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Study and Analysis of MVDR DOA Estimation Algorithm xyz

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***Abstract*--The smart antenna (SA} can adjust the direction pattern adaptively and reduce the interference signals using some adaptive interference mulling algorithms, and thus enhances the performance of mobile telecommunication system, especially enlarges the user capacity of system. The smart antenna system is mainly applied to the base station (BS) now, but next step, the smart antenna technology will be applied to mobile station (MS) along with hardware and software in MS becoming more powerful. The smart antenna system will be applied in both BS and MS in next generation mobile telecommunication system.**

However, performance of smart antenna system greatly depends on efficiency of digital signal processing algorithms. The algorithm uses the Direction of Arrival (DOA) algorithms to estimate the number of incidents plane waves on the antenna array and their angle of incidence. In this paper the performance of Direction-of-Arrival (DOA) algorithm MVDR is investigated. The simulation results show that, the advantages in performance of one algorithm over another vary with the conditions and is significantly influenced by both of the environments well as the system. Thus, careful consideration is imperative to the conditions and system parameters specific to the planned deployment.
The algorithms have been simulated in MATLAB 7.4 version.

***Index Terms*-- DOA, MUSIC and MVDR.**

I. INTRODUCTION

IN resent year the more emphasize on the requirement of higher system capacities has arises because of the increasing dependency on the usage of the wireless communication system. The system capacity can be improved by either enlarging its frequency bandwidth or adding new range of frequency spectrum to wireless services. But because of obvious reasons, since the electromagnetic spectrum is a limited resource, it is not easy to get new spectrum allocation without the international coordination on the global level. So, one alternative approach is to use existing spectrum more efficiently. Efficient source and channel coding as well as reduction in transmission power or transmission bandwidth or both are possible solutions to the challenging issue. With the advances in digital techniques, the frequency efficiency can be improved by multiple access technique (MAT), which gives mobile users access to scarce resource (base station) and hence improves the system's capacity [1]. The existing Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) can be enlarged by adding a new parameter 'space' or 'angle' [2], which results in MAT known as 'Space Division Multiple Access' (SDMA). At the receiver's side, the transmitted signal is received with its multipath components plus interferers' signal, as well as with present noise. Thus, detection of the desired signal is a challenging task. In this context smart antennas emerged as one of the most expected technologies, which are adapted to the demanding high-bit rate or high quality in broadband commercial wireless communication such as mobile internet or multimedia services [3], [4].The Smart Antenna System (SAS) employs the antenna elements and the digital signal processing which enables it to form a beam to a desired direction taking into account the multipath signal components. In this way, Signal-to-Interference-and-Noise Ratio (SINR) improves by producing nulls towards the interferers Signal-of–No-Interest (SONI) [5].The performance of SAS greatly depends on the performance on DOA estimation.

The minimum variance distortion less response (MVDR) spectrum estimator belongs to the class of spatial filter based estimators. It was originally used to analyze the frequency-wavenumber. Due to the capability of automatically canceling the interference while preserving the desired signal, it is also a well-established method for adaptive beam forming, and it provides an estimate of the power density spectrum over the spatial domain of view of an array. Advanced spectral method (e.g., MVDR, MUSIC have superior performance compared to conventional processing techniques**.**

But their application to real systems has been rather limited. One of the main reasons given for this situation is the relatively high sensitivity of these methods to various system errors. This is also the reason of a number of researchers have made contribution to performance analysis of these spectral estimators.Vaidyanatha and Buckley investigated the sensitivity of the MVDR spectrum estimator to random perturbations in signal model and in noise covariance matrix and presented analytical expressions of the variance and bias of the estimator. K. J. Raghunath andV. U. Reddy used the first-order perturbation theory to give the finite data performance analysis of MVDR beam former, in particular, they developed expressions for the mean values of the power gain in any direction of interest, the output power and the norm of the weight-error vector. Cox investigated the effects of mismatch in the signal model on the performance of the beam former. Concerning the study of the effects of amplitude and phase errors on the spectral estimators, no explicit analytical expressions of the mean and variance of the spectrum have been obtained.

II. Estimation Algorithms

The algorithms based on DOA are classified as non-subspace or quadratic type and subspace type [6]. The Barltett and Capon (Minimum Variance Distortion less Response) [6] are quadratic type algorithms. Both the methods are highly dependent on physical size of array aperture, which results in poor resolution and accuracy, [5], [7], [9], [11], [12], [13].
Subspace based DOA estimation method is based on the Eigen decomposition [8]. The subspace based DOA estimation algorithm MUSIC provides high resolution, and is more accurate and not limited to physical size of array aperture [2] [7].
The various DOA algorithm performance is analyzed based on number of snapshots, number of users, user space distribution, number of array elements, SNR and MSE.

