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MI-NLMS Adaptive Beamforming Algorithm with Tracking Ability

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Abstract: In this study, a Matrix Inversion Normalized Least Mean Square (MI-NLMS) adaptive beamforming algorithm is described with tracking. The MI-NLMS was developed by combining the Sample Matrix Inversion (SMI) and the Normalized Least Mean Square (NLMS) algorithms taking the individual good aspects of both algorithms. Simulation results showed that the improvement in Bit Error Rate (BER) performances is proportional to the number of antenna elements employed in the antenna array. The MI-NLMS algorithm demonstrates an outstanding tracking ability with respect to LMS algorithm in the various signal environments.

Key words: Smart antenna, beamforming algorithm, least mean square, normalized LMS, matrix inversion NLMS

INTRODUCTION

In the past decade, a great effort has been made to build the future generation mobile communication systems. It is expected to provide high-speed and high-quality information services. Adaptive beamforming has numerous applications in array signal processing, radar, sonar, astronomy, medical imaging and wireless communications (Xie *et al*., 2008; Chen *et al*., 2007; Yang *et al*., 2006; Krolik, 1996; Godara, 1997; Rapapport, 1998; Gorodetskaya *et al*., 1999). A beamformer in smart antenna systems employing multiple antennas promise increased system capacity, extended radio coverage and improved quality of service through the ability to steer the antenna pattern in the direction of desired user whilst placing nulls at interferer locations (Zhang *et al*., 2003; Rezk *et al*., 2005). Beamforming is a key technology in smart antenna systems so that many different adaptive beamforming algorithms have been the subject of active research (Agee, 1989; Krim and Viberg, 1996; Liberti and Rappaport, 1999; Chen *et al*., 2005).

The employment of the space-division multiple-access technique has been motivated by the ever-increasing demand on mobile communication capacity (Xie *et al*., 2008). The smart antenna array is capable of separating signals transmitted on the same carrier frequency, provided that they are separated in the spatial domain. When there are reference signals, the non-blind algorithm is desirable. Among these algorithms, temporal updating algorithms such as Least Mean Square (LMS) and Recursive Least-Squares (RLS) which determine the optimum weight vectors sample by sample in time domain (Chen *et al*., 2005) take a long time to converge. This situation becomes worse if channel situation varies rapidly in time domain, where in such time variance, weight vectors updating becomes more complicated. To overcome this problem, block adaptation approach such as Sample Matrix Inversion (SMI) is employed. However, due to its discontinuity in updating the weight vectors, adaptive block approach is unsuitable for continuous transmission. A new beamforming algorithm that will be easy to implement with less complexity and having faster convergence speed and accurate tracking capability is extremely crucial and a challenging issue to explore. The individual good aspects of both block adaptive and sample by sample technique that employed by Mohammad and Zainol (2006) is utitilized to address the issue of tracking ability in this study.

SYSTEM MODEL AND MINLMS ADAPTIVE BEAMFORMING ALGORITHM

Consider an antenna array with kth antenna element. It is assumed that the base station is equipped with an antenna array to receive and transmit signals from and to mobiles. No antenna arrays are assumed for mobiles.

Since, the antenna elements are uniformly distributed across the antenna array, the propagation delay along with any two consecutive elements is the same and therefore, the complex envelope representation of the received signal at the kth antenna element can be expressed as:

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$$x_k(t) = x_1(t)\exp\left\{-j\frac{2\pi}{\lambda}(k-1)d\sin\theta\right\}, \quad k = 1,\ldots,M \tag{1}$$

where, λ is the wavelength of the carrier frequency. The received signal is expressed in terms of vector notation. The lower and upper case boldface within the equation represents vector and matrix quantities, respectively. Thus the received signal is identified as (Litva and Lo, 1996):

$$x(t) = [x_1(t), x_2(t), \ldots, x_M(t)]^T \tag{2}$$

where, T represents transpose. Let $a(\theta)$ define a vector which yields:

$$a(\theta) = \left[1,\ e^{-j\frac{2\pi}{\lambda}d\sin\theta}, \ldots, e^{-j\frac{2\pi}{\lambda}(M-1)d\sin\theta}\right]^T \tag{3}$$

The complex envelope representation of the received signal in the array is thus given by:

$$x(t) = a(\theta)x_1(t) \tag{4}$$

The vector $a(\theta)$ is the steering vector.

