Analysis of Smart Antenna Beamformer characteristics using CMA and DMI

V.L.Bhavani.Maddirala, C.Subba Rao

Abstract— The Smart Antenna is a new technology and has been used in the mobile communications systems such as GSM and CDMA. Advent of powerful, low cost, digital processing components and the development of software-based techniques has made smart antenna systems a practical reality for both base station and mobile station of a cellular communications system. The core of the smart antenna system is the selection of smart algorithms in adaptive array. Using beam forming algorithms the weight of antenna arrays can be adjusted to form certain amount of adaptive beam to track corresponding users automatically and at the same time to minimize interference arising from other users by introducing nulls in the respective directions. Thus interferences can be suppressed and the desired signal can be extracted. This paper presents description and comparative analysisand utility of various reference signals based on direct matrix inversion and constant modulus algorithms. Exhaustive studies of simulation of beam patterns and learning characteristics have proved the efficacies of the proposed work from application point of view.

Index Terms— Antenna arrays, Adaptive algorithms, Beam-forming, constant modulus algorithm, Direct matrix inversion, interference, Smart antenna, Signal nulling.

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1 INTRODUCTION

Conventional base station antennas in existing operational systems are either Omni directional or sectorised. There is a waste of resources since the vast majority of transmitted signal power radiates in directions other than towardsthe desired user. In addition, signals power radiated throughout the cell area will be experienced as interference by any other user than the desired one. Concurrently the base staion receives interference emanating from the individual users with in the system. Smart antennas offer a relief by transmitting or receiving the power only to or from the desired directions. Smart Antennas can be used to achieve different benefits. The most important is higher network capacity. It increases network capacity [1], [2] by precise control of signal nulls.

By providing higher network capacity, it increases revenues of network operators and gives customers less probability of blocked or dropped calls. Adaptive beam forming is a technique in which an array of antennas is exploited to achive maximum reception [3] in specified directions by estimating the signal arrival from a desired direction in the presence of noice while signals of the same frequency from other directions are rejected.

2 CONSTANT MODULUS ALGORITHM (CMA)

The configuration of CMA adaptive beam forming is the same as that of the Sample Matrix Inversion system except that it requires no reference signal [5]. It is a gradient -based algorithm that works on the theory that the existence of interference causes changes in the amplitude of the transmitted signal, which other wise has a constant envelope (modulus). The minium shift key (MSK) signal, for example, is a signal that has the property of a constant modulus. The weight is updated by the equation

$$W(n+1) = W(n) + \mu U(n) e(n) \quad (1)$$

Where

μ = step size Parameter

The estimation error is given by

$$e\ (n) = Y(n)(R_2 - |Y(n)|)^2 \quad (2)$$

Here

Y (n) is the array output after n^{th} iteration

R_2 is the covariance matrix is given by

$$R_2 = X.X^H \quad (3)$$

The main disadvantage of the CMA is slow convergence time. So, to avoid this, DMI algorithm has been developed.

The alogorithm of CMA as shown bellow

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Define the of k,$\varphi$      %k= no. of antennas,$\varphi$ = angle

$W = 1/k * [1\ e^{-j\pi sin\varphi}\ e^{-j2\pi sin\varphi} \dots\dots. e^{-j(k-1)\pi sin\varphi}]$

Noise = sin $\pi\varphi + j\ cos\pi\varphi$          %noise signal
X= noise
For an = 1: k

X (n) = noise+$n_1 + n_2 + X$           % input signal
For an= 1: k
$n_{an} = signal_{n_1} * e^{-jk\pi sin\varphi}$           % antenna signals
Yan= $w^* X(an)$           %out put signal
Error=Y (n) (d (n)-|Y (n)|)$^2$           % error signal
W=w+$\mu.error.X(an)$           % update weighting factor
End
Array factor=$w^* e^{-jk\pi sin\varphi}$
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One severe disadvantage of the CMA is slow convergence time. This slow convergence limits the usefulness of the algorithm in the dynamic environment wher the signal must be

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capture quickly. This also limits the usefulness of CMA when channel conditions or rapidly changing. To avoid those problems the DMI algorithm has been proposed.

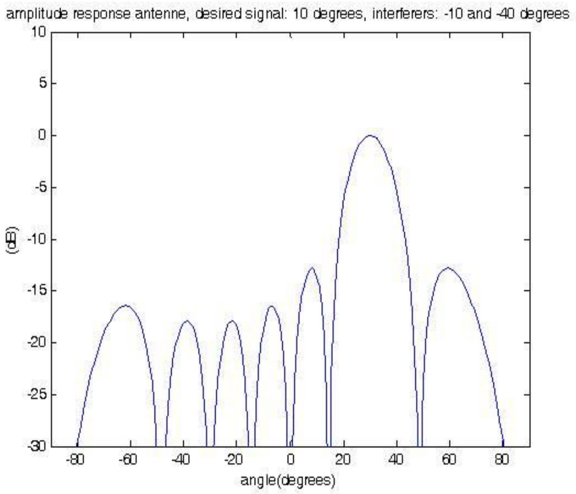

Fig.1. Normalize array factor of CM algorithm when N=8

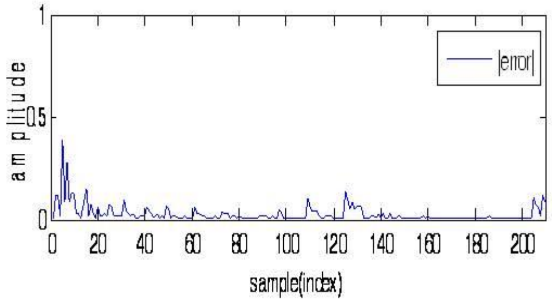

Fig 2 Error response of CM algorithm when N=8

3 DIRECT MATRIX INVERSION ALGORITHM (DMI)

The Direct Matrix Inversion algorithm provides good performance in a discontinuous traffic when the number of interferers and their positions remain constant during the duration of the block acquisition [5]. Weight adaptation in the DMI algorithm can be achieved by using block adaptation technique where the adaptation is carried over disjoint intervals of time is the most common type. This block adaptation technique is suitable for mobile communications where the signal environment is highly time varying. The overlapping block adaptation technique is computational intensive as adaptation intervals are not disjoint but overlapping. This technique gives better performance but number of inversions required is more when compared to block adaptation method. Another block adaptation technique is the block adaptation technique with memory. This method utilizes the matrix estimates computed in the previous blocks. This approach provides faster convergence for spatial channels that are highly time correlated. This technique works better when the signal environment is stationary.

