ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 9, September 2015

Robust 2D-Novel Smart Antenna Array for MIMO Applications

Veerendra[1], Md.Bakhar[2] and Vani.R.M[3]

Research Scholar, Department of E&CE, Visvesvaraya Technological University, Belagavi, India[1]

Departments of E&CE, Guru Nanak Dev Engineering College, Bidar, India[2]

Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga, India[3]

Abstract: This paper introduces robust adaptive beamforming algorithm using novel antenna array geometry. The proposed array geometry consists of doubly crossed uniform linear arrays (ULAs) which gives high accuracy beamforming and angular resolution as compared to conventional ULA. Furthermore, use of this geometry to adaptive beamforming algorithms namely LMS, NLMS and proposed variable step size NLMS (VSSNLMS) improves the convergence rate and interference suppression in smart antenna system. This makes the system robust for interferences and can be used in wireless communication applications, where the fast convergence and interference suppressions are major issues.

Keywords: Beamforming, LMS, MSE, NLMS, Smart-Antenna, VSSNLMS.

I. INTRODUCTION

Smart antennas have received increasing interest for mitigating interference in many wireless applications [1]. Rapid growth in demand for smart antennas is fuelled by two major reasons. First, the technology for high speed analog-to-digital converters (ADC) [2] and high speed digital signal processing is burgeoning at an alarming rate. Even though the concept of smart antennas has been around since the late 50s, the technology required in order to make the necessary rapid and computationally intense calculations has only emerged recently [3],[4]. Smart antennas are the practical realization of the subject of adaptive array signal processing and have a wide range of interesting applications and a block diagram of such a system is shown in Fig. 1 [5]. Proposal of fast converging algorithms are indeed required to meet the demands of 3G and 4G networks for the high speed data transfer in mobile communications [6]. In adaptive beamforming, deep nulls are produced in the directions of undesired signals which symbolize co-channel interference from mobile users in the adjacent cells [7], [8].

In this paper, we propose VSSNLMS algorithm and analyse its performance with LMS and NLMS using 2D novel array geometry to improve the accuracy of beamforming and to mitigate the interferences.

II. PROBLEM FORMULATION

A. *Signal Model of Conventional ULA*

Let us consider system model with ULA consisting of 'N' isotropic sensors. Let 'm' (m < N be the unconstrained signals impinging on a ULA at directions $\theta_1, \theta_2 \ldots \theta_m$. Consider 'd' as inter element spacing of ULA and its value chosen to be $\lambda/2$ in order to reduce mutual coupling effects. The narrowband signal received by a linear antenna array with M - Omni-directional antenna elements at the time instant n can be expressed as

$$x(n) = s(n) + i(n) + n(n) \tag{1}$$

Where $s(n)$, $i(n)$ and $n(n)$ denote the $N\times 1$ vectors of the signal of interest (SOI), interference and noise respectively. For simplicity, all these components of the received signal (1) are assumed to be statistically independent to each other. This assumption is fairly practical since the SOI and the signals from interferers (other objects or users) are typically independent. The conventional (forward-only) estimate of the covariance matrix defined as $\boldsymbol{R} = E\{x(n)x^H(n)\} = \sigma^2\mathbf{I}$, where σ^2 is the noise power at a single antenna element, $\mathbf{I}$ denotes the identity matrix and $(\cdot)^H$ and E $[\cdot]$ stand for the Hermitian transpose and mathematical expectation respectively.

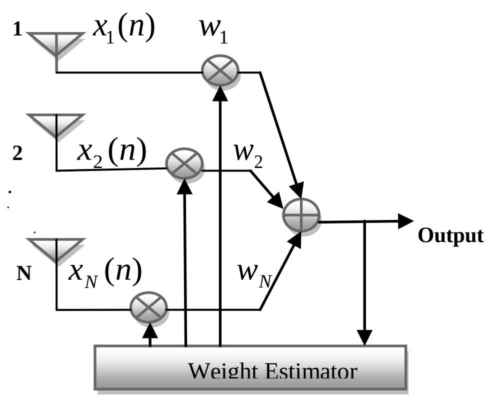

Fig.1: Adaptive beam former used in smart antenna array

B. *Signal Model of 2D Antenna Array*

It consists of doubly crossed ULAs, i.e., superposition of horizontal and vertical ULA and has identical size and computational load as compared to ULA. Fig. 2 shows the geometry of horizontal–vertical ULA [9].

