Analysis of Least Mean Square Adaptive Beam forming Algorithm of the Adaptive Antenna for Improving the Performance of the CDMA20001X BaseMobile Radio Network

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***Abstract*:** This paper focused on improving the performance ofcode division multiple access 20001x base mobile radio network using Least Mean Square adaptive beamforming algorithm. Code division multiple access 20001x(CDMA20001x)ischosen astheplatformforthispapersinceithasbeenadoptedastheair-interfacetechnologyby the3Gwirelesscommunicationsystems.But,the performance of the CDMA20001x mobile radio network is limited by both multiple access interference and multipath fading. Thus, this paper concentrates on using adaptive antennas algorithm in minimizing the effect of multiple access interference and multipath fading in order to achieve greater performance on the network and accommodate more subscribers per base station.

The result for the performance of CDMA20001x with various adaptive beamforming algorithms is simulated in Matlab.The simulation results show that LMS adaptivebeamforming algorithm achieved the desired maximum narrow beam towards the desired user and placed nulls on the interfering user in order to suppress the interfering signal.

Keywords*: Adaptive antenna,CDMA20001x,beamforming algorithm, LMS, Multipath fading*

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I. INTRODUCTION.

Over the last few years, wireless cellular communications has experienced rapid growth in the demand for provision of high data rate and voice services. These wireless multimedia services include internet access, multimedia data transfer and video conferencing [1].This increasing demand for high data rate mobile communication services without a corresponding increase in radio frequency spectrum allocationmotivates the need for new techniques to improve spectrum efficiency [2]. Adaptive antenna arrays have emerged as one of the most promising technologies for increasing the spectral efficiency and improving the performance of the present and future wireless communication systems [3]. Adaptive antennas array are arrays of antenna elements that change their antenna pattern dynamically to adjust to the noise, interference in the channel and mitigate multipath fading effects on the signal of interest [4]. In order words, adaptive antenna has a radiation pattern that is not fixed but adapts to current radio conditions, and nulls out the interferers.Code division multiple access 20001x as one of the 3G wireless networks is prone to the effect of multipath fading and multiple access interference [5].Thus, this paper considered Least Mean square adaptive beam forming algorithm of the adaptive antenna for improving the performance of the CDMA20001x by forming a narrow beam towards the desired user and minimizing side lobes towards the interfering signals.

II. ADAPTIVE BEAMFORMING .

Adaptive beam antennas are the most advanced smart antenna systems unlike the switched beam and phase array beam antennas [6].These antenna make use of complex and sophisticated signal processing algorithms to locate and track signals so as to maximize the signal to interference and noise ratio with a view of forming appropriate complex weight values to steer the main beam towards the desired user and place nulls towards the interfering user.Adaptive beamforming is the process of altering the complex weights to maximize the quality of the communication channel[7].During the process of beam forming the digital signal processor interprets the incoming data information,determines the complex weights(amplification and phase information)and multiplies the weights to each element output to optimize the array pattern.The optimization is based on a particular criterion,which minimizes the contribution from noise and interference while producing maximum beam gain at the desired direction. The most widely used adaptive algorithm include Least Mean Square(LMS),sample Matrix inverse(SMI) and Recursive Least Squares(RLS) since they require a training sequence(training) to update its complex weight vector[8].

2.1 LEAST MEAN SQUARE (LMS) ALGORITHM

The least mean square algorithm is a gradient based approach[9].This algorithm varies the weights of the antenna array based on the received data in order to maximize the signal strength of the signal of interest(SOI) and crucial in steering the main beam of the antenna array. Figure 1shows the plane waves arriving at the antenna elements. The signals are then down converted to an Intermediate Frequency and sampled by an Analog to Digital (A/D) converter. The A/D converter converts the electrical signal from analog to digital form. Then, this input signal is multiplied with a variable weight and all the symbols are summed to produce an output, y(k).The reference signal x(k) is generated with local oscillator whose carrier frequency exhibits high correlation with the SOI.

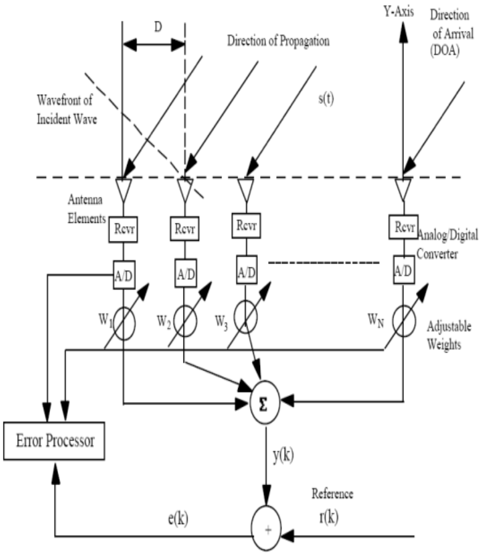

Figure1.Adaptive antenna array system[10]

The error signal e(k) is the difference between the summed output ,y(k) and the reference signal, x(k). The error, as indicated in Figure 1 can be written as[10]:

$$e(k) = d(k) - y(k) \qquad (1)$$

Where , $y(k) = w^H x(k)$

(2)

