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MMSE Adaptive Beam Forming Algorithms for WCDMA Mobile Communication System

Shibila T M[1], Abdul Rias P[2]

PG Scholar, Department of Electronics & Communication Engineering, Al Ameen Engineering College, Shoranur, Kerala, India[1]

Assistant Professor, Department of Electronics and Communication Engineering,

Al Ameen Engineering College, Shoranur, Kerala, India[2]

Abstract: Smart antenna technologies are very important for the system implementation. Smart Antennas serve different users by radiating narrow beams. The same frequency can be reused even if the users are in the same cell or the users are well separated. Thus, the capacity of the system is increased by implementing this additional intra cell reuse. This paper discusses algorithms developed for smart antenna applications to WCDMA. The Minimum mean-square error (MMSE) Algorithm is an adaptive beam forming algorithms used in smart antennas.

Keywords: Minimum mean-square error (MMSE), Maximum likelihood (ML), Adaptive beam forming, smart antenna.

I. INTRODUCTION

Adaptive Beam forming is a technique in which an array of antennas is exploited to achieve maximum reception in a specified direction by estimating the signal arrival from a desired direction (in the presence of noise) while signals of the same frequency from other directions are rejected. This is achieved by varying the weights of each of the sensors (antennas) used in the array. It basically uses the idea that, though the signals emanating from different transmitters occupy the same frequency channel, they still arrive from different directions. This spatial separation is exploited to separate the desired signal from the interfering signals. In adaptive beam forming the optimum weight are iteratively computed using complex algorithms based upon different criteria [1],[2].

II. THEORY

Antennas (and antenna arrays) often operate in dynamic environments, where signals (both desired and interfering) arrive from changing directions and with varying powers. As a result, adaptive antenna arrays have been developed. These antenna arrays employ an adaptive weighting algorithm that adapts the weights based on the received signals to improve the performance of the array [3].

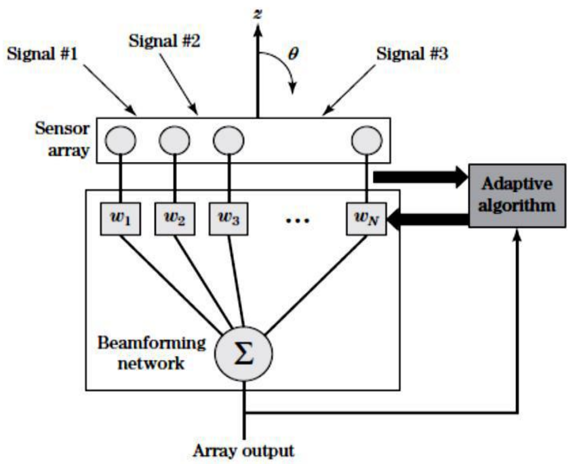

Figure (1): Functional diagram of an N-element adaptive array [6].

Figure (1) shows a diagram of an adaptive array. It consists of the sensor array, the beam forming network, and the adaptive processor that adjusts the variable weights in the beam forming network. The array design depends on the propagation medium in which the array operates the frequency spectrum of interest, and the user's knowledge of the operational signal environment [4].
The array consists of N sensors designed to receive (and transmit) signals in the propagation medium. The output of each of the N elements goes to the beam forming network, where the output of each sensor element is first multiplied by a complex weight (having

both amplitude and phase) and then summed with all other weighted sensor element outputs to form the overall adaptive array output signal. The weight values within the beam forming network then determine the overall array pattern. It is the ability to shape this overall array pattern that in turn determines how well the specified system requirements can be met for a given signal environment [5].
The weight values within the beam forming network then determine the overall array pattern. It is the ability to shape this overall array pattern that in turn determines how well the specified system requirements can be met for a given signal environment [7].