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 9, September 2015

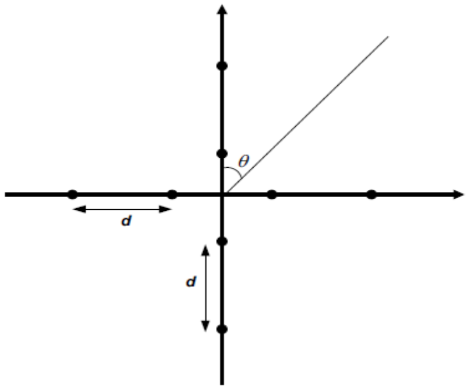

Fig.2: Geometry of horizontal–vertical ULA.

Now, let us apply all components of the received signal (1) to the above geometry to analyse the performance. The user signal $x(n)$ can then be modelled for k snapshots as:

$$x(n) = x_h(n) + x_v(n) = \left[\sum_{m=1}^{M} a_h(\theta_m) + a_v(\theta_m)\right] x_m(t)$$

Here $a_h(\theta_m)$and $a_v(\theta_m)$are the *N x 1* array steering vectors of horizontal- and vertical array respectively. The expressions of these steering vectors are given by:

$$a_h(\theta_m) = [\exp\{j(n-1)2\pi(d/\lambda)\}\sin\theta_m]^T \quad (2)$$

$$a_v(\theta_m) = [\exp\{j(n-1)2\pi(d/\lambda)\}\cos\theta_m]^T \quad (3)$$

III. Proposed VSSNLMS Algorithm

The main aim of the VSSNLMS is to overcome the problem of slow converengence rate of NLMS, which uses fixed step size. This can be achieved by using variable step size for NLMS. This improves the converengence rate and speeds up the algorithm. Furthermore, we studied VSSNLMS using 2D novel ULA geometry and the results are compared with LMS and NLMS algorithms. The array weight is given by

$$w(n+1) = w(n) + \frac{\mu(n)e(n)x(n)}{\sigma + \|x(n)\|^2} \quad (4)$$

The step size varied for the various iterations and is given by the equation

$$\mu(n) = \left\{\left(\frac{6}{N}\right)^2 \left(k\left(\frac{6}{N}\right)^2\right) + 0.001\right\}, 1 \le k \le \frac{N}{6}$$

$$0.0001 \qquad \frac{N}{6} \le k \le N$$

Algorithm: 2D Novel Variable step size normalized least mean square(VSSNLMS) algorithm for interference suppression

1. Compute the steering vector for desired direction θ_0
2. Compute the array manifold vector corresponding to M interference sources.
3. obtain signal samples by sampling continuous time signal of baseband frequency. (For simulation sine wave samples is considered).
4. Compute the autocorrelation matrix R_{XX}
5. Compute the step size by using equation

$$\mu = \frac{2}{3tr(R_{XX})}$$

6. Compute the following for all signal samples $0 \le n \le N_S$ where, N_S is the total number of signal samples.

$$x(n) = a(\theta_0)s(n) + i(n)\sum_{i=1}^{M} a(\theta_i) + n(n)$$

$$y(n) = w(n)^T x(n)$$

$$e(n) = s(n) - y(n)$$

$$w(n+1) = w(n) + \frac{\mu(n)e(n)x(n)}{\sigma + \|x(n)\|^2}$$

7. The array factor is computed using :

$$AF = \sum_{i=1}^{N} w^H(i) e^{j\pi \sin\theta}$$

8. Plot AF versus angles to get array beam pattern.
9. END

IV. Simulation Results

A two dimensional novel ULA geometry has been used to implement the proposed VSSNLMS algorithm. The simulation results are compared with LMS and NLMS algorithms using both conventional ULA and 2D novel ULA.