III. Minimum Variance Distortion less Response

MVDR means Minimum Variance Distortion less Response. In Figure-1 a uniform linear array (ULA) of N equally spaced sensors is shown. A number of plane waves from M narrow bandsources impinging from different angles θ_i, i = 1, 2…M. At a particular instant of time t, t=1, 2… K, where K is the total number of snapshots taken, the array output will consist of the signal, and in addition to that noise components.

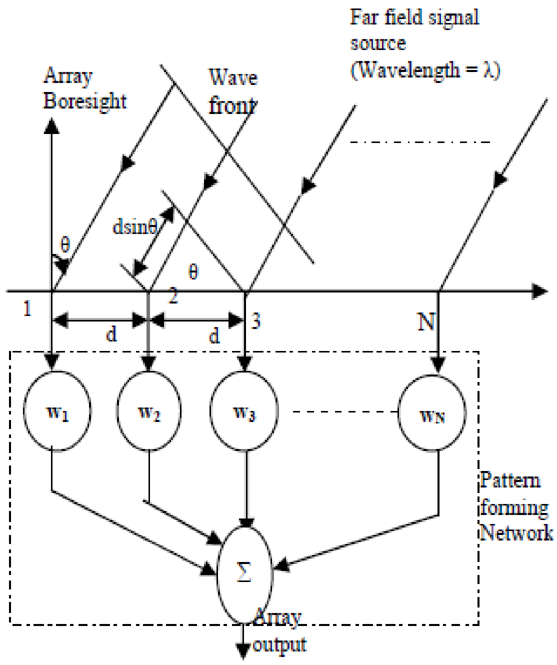

Fig.-1. Uniform Linear Array with M- Element

The signal vector x (t) can be defined as different angles θ_i, i = 1, 2……M.

$$x(t) = \sum_{m=1}^{M} a(\theta_m) s_m(t) \qquad (16)$$

Where s (t) is an M×1 vector of source waveforms and for a particular source at direction θ from the array bore sight; a(θ)is an N×1 vector referred to as the array response to that source or array steering vector for that direction. It is given by:

$$a(\theta) = \left[e^{-j\emptyset} \dots\dots\dots e^{-j(N-1)\emptyset}\right]^T \quad (17)$$

Where T is the transposition operator and Φ represents the electrical phase shift from element to element along the array. This can be defined by:

$$\emptyset = (2\pi/\lambda)\, d\cos\theta$$

Where d is the element spacing and λ is the wavelength of the received signal. The signal vector x (t) of size N×1 can be written as:

$$x(t) = A.s(t)$$

Where,$A = [a(\theta_1) \dots a(\theta_M)]$ is an N×M matrix of steering vectors. The array output consists of the signal plus noise components, and it can be defined as:

$$u(t) = x(t) + n(t)$$

Where $x(t) and n(t)$ are signal and noise components?
If there are D signals incident on the array, the received input data vector at an M-element array can be expressed as a linear combination of the D incident waveforms and noise.

$$u = \sum_{n=1}^{D} a(\emptyset_1)S_1 + n = AS + n \quad (18)$$

Where A is the matrix of steering vectors,

$$A = [a(\emptyset_1)\, a(\emptyset_2) \dots \dots \dots a(\emptyset_D)]$$

Where $S = [S_1 \dots \dots S_D]$the signal is vector, and $n = n_1 \dots \dots n_M]$is a noise vector with components of varianceσ_n^2.
Now equation -18 can be written in the form of matrix of size N×K as:

U= A.S + N

Where S=[s (1) … s (K)] is an M×K matrix of source waveforms and N= [n (1)………. N (K)] is an N×K matrix of sensor noise. The spatial correlation matrix R of the observed signal vector u (t) can be defined as:

$$R = E[u(t).u(t)^H] (19)$$

Where E and H are the expectation and conjugate transpose operators, respectively. The spatial correlation matrix R can now be express can now be expressed as:

$$R = E[A.s(t).s(t)^H.A^H] + E[n(t).n(t)^H] (20)$$

The peaks in the MVDR angular spectrum occur whenever the steering vector is orthogonal to the noise subspace. This technique minimizes the contribution of the undesired interferences by minimizing the output power while maintaining the gain along the look direction to be constant, usually unity. That is

$$min\ E[|y(\theta)|^2] = \min w^H Rw, w^H A = 1 \quad (21)$$

Using Lagrange multiplier, the weight vector can be given by,

$$W = \frac{R^{-1}A}{R^{-1}A^H A} \quad (22)$$

The output power of the array as a function of the DOA estimation, using MVDR beam forming method, is given by MVDR spatial spectrum as,

$$P_{MVDR}(\theta) = \frac{R^{-1}A}{R^{-1}A^H A} \quad (23)$$

The angles of arrival are estimated by detecting the peaks in the angular spectrum.