There are type of arrays have proven useful in different applications is called the conventional array illustrated in Figure (2)

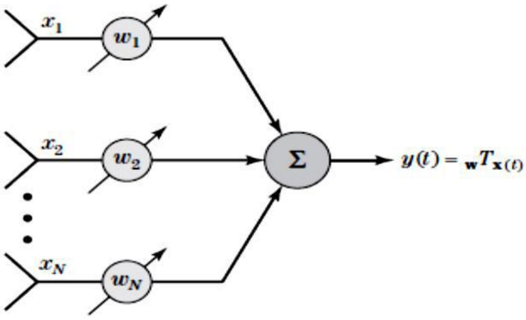

Figure (2): Conventional narrowband array

The outputs of the array illustrated in Figures (2) as:

$$y(t) = w^t x(t) \qquad (1)$$

Where $x(t) = s(t) + n(t)$is the vector of received signals that are complex valued functions. The signal vector $s(t)$induced at the sensor elements from a single directional signal source is assumed to be:

$$s(t) = Se^{j\omega_0 t} \qquad (2)$$

Where ω_0 is the (radian) carrier frequency and S represents the signal power. Assuming identical antenna elements, the resulting signal component in each array element is just a phase-shifted version of the signal appearing at the first array element encountered by the directional signal source. It therefore follows that the signal vector $s(t)$ is written as

$$s^T(t) = Se^{j\omega_0 t}, Se^{j\omega_0 t+\theta_1}, \dots\dots, Se^{j\omega_0 t+\theta_{N-1}} = s(t)v^T \qquad (3)$$

Where v is defined to be the array propagation vector

$$v^T = 1, e^{j\theta_1}, \dots\dots, e^{j\theta_{N-1}} \qquad (4)$$

Consequently, the received signal vector for the conventional array

$$\mathrm{x(t) = s(t)v + n(t)} \qquad (5)$$

In developing the optimal solutions for selected performance measures, four correlation matrices will be required. These correlation matrices are defined as follows for narrowband uncorrelated signal processes:

$$\mathrm{R_{ss} \cong E\{s^*(t)s^T(t)\}} \qquad (6)$$

Where S denotes the signal power

$$\mathrm{R_{nn} \cong E\{n^*(t)n^T(t)\}} \qquad (7)$$

$$\mathrm{r_{xs} \cong E\{x^*(t)s(t)\}} \qquad (8)$$

And $$R_{xx} \cong E\{x^*(t)x^T(t)\} = R_{ss} + R_{nn} \qquad (9)$$

Suppose the desired directional signal $s(t)$ is known and represented by a reference signal $d(t)$.This assumption is never strictly met in practice because a communication signal cannot possibly be known a priori if it is to convey information; hence, the desired signal must be unknown in some respect. Nevertheless, it turns out that in practice enough is usually known about the desired signal that a suitable reference signal $d(t)$ is obtained to approximate $s(t)$ in some sense by appropriately processing the array output signal. For example, when $s(t)$is an amplitude modulated signal, it is possible to use the carrier component of $s(t)$ for $d(t)$ and still obtain suitable operation. Consequently, the desired or “reference” signal concept is a valuable tool, and one can proceed with the analysis as though the adaptive processor had a complete desired signal characterization.
The difference between the desired array response and the actual array output signal defines an error signal as shown in Figure2.3.

$$y(t) = w^T(t)x(t) \qquad (10)$$

$$e(t) = d(t) - y(t) = d(t) - w^T(t)x(t) \qquad (11)$$

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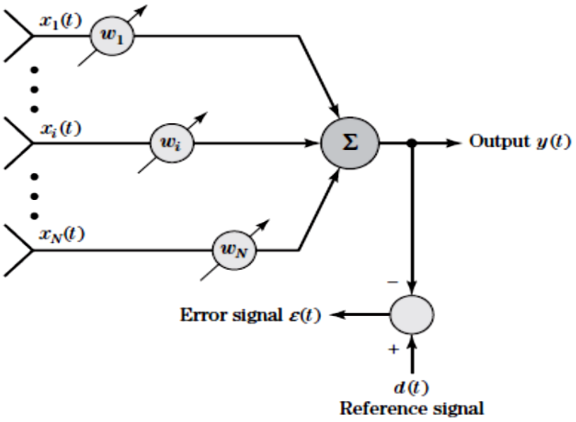

Figure2.3. Basic adaptive array structure with known desired signal

Since $d(t) = s(t)$ it follows that the optimum choice for the weight vector must satisfy
$R_{xx}w_{opt} = r_{xd}$ or $w_{opt} = R_{xx^{-1}}r_{xd}$ (12)

1. *Minimum mean-square error (MMSE)*

The signal $d(k)$ is the reference signal. Preferably the reference signal is either identical to the desired signal $s(k)$ or it is highly correlated with $s(k)$ and uncorrelated with the interfering signals $i(k)$. If $s(k)$ is not distinctly different from the interfering signals, the minimum mean square technique will not work properly. The signal $e(k)$ is the error signal such that:

$\varepsilon(k) = d(k) - wH_x(k)$ (13)

$|\varepsilon(k)|^2 = |d(k)|^2 - 2d(k)w^H x(k) + w^H x(k)x^H(k)w$ (14)

Taking the expected value of both sides and simplifying the expression we get

$E[|\varepsilon|^2] = E[|d|^2] - 2w^H r + w^H R_{xx} w$ (15)

Where the following correlation are defined $r = E[d^*.x] = E[d^*.(x_s + x_i + n)]$ (16)

$R_{ss} = E[xx^H] = R_{ss} + R_{uu}$ (17)

$R_{ss} = E[x_s x_s^H]$ (18)

$R_{uu} = R_{ii} + R_{nn}$ (19)

In general, for an arbitrary number of weights, we can find the minimum value by taking the gradient of the MSE with respect to the weight vectors and equating it to zero. Thus the Wiener-Hopf equation is given as

$\nabla_\omega E[|\varepsilon|^2] = 2R_{xx}\omega - 2r = 0$ (20)

Simple algebra can be applied to yield the optimum Wiener solution given as

$\omega_{MSE} = R_{xx}^{-1} r$ (21)

If we allow the reference signal d to be equal to the desired signal s, and if s is uncorrelated with all interferers, we may simplify the correlation. So the simplified correlation $r = E[s^*.x] = S.a_0$ (22)

$S = E[|s|^2]$ (23)

The optimum weights can then be identified as

$\omega_{MSE} = SR_{xx}^{-1} a_0$ (24)

III. RESULTS AND DISCUSSION

Let N = 8 element array with d = 0.5λ has a received signal S = 1 arriving at θ0 = 30º, and interferer arriving at angle θ1 = −60º, with noise variance 0.001. Calculate the optimum weights and plot the pattern.

Matlab code:

```
a0 = exp(1j*2*pi*d*(n-1)*sin(th0)).';
a1 = exp(1j*2*pi*d*(n-1)*sin(th1)).';
Rss = a0*a0';
Rnn = 0.001*eye(N);
Rii = a1*a1';
Ruu = Rii + Rnn;
```

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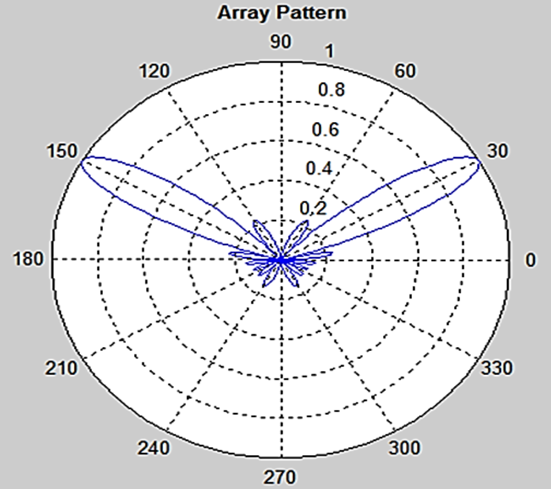
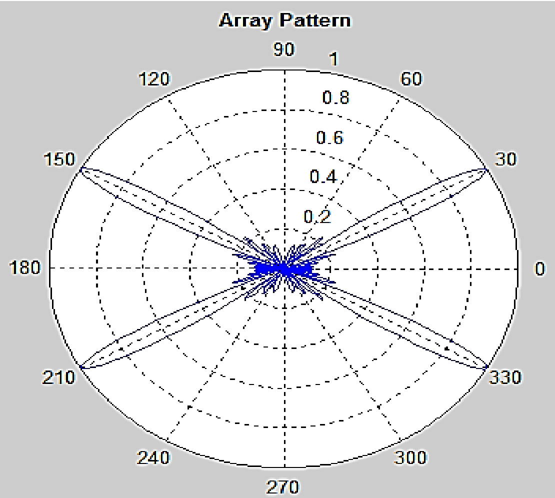
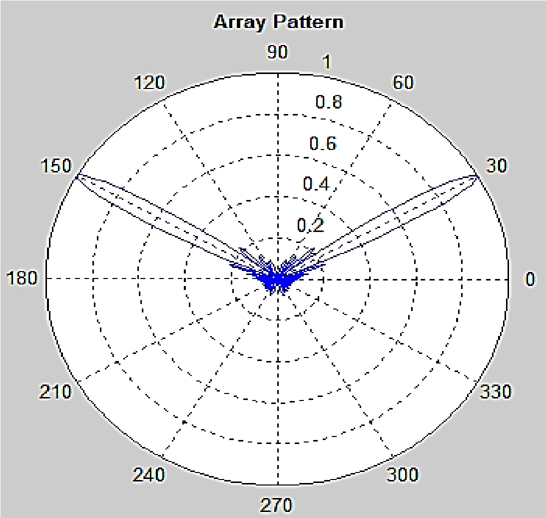
Rxx = Ruu + Rss;
w = inv(Rxx)*a0;
For N=8, d=0.5
signal arriving at the angle θ0 = 30◦,
an interferer at θ1 = −60◦.