Assuming multiple users transmitting at the same time, antenna elements are isotropic and the channel is considered to be an Additive White Gaussian Noise (AWGN). The complex envelope representation of the received signal can be expressed as follows:

$$x(t) = \sum_{k=1}^{q} a(\theta_k)s_k(t) + n(t) \tag{5}$$

where, q is the number of users, θ_k is the direction of arrival for the kth user, $s_k(t)$ is the transmitted signal for the kth user, n(t) denotes the M×1 vector of the noise at the array element and

$$a(\theta_k) = \left[1,\ e^{-j\frac{2\pi}{\lambda}d\sin\theta_k}, \ldots, e^{-j\frac{2\pi}{\lambda}(M-1)d\sin\theta_k}\right]^T \tag{6}$$

where, $a(\theta_k)$ is the corresponding array response vector of each of the signals. In matrix notation, Eq. 5 becomes:

$$x(t) = A(\theta)s(t) + n(t) \tag{7}$$

Where:

$$A(\theta) = \left[a(\theta_1), a(\theta_2), \ldots, a(\theta_q)\right] \tag{8}$$

In Eq. 8, $A(\theta)$ is the matrix containing the steering vectors and

$$s(t) = \left[s_1(t), s_2(t), \ldots, s_u(t)\right]^T \tag{9}$$

where, s(t) is the input signal. The proposed beamforming algorithm is utilized to determine the input signal s(t) from the received signal vector x(t).

The adaptive beamforming algorithm MINLMS (Mohammad and Zainol, 2006) is employed in this study to calculate final weights vectors according to the Eq. 10 as follows:

$$\begin{aligned} w(n+1) &= w(n) + \mu x(n)e^*(n) \\ &= w(n) + \frac{\mu}{\|x(n)\|^2}x(n)e^*(n) \\ &= w(n) + \frac{\mu}{\|x(n)\|^2}x(n)[d(n) - w^H x(n)]^* \end{aligned} \tag{10}$$

where, w(n) denotes the estimate of the weight vector at the nth iteration and e(n) is the mean square error, μ is a small positive constant, called the step size whose value is between 0 and 1 and the next estimation of the weight vector for the (n+1)th iteration is w(n+1).

In this algorithm, the initial weight vector is obtained by matrix inversion through SMI algorithm, only for the first few samples or for a small block of incoming data instead of arbitrary value before calculating the final weight vector. The final weight vector is updated by using the LMS algorithm.

RESULTS AND DISCUSSION

The performance of the MINLMS algorithm is evaluated through simulation study by using MATLAB®6.5. The adaptive algorithm must be able to track the desired signal source because of the mobility of user terminal in the dynamical environment. In this study the tracking capability of the MI-NLMS algorithm is investigated. For the sake of simplicity the radio channel is assumed to be multipath free and non-dispersive with Additive White Gaussian Noise (AWGN). A simple uniform linear array antenna with half wavelength spacing between the elements is considered. Data sequences are generated using Binary Phase Shift Keying (BPSK) modulation. All DOAs of the signals are uniformly distributed from 30 and 180°. The array antenna receives 8 users signals with different DOAs of 30, 50, 70, 90, 110, 130, 150 and 170°, respectively. In the simulation, an 8 element simple uniform linear array antenna with half wavelength spacing between the elements is assumed to be located at the base station to perform spatial filtering.