The DMI algorithm employs direct inversion of the covarience matrix R and therefore it has faster convergence rate. The weight vector can be estimated as shown below

W=$R^{-1}r$ (4)

From the above equation the weights will be updated for each incoming block. Because of the estimation there is a chance to have residual error in the direct matrix inversion (DMI) algorithm. The estimates of the covariance matrix R and correlation matrix r are given by

$R = E[d(n)X^{H}(n)]$ (5)

$r = E[d(n)X(n)]$ (6)

Here

d= interference signal
x= desire signal
R=co-varience matrix
r= correlation matrix

The error e due to estimation can be computed by

e= RW- r (7)

Here

R=co-variance matrix
W= weighted factor
R= correlation matrix

The main disadvantage of DMI alogorithm is extremely simple to implement and better convergence.

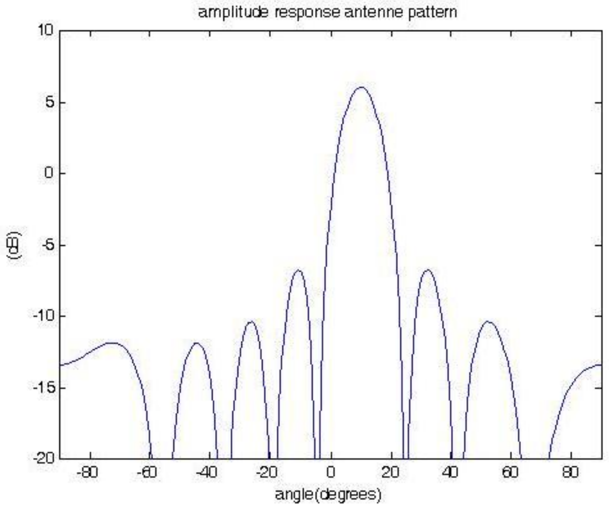

Fig.3. Normalize array factor of Direct matrix inversion algorithm when N=8

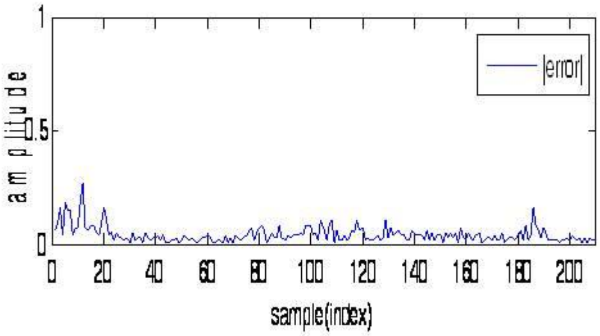

Fig.4. Error response of DMI algorithm when N=8

4 RESULTS

For simulation purpose an N element liner array is used with its individual elements spaced at half wave length distince. For simplicity sake the reference signal d (t) is considered to be same as the desired signal x (t). The array factor is obtained for the Anglen of Arrival of the desired user is at 30^0 and interferer is at 60^0. The algorithms are simulated by using MATLAB. The simulation was done with a relatively low system noise, which is Gaussian noise with a sigma of 0.01.

Results observed from the CM algorithm are as follows. Fig.1 and Fig.2 shows the array factor response and error response of CM algorithm for n=8. From the array factor response, it was observed the main beam is at 30^0, starting at 10^0 for the desired user. From the graph of the error response it was observed that the amplitude of CMA at 10th sample is near to 0.5.

Results observed from the DMI algorithm are, Fig.3 and Fig.4 shows the array factor response and error response pf DMI algorithm for n=8. From the arrayfactor response it was observed that yhe main beam is at 30^0, startng at 10^0 for the desired user. From the graph of the error response it was observed that the amplitude at 10th sample reduces nearly to0.2 for DMI algorithm.

From both the algorithms it was observed that the CM algorithm converges slower than the DMI algorithm. In both algorithms the main beam is obtained at the same angle if the adaptive array, where in both the interference was rejected. But the error response of DMI is reduced compared to CMA as shown in Fig.2 and Fig.4

5 CONCLUSION

This paper discussed various adaptive beamforming algorithms like Direct Matix Inversion algorithm (DMI) and constant modulus algorithm (CMA) used in smart antennas. The result obtained from the simulations showed that the DMI had better performancein convergence compared to CMA, and the DMI algorithm is most efficient algorithm. The SMI algorithm has been proposed because of its fast convergence. However, it is computationally too complex. The use of a DMI adaptive array at the base station site can suppress interference and increase the user capacity of a CDMA cellular system. Smart antennas technology suggested in this present work offers a significantly improved solution to reduce interference levels and improve the system capacity. With this novel approach, each user's signal is transmitted and received by the base station only in the direction of that particular user. This drastically reduces the overall interference in the system. Further through adaptive beamforming, the base station can form narrow beams towards the desired user and nulls towards interfering users, considerably improving the signal-to- noise-plus-interference ration. Such smart antennas also can be used to achieve different benefits.

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