We considered antenna array elements *N=8*, element spacing d = $\lambda/2$, angle of SOI, θ = *0*, signal to noise ratio (SNR) = 20 dB, white Gaussian noise with zero mean and σ^2 variance. Let interference signals are arriving at angles -60°,-40°,-20°, 20°, 40° and 60°.

The fixes step size is used for simulation of LMS and NLMS algorithms, whereas the variable step size is used for proposed VSSNLMS algorithm.

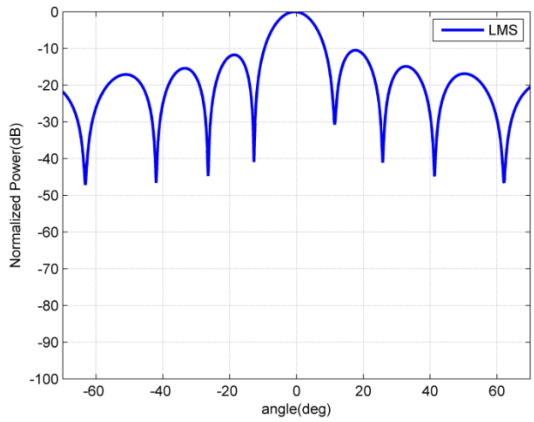

Fig.3: Beam pattern using LMS algorithm.

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 9, September 2015

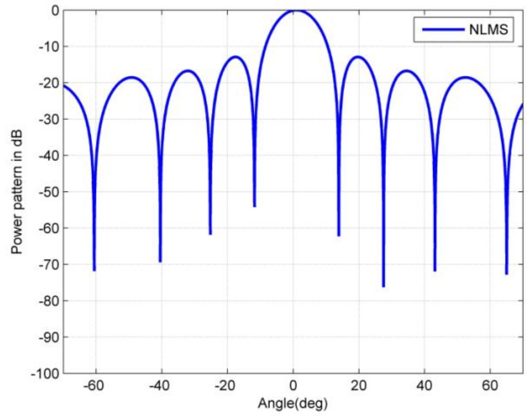

Fig.4: Beam pattern using NLMS algorithm.

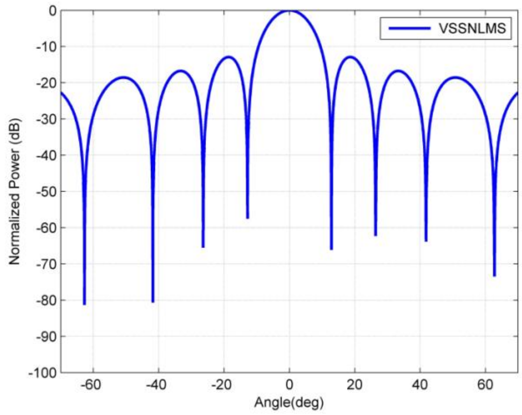

Fig.5: Beam pattern using VSSNLMS algorithm

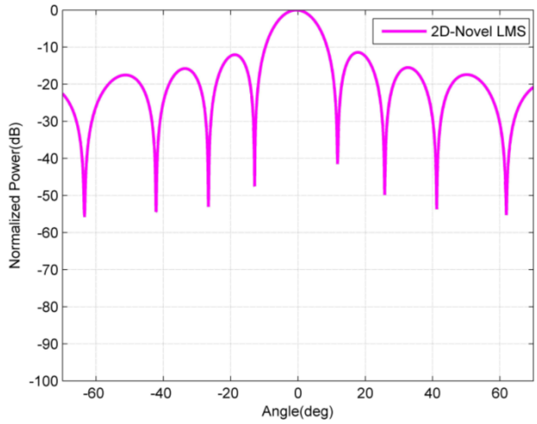

Fig.6: Beam pattern using 2D-Novel LMS algorithm.

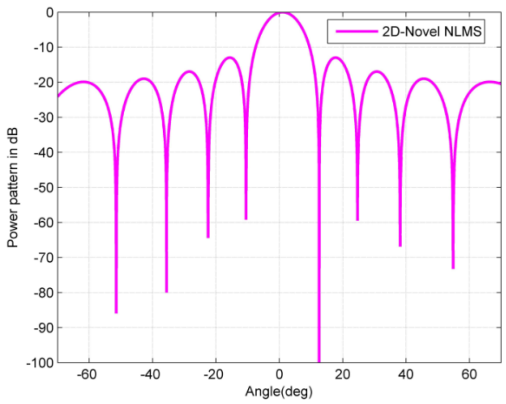

Fig.7: Beam pattern using 2D-Novel NLMS algorithm.