The SNR is set at 20 dB and the number of data bit length is 500. The main source of the AWGN is the receiver front-end noise and the noise from the receiver front-end appears to be coming from the all azimuthal directions.

Figure 1 shows the BER performance of the MI-NLMS algorithm with SNR variation when the number of antenna element changes. In the simulation, the angle of arrival of the desired user and the interferer are at 30 and 60°, respectively. The improvement in BER performances is proportional to the number of antenna elements employed in the antenna array. From the Fig. 1, the BER performance can be clearly seen that the BER decreases with the increase of the number of antenna elements. For instance in the AWGN channel, at SNR = 2 dB with antenna element 2, BER is 0.1183 while for the number of antenna element 4, 6, 8 and 10, the corresponding values of BER are 0.0521, 0.0039, 0.0164, 0.0039 and 0.0016. On the other hand, the SNR value decreases with the number of antenna elements increases.

Figure 2 and 3 show the beampattern of first 4 user and last 4 user generated by using the MI-NLMS algorithm in the well separated changing environment, respectively.

In Fig. 2 and 3, it can be seen that most of the signals can be extracted by nulling out all other interference except for the signals with DOAs near the endfire of the array. As shown in both Fig. 2 and 3, the nulls are not constructed perfectly, but the interference suppression is almost less than -25 dB in the most cases except endfire due to the existence of noise. For the signals with DOAs near the endfire of the array (e.g., signals of user 1 and user 8), two or more signals may be fallen into one main beam depending on the angle separation of the signals since the beamwidth of the beam near the endfire is wider than that of the beam steered to other direction.

In such a case, although the interference is not completely rejected due to the wide beamwidth of the main beam directed to the endfire, most of the interference coming from other directions is rejected; therefore, the overall interference level is reduced.

