the received signal given as,

$$d(k) = \frac{y(k)}{|y(k)|} \tag{8}$$

An adaptive signal canceller, removes the captured signal by weighting the output $y(k)$ with the canceller weights

$$c(k) = [c_1(k), c_2(k).....c_m(k)] \tag{9}$$

which is then subtracted from $x(k)$ to generate the input vector to the next stage and also be used to update the canceller weights as follows [3].

$$c(k+1) = c(k) + 2\mu y^*(k)e(k) \tag{10}$$

where $\mu > 0$ is the step size and the input vector to the next stage $e(k)$ is calculated as :

$$e(k) = x(k) - y(k)c(k) \tag{11}$$

IV. Simulation and Results

A two stage LS -CMA beamformer with adaptive signal canceller has been modelled using Matlab in multipath environment. The simulations assume that there are $P = 3$ sources with $L = 20$ multipaths for each source, and using a uniform antenna array with $m = 8$ elements. The source signal is modulated using BPSK modulation, which undergoes Rayleigh fading with Signal to Noise Ratio (SNR) of 5 dB. Figure 3 , 4 and 5 shown the array pattern for 3 stages.

Figure 3 shows the beamformer response for the first stage. We can clearly see that the adaptive block size beamformer is capable of capturing the 3 sources (source 1 in stage 1, source 2 in stage 2 an source 3 in stage 3) as shown in figure 4 and 5.

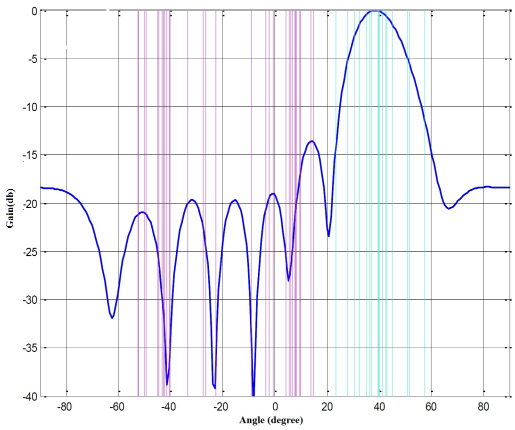

Fig. 3. Array pattern after 500 iterations. Signal 1 detection

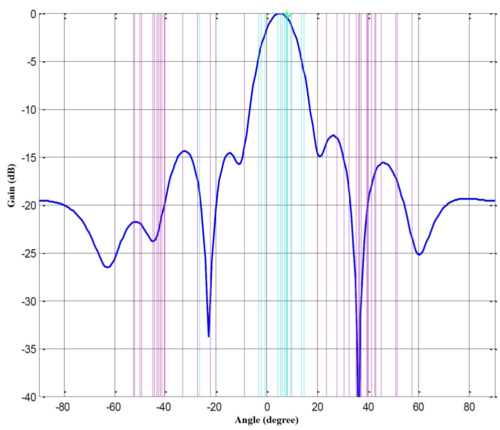

Fig. 4. Array pattern after 800 iterations. Signal 2 detection.

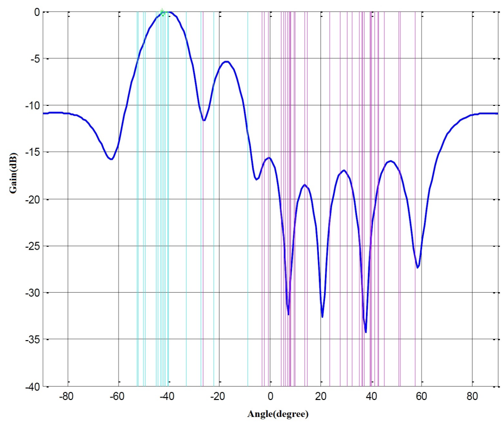

Fig. 5. Array pattern after 1000 iterations. Signal 3 detection.

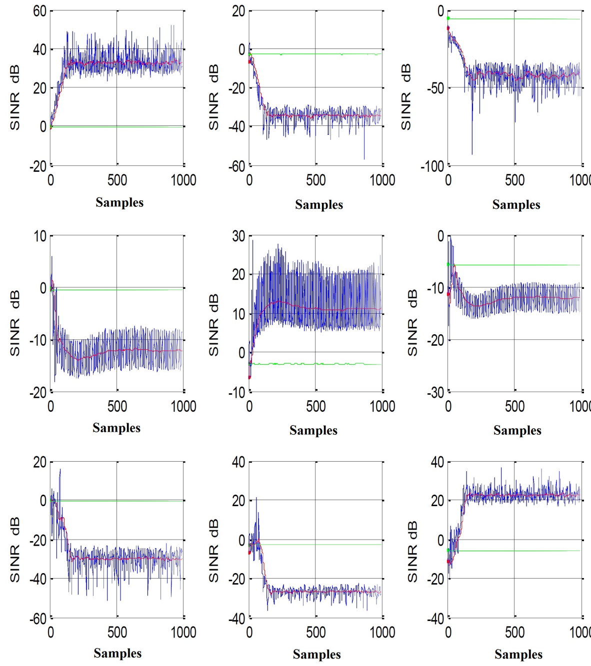

Fig. 6. SNIR evolution for the three stages .

We can clearly see from figure 6 that the first signal is detected from the 500 first simples. The identification of the second signal is carried out after 800 iterations. Finally, the last signal is detected on the last 200 iterations.
So, we can conclude that the LSCMA system detects signals following a multistage process where each floor will extract a signal on a finite number of iterations and passes the pointer to the next.

V. Conclusion

This paper presented multistage LS -CMA array with SMI initialization for signal separation. The Initial weight vector is adapted using SMI. It is shown that the use of SMI enables the beamformer to capture different sources faster than with classical initial weight vector . It also shown with the proposed algorithm that the SNIR are improved and beamformer has converged it can still lock on the captured signal even when the amplitude of the captured signal is smaller than that of the other signal present. This method gives more robust beamforming technique due to the better averaging of the estimated source during short term fading.

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