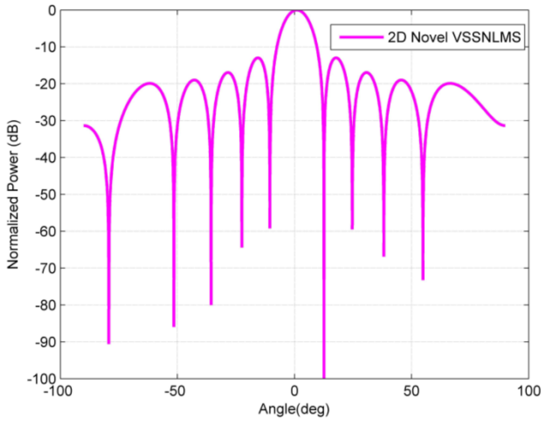

Fig.8: Beam pattern using 2D-Novel VSSNLMS algorithm.

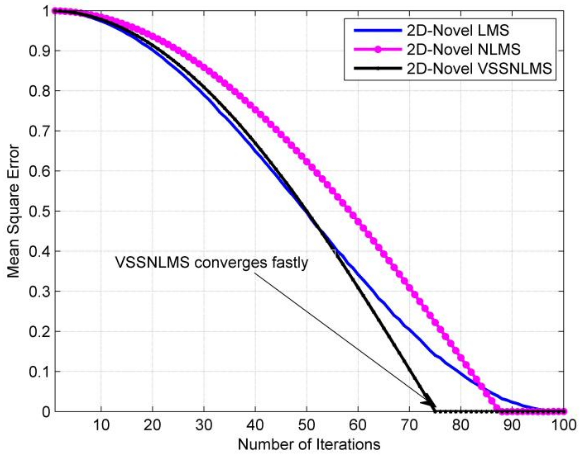

Fig. 9: Convergence analysis of LMS, NLMS and VSSNLMS using 2D Novel ULA.

Fig. 3, 4 and 5 show the beampattern of LMS, NLMS and VSSNLMS algorithms respectively using conventional ULA. Furthermore, we applied same parameters and algorithms to the 2D novel ULA geometry to study the performance analysis.

The simulation results of novel method are shown in Fig. 6, 7 and 8 respectively. Convergence rate of LMS, NLMS and VSSNLMS algorithms using 2D novel ULA is shown in Fig. 9.

Normalized power for selected nulls using conventional ULA and 2D novel ULA is summarized in Table I and II respectively.

TABLE 1: NORMALIZED POWER IN DB OF SELECTED NULLS

Interference Signals	LMS	NLMS	VSSNLMS
-60	-48	-72	-80
-40	-47	-70	-80
-20	-45	-61	-68
20	40	-78	-78
40	43	-70	-72
60	45	-70	-75

TABLE 2: NORMALIZED POWER IN DB OF SELECTED NULLS

Interference Signals	2D-Novel LMS	2D-Novel NLMS	2D-Novel VSSNLMS
-60	-56	-88	-90
-40	-55	-80	-87
-20	-52	-65	-80
20	50	-60	-62
40	-53	-68	-68
60	-55	-72	-74

From Table I and II, it is clear that proposed VSSNLMS algorithm has deep nulls for both conventional and 2D novel method, but still interference suppression is more in 2D VSSNLMS as compared to other methods.

From Fig. 9, we note that convergence rate of 2D LMS, 2D NLMS and 2D VSSNLMS is 95, 90 and 75 respectively. Hence converengence rate of 2D VSSNLMS is fast as compared to other methods.

