Implementation of an Adaptive Beam Forming Antenna for Radio Technology

Chhaya Singh, B G Hogade

Abstract— ***Beamforming antennas for fixed and mobile wireless communications have received enormous interest worldwide in recent decades, and a wide variety of approaches for smart antenna design and application. Smart antenna techniques at the base station can dramatically improve the performance of the mobile radio system by employing spatial filtering. The wideband smart antennas are widely used antennas. A wideband beamforming algorithm which is derived from spatial signal processing technique is considered in this technique. We will be using circular array geometry for the wideband smart antenna. A well known LMS algorithm will be applied to the circular array geometry. The DOA/validation component uses a MATLAB script to implement the MUSIC algorithm to estimate the DOA for both incoming sources. In this paper directional beam pattern for the given design parameters will be displayed.***

Index Terms— ***Wireless communication, Smart antenna, Circular array goemetry, DOA estimation, MATLAB .***

I. INTRODUCTION

As the growing demand for mobile communications is constantly increasing, the need for better coverage, improved capacity and higher transmission quality rises. Thus, a more efficient use of the radio spectrum is required. Smart antenna systems are capable of efficiently utilizing the radio spectrum and promise an effective solution to the present wireless systems' problems while achieving reliable and robust high-data-rate transmission. Smart antenna systems comprise several critical areas such as individual antenna array design, signal processing algorithms, space-time processing, wireless channel modeling and coding, and network performance. A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source (transmitter), the destination (receiver), or both. Diversity effect involves the transmission and/or reception of multiple radio frequency (RF) waves to increase data speed and reduce the error rate.

II. OBJECTIVE

The rapid growth in demand of wideband wireless services has led to the need to increase the capacity and data-rate transmission of wireless communications systems.

Manuscript Received on August 2014

Chhaya Singh, working as lecturer in the department of Electronics Engineering in Yadavrao Tasgaonkar Institute Of Engineering and Technology , Bhivpuri, Mumbai, India.

Dr. B.G.Hogade , working as Associate Professor in the department of Electronics Engineering in Terna Engineering, Nerul, Navi Mumbai, India.

Since, the available spectrum to provide high-data-rate service to all the subscribed users is limited; and moreover, in densely populated areas the main source of noise in mobile systems is the interference from other users; the attention of latest research has turned to find a technology able to fulfill these requirements. Smart antenna systems, have been conceived as the best solution, because, using spatial filtering, are able to simultaneously increase the useful received signal level and decrease the interference level. In this way, the system capacity and power efficiency can be increased and therefore, reduce overall cost.

III. TYPES OF SMART ANTENNA

There are two types of smart antennas and they are switched beam smart antennas and adaptive array smart antennas. Switched beam systems have several available fixed beam patterns. A decision is made as to which beam to access, at any given point in time, based upon the requirements of the system. Adaptive arrays allow the antenna to steer the beam to any direction of interest while simultaneously nulling interfering signals.

A. Switched Beam Antennas

It form multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect signal strength, choose from one of several predetermined, fixed beams, and switch from one beam to another as the mobile moves throughout the sector.

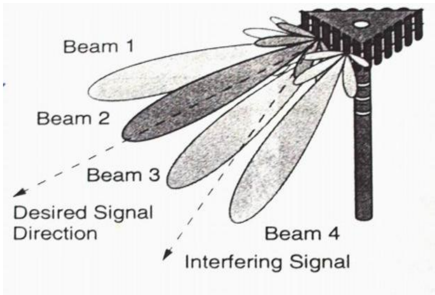


Fig 1. Switched Beam Antennas

B. Adaptive Array Antennas

Adaptive antenna technology represents the most advanced smart antenna approach by using a variety of new signal-processing algorithms. It provides optimal gain while simultaneously identifying, tracking, and minimizing interfering signals.