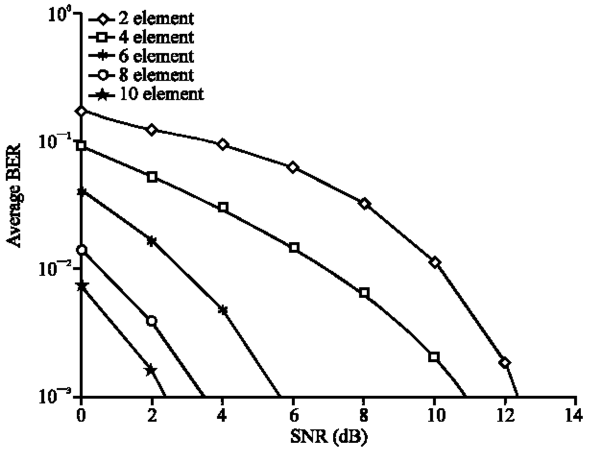

Fig. 1: BER performance of the MI-NLMS algorithm with different antenna elements

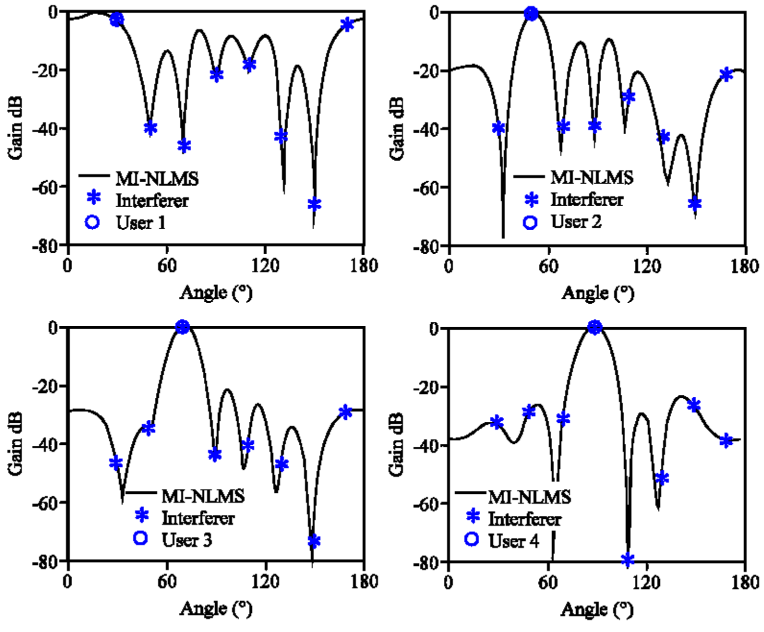

Fig. 2: Beampattern corresponding first 4 user generated by MI-NLMS

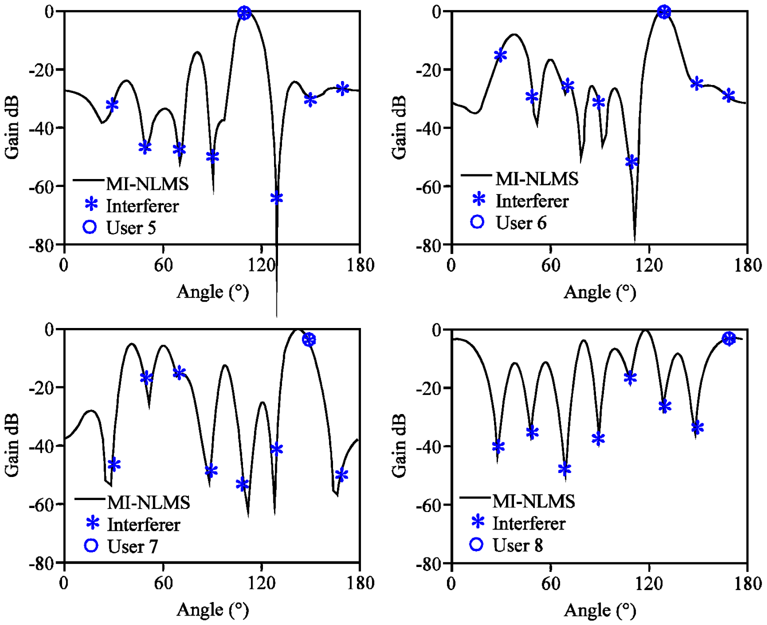

Fig. 3: Beampattern corresponding to last 4 user generated by MI-NLMS

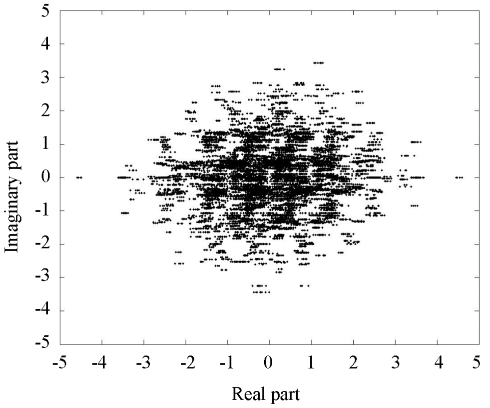

Fig. 4: Signal constellation of user 3 before the beamformer processing

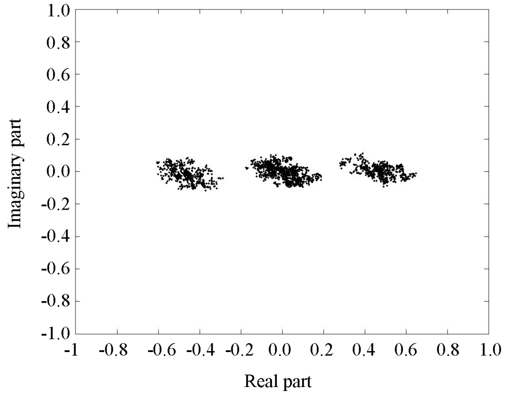

Fig. 5: Signal constellation of user 3 after the beamformer processing

Figure 4 and 5 show the signal constellations of user 3 before and after the beamformer processing using MI-NLMS algorithm, respectively.