V. CONCLUSION

The adaptive beamforming algorithms namely LMS and NLMS have trade-off issue between convergence rate and steady-state Mean Square Error (MSE). The proposed VSSNLMS algorithm uses veriable step size to solve this problem. As a result of this, VSSNLMS algorithm gives fast convergence rate by reducing MSE. Furthermore, the proposed VSSNLMS algorithm along with LMS and NLMS algorithms using 2D novel ULA gives still better resolution, beamforming, converengence and interference suppression as compared to conventional ULA. This makes it suitable for low-cost, low-power applications in anti-interference multiple-input–multiple-output (MIMO) wireless local area network (WLAN), i.e., MIMO WAN and as well as other MIMO systems such as Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE), other mobile communication systems and so on.

REFERENCES

[1] Frank B. Gross, "Smart Antennas for wireless communications", Tata McGraw-Hill, October 2005.
[2] Walden, R.H. "Performance Trends for Analog-to-Digital Converters," *IEEE Commn. Mag.*, pp. 96–101, Feb. 1999.
[3] Howells, P. "Explorations in Fixed and Adaptive Resolution at GE and SURC," *IEEE Transactions on Antenna and Propagation*, Special Issue on Adaptive Antennas, Vol. AP-24, No. 5, pp. 575–584, Sept. 1976.
[4] Liberti, J., and T. Rappaport, *Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications*, Prentice Hall New York, 1999.
[5] Reed, J., *Software Radio: A Modern Approach to Radio Engineering*, Prentice Hall, New York, 2002.
[6] Fishler, E., A. Haimovich, R. Blum, et al., "MIMO Radar: An Idea Whose Time Has Come," *Proceedings of the IEEE Radar Conference*, pp. 71–78, April 26–29, 2004.
[7] Ali Hakam, Raed Shubair,, Shihab Jimaa, and Ehab Salahat" *Robust Interference Suppression Using a New LMS Based Adaptive Beamforming Algorithm",* 17th IEEE Mediterranean electro technical conference beirut,lebanon,13-16, April 2014.
[8] Veerendra, Md. Bakhar, Vani R.M and P.V.Hunagund, "*Implementation and Optimization of Modified MUSIC Algorithm for High Resolution DOA Estimation",* IEEE MTT-S Int. Microwave and RF Conf., pp 190-193, Dec. 15-17, 2014.
[9] Raed M. Shubair, Ali Hakam, *"Adaptive Beamforming Using Variable Step-Size LMS Algorithm with Novel ULA Array Configuration,"* in IEEE International Conference on Current Trends in Information Technology (ICCT2013), pp. 650-655, 2013.

BIOGRAPHIES

Mr. Veerendra, received B.E in Electronics and Communication Engineering from Bheemanna Khandre Institute of Technology, Bhalki, India in 2007 and M.Tech(PE) from P.D.A Engineering College, Gulbarga, India in 2011. He is currently pursuing PhD in Visvesvaraya Technological University, Belagavi, India. He is working as Assistant Professor in Guru Nanak Dev Engineering College, Bidar, India, since 2010. His field of interests are Microwaves, Antennas, wireless and digital communications. He is associate member of IETE.

Dr. Md. Bakhar, received B.E in Electronics and Communication Engineering from Bapuji Institute of Engineering and Technology, Davangere, India in 1995 and M.E in Communication systems from P.D.A Engineering College, Gulbarga, India in 1998. He has awarded PhD in Applied Electronics from Gulbarga University, Gulbarga, India in the year 2013. He is working as Professor in Guru Nanak Dev Engineering College, Bidar, India, since 2005 and he is a registered supervisor in VTU, Belgaum. His field of interests are Microwaves, Antennas, wireless and digital communications.

Dr. Vani. R.M, received her B.E.(E&E) from the B.I.E.T., Davanagere, Karnataka, and M.Tech(IE) from Mysore University, Mysore. She has received her Ph.D in Applied Electronics from Gulbarga University, Gulbarga, India, in the year 2005. She is working as Reader/Technical officer-II & Head, University Science Instrumentation Centre, Gulbarga University, Gulbarga, since 1995.She has more than 90 research publications in national and international reputed journals. Also she presented the research papers in national and international conferences in India and abroad. She has conducted several courses, workshops for the benefits of faculties and field engineers. Her areas of interest are microwave antennas, PC based instrumentation Embedded controllers and wireless communication.