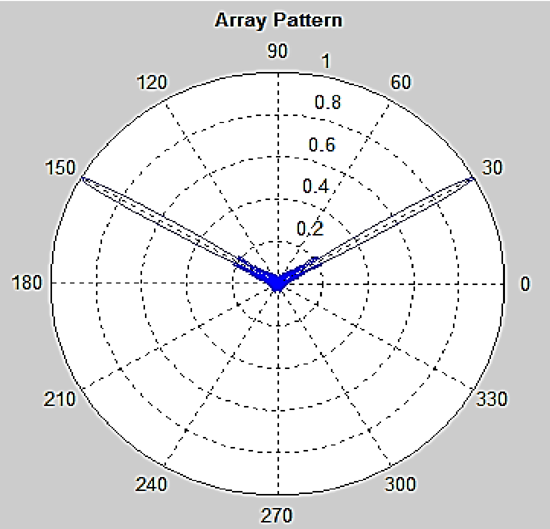
For N=8, d=1



For N=16, d=0.5



For N=32, d=0.5



IV. CONCLUSION

In this project, two of adaptive algorithms have been discussed and simulated using Matlab. These algorithms were found differ in their complexity and convergence. The adaptive algorithm in 3G must have low computational complexity and hardware implementation. For (MMSE) system, it was found that any increasing in the number of elements (N) will enhance the efficiency of received signal and decrease the effect of noise, but at the same time this increasing in (N) will make the beam width of radiated pattern narrower more due to reduction in the radiated energy signal.

REFERENCES

[1] Paul C. Wei, Jun Han, James R. Zeidler, and Walter H. Ku, *Comparative Tracking Performance of the LMS and RLS Algorithms for Chirped Narrowband Signal Recovery*, IEEE Transactions On Signal Processing, VOL. 50. NO. 7, p.p. 1602-1609, JULY 2002.
[2] Bhavishya R., G. Chaitanya S., K. Abhishek J., M. Siva G., T. V. Ramakrishna, and K. Sarat K., *Comparison and performance evaluation of different adaptive beam forming algorithms in wireless communications with smart antenna*, International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 3, p.p. 630-633, 2012
[3] SeifuGirma, *Investigation of Adaptive Beamforming Algorithm for Smart Antenna system to Improve the Effect of Angle Separation*,, Master thesis, Addis Ababa University, July, 2012.
[4] Jyoti D., Shadab A., Kuldeep G., *Comparison between Adaptive filter Algorithms (LMS, NLMS and RLS)*, International Journal of Science Engineering and Technology Research (IJSETR),V. 2, No. 5, p.p. 1100-1103, 2013.
[5] Santhi rani, P.V Subbaiah and K. Chennakesavareddy, *Smart Antenna Algorithms for WCDMA Mobile Communication Systems*, IJCSNS International Journal of Computer Science and Network Security, V.8, No.7, p.p.182- 186. 2008.
[6] ZhigangRong, *Simulation of Adaptive Array Algorithms for CDMA Systems*, Master thesis, Electrical Engineering, Blacksburg, Virginia, 1996.
[7] R. Struzak , *Basic Antenna Theory*, 4th edition, March 2005.
[8] Joel R. Hallas, *Basic Antennas: Understanding Practical Antennas and Design*, February 28, 2009.
[9] Yi Huang, Kevin Boyle, *Antennas: From Theory to Practice*, August 2008.
[10] T. K. Sarkar, Michael C. Wicks, M. Salazar-Palmaand Robert J. Bonneau, *Smart Antennas*, May 2003.
[11] Robert A. Monzingo ,Randy L. Haupt and Thomas W. Miller, *Introduction to Adaptive Arrays*, 2nd Edition 2011.