IV. Simulation Result

The MVDR technique for DOA estimations are simulated using MATLAB. Performance of the algorithm has been analyzed by considering function of array elements, of SNR and as a function of snapshots. The simulation has been run for signals coming from different angles at 15°, 20°, 25°, 30° and 35° for 200 snapshots, power of incoming signal 15 dB, SNR of 50dB, and 8 array elements.

It has been observed that in MVDR spectrum there is sharp peak in an angular spectrum and a lower noise floor compared to the MUSIC algorithm. In MUSIC spectrum sharper peak indicates the location of desired user where as in MVDR power plot maximum power at an angle indicates the location of desired user. Fig-2 to Fig-11 shows the comparison of both the algorithms.

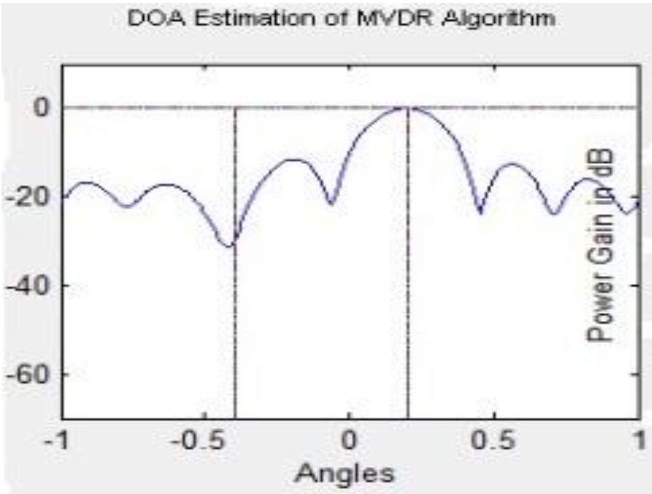

Fig.2 -DOA estimation at angle-15°

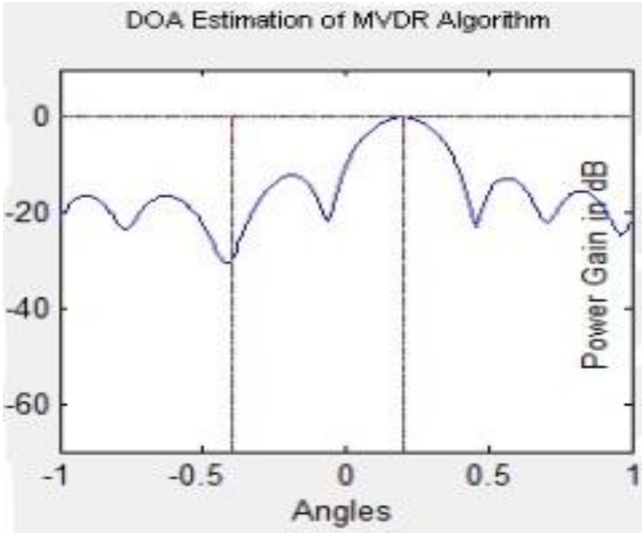

Fig.3 -DOA estimation at angle-20°

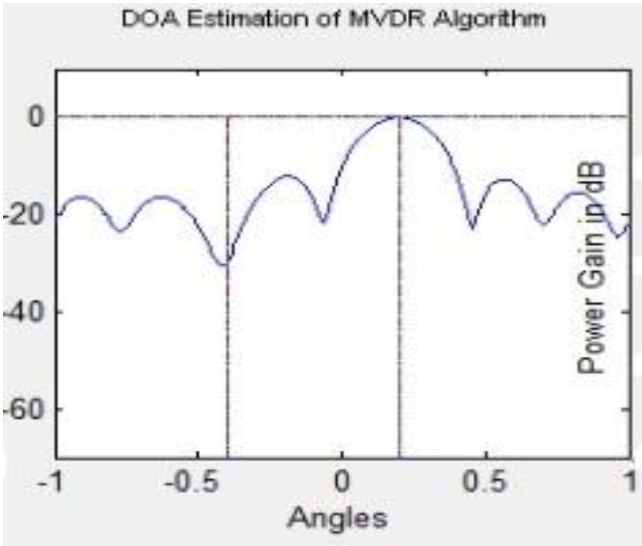

Fig.4 -DOA estimation at angle-25°

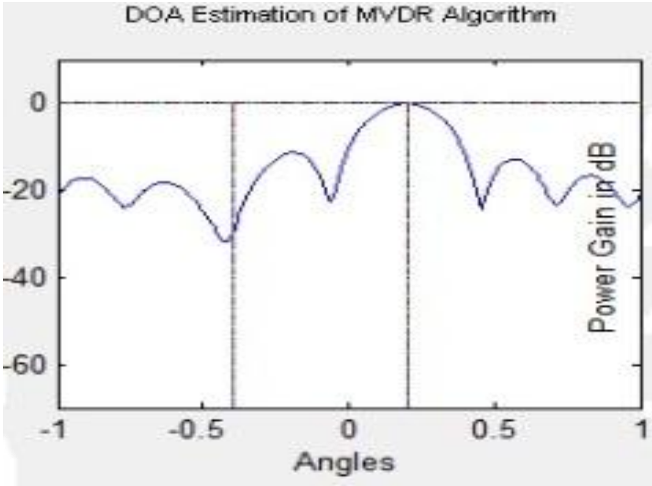

Fig.5 -DOA estimation at angle-30°

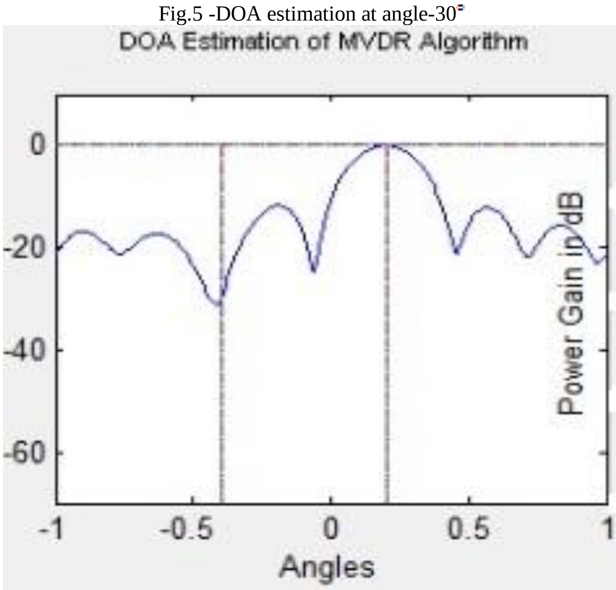

Fig.6 -DOA estimation at angle-35°

V. CONCLUSION AND FUTURE WORK

This paper presents results of direction of arrival estimation using MVDR algorithms. The simulation results show that performance of MVDR improves on increasing the numbers of elements in array. These improvements