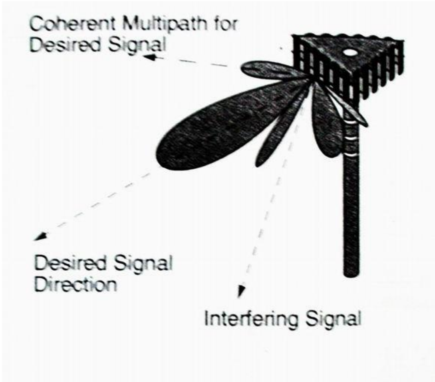


Fig 2. Adaptive Array Antennas

IV. SMART ANTENNA TECHNOLOGY

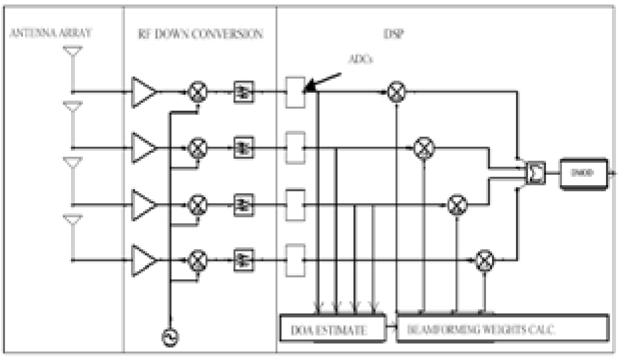


Fig 3.General Smart Antenna Architecture

A smart antenna combines antenna arrays with digital signal processing units in order to improve reception and transmission of radiation patterns dynamically in response to the signal environment. It can increase channel capacity, extend range coverage, steer multiple beams to track many mobiles and reduce multipath fading and co-channel interference.

The smart antenna system needs to differentiate the desired signal from the co-channel interferences and normally requires either the knowledge of a reference signal (or training signal), or the direction of the desired signal source. There exists a range of schemes to estimate the direction of sources with conflicting demands of accuracy and processing power. Similarly, there are many methods and algorithms to update the array weights, each with its speed of convergence and required processing time. By changing the complex weights on real time basis maximization of quality in communication channel can be obtained. The smart antenna system can be divided mainly into three parts:

1) The first one performs the direction of arrival (DOA) estimation and determines the number of incoming signals.

2) The second part performs the DOA classification. It finds out which signals originate from the user and which ones from the interferers.

3) The third part consists in the Beamforming algorithm. It forms an antenna pattern with a main beam steered in the direction of the user, while minimizing the influence of the interfering signals and the noise.

V. DIRECTION OF ARRIVAL (DOA) ESTIMATION

The purpose of DOA estimation is to use the data received by the array to estimate the direction of arrival of the signal. The results of DOA estimation are used by the array to design the adaptive beam former in such way as to maximize the power radiated towards the users and to suppress the interference. In short the successful design of adaptive array smart antenna depends highly on the performance of DOA estimation algorithm. In the design of adaptive array smart antenna for mobile communication the performance of DOA estimation algorithm depends on many parameters such as number of mobile users and their space distribution , the number of array elements and their spacing, the number of signal samples and SNR.

The smart antenna system estimates the direction of arrival of the signal, using techniques such as MUSIC (Multiple Signal Classification), estimation of signal parameters via rotational invariance techniques (ESPRIT) algorithms, Matrix Pencil method or one of their derivatives.

VI. MUSIC ALGORITHM

MUSIC is an acronym which stands for Multiple Signal classification. It is high resolution technique based on exploiting the eigen structure of input covariance matrix. MUSIC makes assumption that the noise in each channel is uncorrelated making correlation matrix diagonal. The incident signals are somewhat correlated creating non diagonal signal correlation matrix.

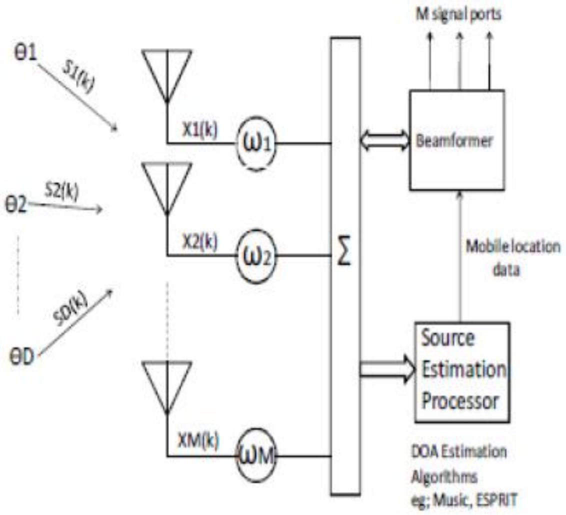


Fig 4. M element antenna array with D arriving signals.

If the number of signals impinging on M element array is D, the number of signal eigen values and eigenvectors is D and number of noise eigen values and eigenvectors is M-D. The array correlation matrix with uncorrelated noise and equal variances is then given by,

$$R_{XX} = A*R_{SS}*A^H + \sigma_n^2*I \qquad \ldots\ldots(1)$$

Where A= [a(θ_1) a(θ_2) a(θ_3) --- a(θ_D)] is M x D array steering matrix and

$R_{SS}=[s_1(k)\ \ s_2(k)\ \ s_3(k)\ \ ----\ \ s_D(k)]^T$ is D xD source correlation matrix.