Thus, $e(k) = d(k) - w^H \ x(k)$

(3)

Squaring the error give

$$|e(k)|^2 = |d(k) - w^H \ x(k)|^2 \qquad (4)$$

Expanding the squared error gives us

$$|e(k)|^2 = |d(k)|^2 - 2d(k) \ w^H \ x(k) + w^H \ x(k) \ x^H(k) \ w \ (5)$$

Simplifying the equation gives

$$E[|e(k)|^2] = E[|d(k)|^2] + w^H(k) R_{xx} w(k) \ 2w^H(k) r \ (6)$$

Writing it in terms of the cost function becomes

$$J(w) = D - 2w^H \ r \ + w^H \ R_{xx} \ w \qquad (7)$$

Where $D = E[|d(k)|^2]$

Employing the gradient method to locate the minimum of, gives

$$\nabla w(J(w)) = 2R_{xx} \ w - 2r \qquad (8)$$

The minimum occurs when the gradient is zero. Thus, the solution for the weights which is the optimum Wiener solution (w or w_{opt}) is given by:

$$0 = 2R_{xx} \ w - 2r \qquad (9)$$

$$w = w_{opt} = R_{xx}^{-1} \ r \qquad (10)$$

The solution in (9) is predicated on our knowledge of all signal statistics and thus in our calculation of the correlation matrix. In general, we do not know the signal statistics and thus must resort to estimating the array correlation matrix ($\bar{R}_{xx}$) and the signal correlation vector ($\bar{r}$) over a range of snapshots or for each instant in time. The instantaneous estimates of these values are given as:

$$\bar{R}_{xx}(k) \approx x(k) x^H(k) \qquad (11)$$

and

$$\bar{r} \approx d^*(k) x(k) \qquad (12)$$

The LMS algorithm can also employ an iterative technique called the method of *steepest descent* to approximate the gradient of the cost function. The direction ofsteepest descent is in the opposite direction as the gradient vector. This method recursively computes and updates the sensor array weights vector w. It is intuitively reasonable that successive corrections to the weights vector in the direction of the negative of the gradient vector should eventually lead to minimum mean square error, at which point the weights vector assumes its optimum value. The method of steepest descent can be approximated in terms of the weights using the LMS method. The steepest descent iterative approximation is given as

$$w(k+1) = w(k) - \frac{1}{2} \mu \ \nabla w \ (J(w(k))) \qquad (13)$$

where, μ is the step-size parameter and ∇w is the gradient of the performance surface. If we substitute the instantaneous correlation approximations, we have the LMS solution.

$$w(k+1) = w(k) - \mu \ [\bar{R}_{xx} \ w - \bar{r}] \qquad (14)$$

$$= w(k) + \mu \ [\bar{r} - \bar{R}_{xx} \ w]$$

$$= w(k) + \mu \ e^*(k) \ x(k) \qquad (15)$$

But, $e(k) = d(k) - w^H(k) x(k)$

(16)

where, μ is the step-size parameter and ∇w is the gradient of the performance surface.

$d(k)$ is the desired signal at the receiver, equal to the transmitted signal and $w(k+1)$ denotes the weights vector to be computed at iteration $(k+1)$ and μ is the LMS gradient step size (gain constant). In order to ensure the stability and convergence of the algorithm, the adaptive step size should be chosen within the range specified as:

$$0 < \mu < \frac{1}{2\lambda_{\max}} \ (17)$$

III. TESTBED

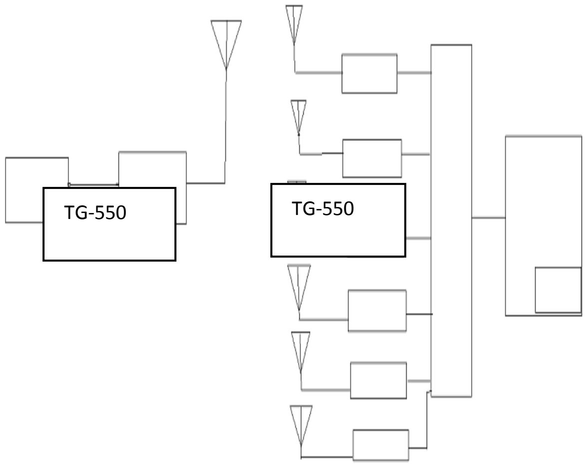

Figure 2.Block diagram of practical experimental Testbed setup

The digital back end of our 1x6 element antenna array is shown in Figure 2. The test bed consists of the PCI-6052E which comprises the ADC. The PCI-6052E is a 16-channel, 14-bit, 105 MHz board (with channels that update simultaneously) for digital sampling. PCI-6052E is installed into the PCI slots of the test bed PC. At the multiple antenna receiver, each of six RF receive signals are down converted to base band and split into their respective I/Q signal pairs. The PCI-6052E installed in the PCI slot of the test bed PC then samples these signals at 20 Msamples/s. The captured samples are then transferred into the MATLAB workspace ready for signal processing.