are analyzed in the form of sharper peaks in spectrums and smaller errors in angle detection. Results indicate that as the number of snapshots increased, a decrement in MSE is observed. It results in accurate detection of closely spaced signals. The simulation results show that, the advantage of performance of one algorithm over another varies with the conditions and is significantly influenced by both of the environments well as the system. Thus, careful consideration is imperative to the conditions and system parameters specific to the planned deployment.

In this context, this study proposes a new possibility of user separation through SDMA and can be widely used in the design of smart antenna system.

VI. References

[1] John Litva, Titus Lo," Digital Beam forming in Wireless Communication",Artech House Bostan-London,1996.

[2] Shauerman, Ainur K. Shauerman, Alexander A.," Spectral-based algorithms of direction-of-arrival estimation for adaptive digital antenna arrays",9th international conference and seminar on Micro/Nanotechnologies and Electron Devices (EDM) 2010, pp 251-255,Sept. 2010.

[3] Ogawa Y. and Ohgane T., "Adaptive Antennas for Future Mobile Radio", *Computer Journal of IEICE Transaction Fundamentals*, 79 (7), pp. 961 – 967, 1996..

[4] Ogawa Y., Ohmiya M. and Itoh K., "An Adaptive Array System for High-speed Mobile Communications", 75 (5), pp. 413 – 421, 1992.