It can be observed in the Fig. 5 that the interference from different DOAs is indeed rejected and the signal constellation is reconstructed.

CONCLUSION

In this study, the tracking ability of less complex MI-NLMS adaptive beamforming algorithm is presented. MI-NLMS combines the SMI and NLMS algorithms by considering individual good aspects of both the sample by sample and block adaptive algorithms. Simulation results showed that the proposed algorithm outperforms the conventional LMS adaptive beamforming algorithm. The proposed algorithm provided a superior performance y varying the number of antenna element and outstanding tracking ability even when the signal environment changes.

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REFERENCES

Agee, B.G., 1989. Blind separation and capture of communication signals using a multitarget constant modulus beamformer. Proceedings of the IEEE Military Communications Conference, Oct. 15-18, Boston, MS, USA., pp: 340-346.

Chen, S., N.N. Ahmad and L. Hanzo, 2005. Adaptive minimum bit-error rate beamforming. IEEE Trans. Wireless Commun., 4: 341-348.

Chen, H.H., S.C. Chan and K.L. Ho, 2007. New recursive adaptive beamforming algorithms for uniform concentric spherical arrays with frequency invariant characteristics. Proceedings of the IEEE International Symposium on Circuits and Systems, May 27-30, New Orleans, LA., pp: 2403-2406.

Godara, L.C., 1997. Applications of antenna arrays to mobile communications. Part I: Performance improvement, feasibility and system considerations. Proc. IEEE, 85: 1031-1060.

Gorodetskaya, E.Y., A.I. Malekhanov, A.G. Sazontov and N.K. Vdovicheva, 1999. Deep-water acoustic coherence at long ranges: Theoretical prediction and effects on large-array signal processing. IEEE J. Ocean. Eng., 24: 156-171.

Krim, H. and M. Viberg, 1996. Two decades of array signal processing research: The parametric approach. IEEE Signal Process. Maga., 13: 67-94.

Krolik, J.L., 1996. The performance of matched-field beamformers with Mediterranean vertical array data. IEEE Trans. Signal Process., 24: 2605-2611.

Liberti, J.C. and T.S. Rappaport, 1999. Smart Antenna for Wireless Communications Is-95 and Third Generation CDMA Applications. 1st Edn., Prentice-Hall PTR, New Jersey.

Litva, J. and T.K.Y. Lo, 1996. Digital Beamforming in Wireless Communications. 1st Edn., Artech House Inc., Norwood, MA, USA., ISBN: 0890067120.

Mohammad, T.I. and A.A.R. Zainol, 2006. MI-NLMS adaptive beamforming algorithm for smart antenna system applications. J. Zheijang Univ. Sci. A, 7: 1709-1716.

Rapapport, T.S., 1998. Smart Antennas: Adaptive Arrays, Algorithms and Wireless Position Location. 1st Edn., Piscataway, New Jersey, ISBN: 0780348001.

Rezk, M., W. Kim, Z. Yun and M.F. Iskander, 2005. Performance comparison of a novel hybrid smart antenna system versus the fully adaptive and switched beam antenna arrays. IEEE Antennas Wireless Propagation Lett., 4: 285-288.

Xie, N., Y. Zhou, M. Xia and W. Tang, 2008. Fast blind adaptive beamforming algorithm with interference suppression. IEEE Trans. Veh. Technol., 57: 1985-1988.

Yang, J., H. Xi, F. Yang and Y. Zhao, 2006. RLS-Based adaptive algorithms for generalized eigen-decomposition. IEEE Trans. Signal Process., 54: 1177-1188.

Zhang, Z.M., F. Iskander, Z. Yun and A. Host-Madsen, 2003. Hybrid smart antenna system using directional elements-performance analysis in flat Rayleigh fading. IEEE Trans. Antennas Propagat., 51: 2926-2935.