Table1:Simulation Parameters

Parameter	**Value**
Angle of arrival of desired signal	30^0
Angle of arrival of interfering signal	-60^0
Number of iterations	100
Step size, µ	0.0234
Number of element	6
Inter-element spacing	0.5λ
Antenna geometry	ULA
Receiver	Adaptive antenna
Weight computation	LMS,RLM,DMI

Table 2:The weights for 6 uniform linear array antenna element

Element	**W**	**Weight(LMS)**	**Weight(RLM)**
1	W_1	1.053-0.17i	1.0000
2	W_2	0.050383+0.78618i	0.2763-1.1742i
3	W_3	-0.59623-0.059965i	-0.5093 + 0.0138i
4	W_4	0.27067-0.53408i	0.3975 + 0.6210i
5	W_5	0.63374+0.46644i	0.7968 - 0.5321i
6	W_6	-0.54016+0.84068i	-0.4151 - 0.9447i

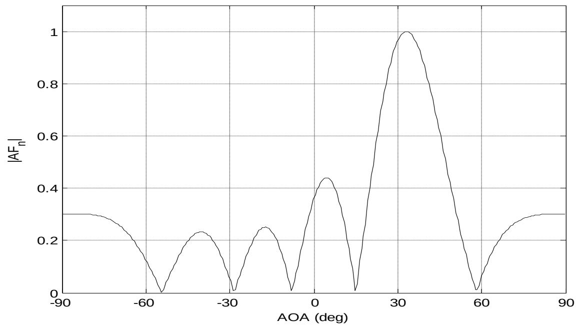

Figure 3:Array factor versus AoA performance with RLS algorithm

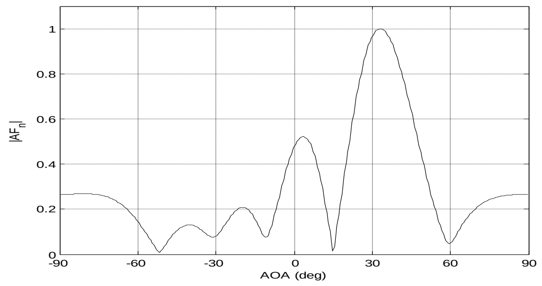

Figure 4:Array factor versus AoA performance with DMI algorithm

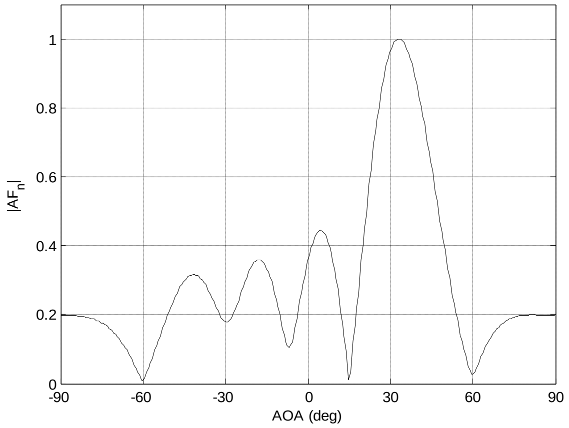

Figure 5:Array factor versus AoA performance with LMS algorithm

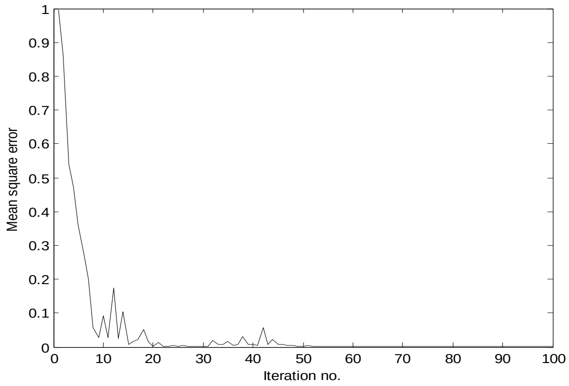

Figure 6:Plot of MSEVs number of iterations for 6 elements,spacing=0.5λ

IV. SUMMARY OF RESULTS

The performance of CDMA20001x with various beam forming algorithm is shown in Figure 3,4,5.As observed from Figure 5,it is noticed that the LMS adaptive algorithm achieved maximum and sharp beam at 30^0 ,the direction of the desired signal and place null at -60^0,the direction of interfering signal in order to suppress interfering signal.Figure 6 show that LMS algorithm converges after 50 iterations with LMS error of 0.The LMS algorithm is characterized by its ease of computation, simplicity in implementation as well as does not require off-line gradient estimations or repetition of data.

V. CONCLUSION

In this paper,we considered the null steering and array pattern synthesis of the LMS adaptive beamforming algorithm**.**The combination of direction of arrival estimation and array synthesis gave a good approach towards interference suppression .Least Mean Square technique was used to achieve null steering and beamforming. Thus, using the LMS algorithm it is therefore possible to steer the main beam in any direction of interest with nulls in the estimated direction of interferer.

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