[5] C.Balanis,"Antenna Theory, Analysis and Design", 3rd edition, John wiley and Sons, Hoboken, New Jersey, 2005.

[6] Harry Trees," Optimum Array Processing, Detection, Estimation and Modulation Part IV",John Wiley and Sons,NEW York , 2002.

[7] Lavate, T.B. Kokate, V.K. Sapkal, A.M. ,"Performance Analysis of MUSIC and ESPRIT DOA Estimation Algorithms for Adaptive Array Smart Antenna in Mobile Communication " , 2nd International Conference on Computer and Network Technology (ICCNT), pp 308-311,Apr.2010

[8] Rao, B.D. Hari, K.V.S. , "Performance analysis of ROOT-MUSIC", IEEE Transactions on Acoustics, Speech and Signal Processing, Vol 37 pp: 1939-1949,Dec 1989.

[9] Jalali, M. Moghaddasi, M.N. Habibzadeh, A. , "Comparing accuracy for ML, MUSIC, ROOT-MUSIC and spatially smoothed algorithms for 2 users", Microwave Symposium (MMS), 2009 Mediterranean ,IEEE conference ,pp: 1–5,Nov.2009.

[10] Khan, Z.I. Awang, R.A. Sulaiman, A.A. Jusoh, M.H. Baba, N.H. Kamal, M.M.D. Khan, N.I.," Performance analysis for Estimation of signal Parameters via Rotational Invariance Technique (ESPRIT) in estimating Direction of Arrival for linear array antenna",IEEE International Conference on RF and Microwave Conference, 2008,pp530 – 533 , Dec. 2008.

[11] Varade, S.W., Kulat, K.D,"Robust Algorithms for DOA Estimation and Adaptive Beamforming for Smart Antenna Application",2nd international conference on Emerging Trends in Engineering and Technology (ICETET), 2009 , pp: 1195 – 1200, Dec. 2009.

[12] De Leon, F.A. Marciano, J.J.S. ," Application of MUSIC, ESPRIT and SAGE Algorithms for Narrowband Signal Detection and Localization", TENCON ,IEEE Region 10 Conference, pp 1-4, Nov. 2006.

[13] Sheng, W.X.; Zhou, J.; Fang, D.G.; Gu, Y.C.," Super resolution DOA Estimation in switched beam smart antenna", Antennas, Propagation and EM Theory, 2000. Proceedings. ISAPE 2000. 5th International Symposium, pp 603-606, 2000.

[14] M. Ali Akbar, Hamza Bin Tila, M. Zulkifl Khalid and Muhammad AsimAjaz ,"Bit Error Rate Improvement using ESPRIT based Beamforming and RAKE receiver , Multitopic Conference, 2009. INMIC 2009. IEEE 13th International, pp 1-6, Dec. 2009.

[15] Walid G. Diab, Hassan M. ElkamchouchiA Deterministic Real-Time DOA-based Smart Antenna Processor Personal, Indoor and Mobile Radio Communications, 2007. PIMRC 2007. IEEE 18th International Symposium, pp 1-7, 2007.

[16] A. Paulraj, R. Roy, and T. Kailath,-Estimation of signal parameters via rotational invariance techniques – ESPRIT", In Proc. Nineteenth Asdomar Conference on Circuits, Systems and Comp., Asilomar, CA., November 1985.

[17] A. Paulraj, R. Roy, and T.Kailath, Patent Application: Met &ods and Meam for SigndReception and Parameter Estidion , Stanford University, Stanford, Ca., 1985.

[18] Multiresolution ESPRIT Algorithm Aweke N. Lemma, Alle-Jan van der Veen, and Ed F. Deprettere, IEEE Transactions On Signal Processing, Vol. 47, No. 6, June 1999.

[19] R. M. Shubair and A. Merri, "Convergence of adaptive beamforming algorithms forwireless communications," Proc. IEEE and IFIP International Conference on Wireless and Optical Communications Networks, Dubai, UAE, March 6-8, 2005.

[20] AngelikiAlexiou and Martin Haardt, "Smart antenna technologies for future wireless systems: Trends and Challenges", *IEEE Comm. Magazine*, pp. 90-97, September 2004.

[21] G. Lorenz and S. P. Boyd, "Robust minimum variance beamforming," Signal Processing, IEEE Transactions on, vol. 53, Issue 5, pp. 1684–1696, May 2005.

[22] Abratasinha, Alan D. George and Keonwook Kim" "parallel algorithms for robust broadband mvdrbeamforming" in Information Technology (IIT'05)

[1] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.