R_{XX} has D eigenvectors associated with signals and M – D eigenvectors associated with the noise. We can then construct the M x (M-D) subspace spanned by the noise eigenvectors such that

$$V_N = [v_1\ \ v_2\ \ v_3\ \ -------\ v_{M-D}] \quad \ldots\ldots (2)$$

The noise subspace eigenvectors are orthogonal to array steering vectors at the angles of arrivals θ_1, θ_2, θ_3, θ_D and the MUSIC Pseudospectrum is given as

$$P_{MUSIC}(\theta) = 1/\mathrm{abs}\left((a(\theta)^H * V_N * V_N^H * a(\theta)\right) \quad \ldots..(3)$$

However when signal sources are coherent or noise variances vary the resolution of MUSIC diminishes. To overcome this we must collect several time samples of received signal plus noise, assume ergodicity and estimate the correlation matrices via time averaging as

$$R_{XX} = \frac{1}{k}\sum_{k=1}^{k} x(k) * x(k)^H \quad \text{and}$$

$$R_{XX} = A*R_{SS}*A^H + A*R_{sn} + R_{ns} * A^H + R^{nn} \quad \ldots\ldots(4)$$

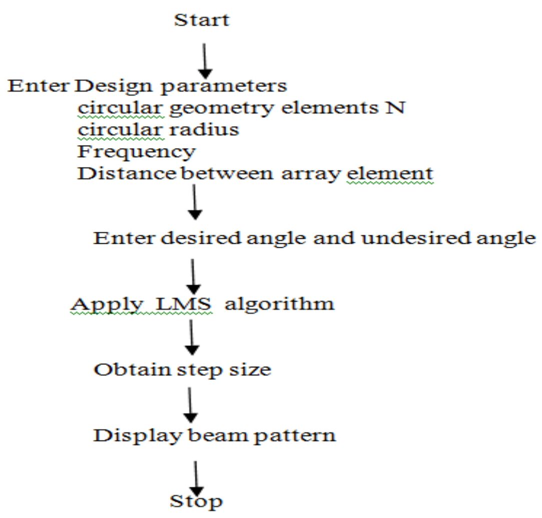
The MUSIC Pseudospectrum using equation (3) with time averages now provides high angular resolution for coherent signals.

VII. MINIMUM VARIANCE DISTORTION LESS ALGORITHM (MVDR)

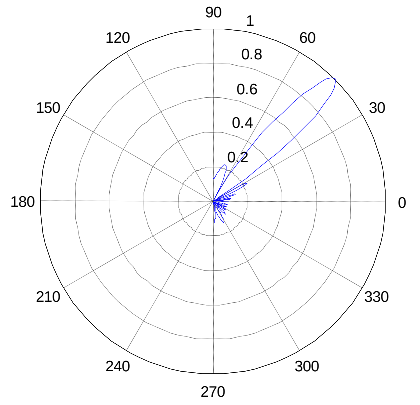
MUSIC estimates the number of incident signals on the array and their directions of arrival. It also gives the direction of arrival of desired signal. The Minimum Variance Distortion less Response (MVDR) is a very well known algorithm to obtain the optimum weight vector, which maximizes the output signal to noise and interference ratio (SNIR) of multiple antennas.

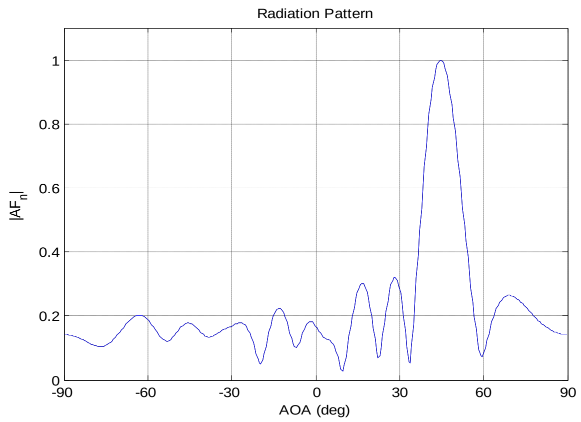
The LMS algorithm, which has been simulated, is a simple yet efficient technique for robust adaptive beamforming. The LMS algorithm recursively computes and updates the weight vector. It has been observed that LMS algorithm gives the response for the two different DOA estimation algorithms MUSIC & MVDR depending upon the DOA estimations .

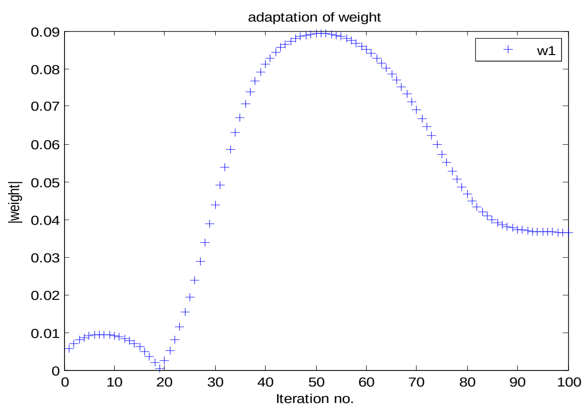
VIII. FLOW DIAGRAM

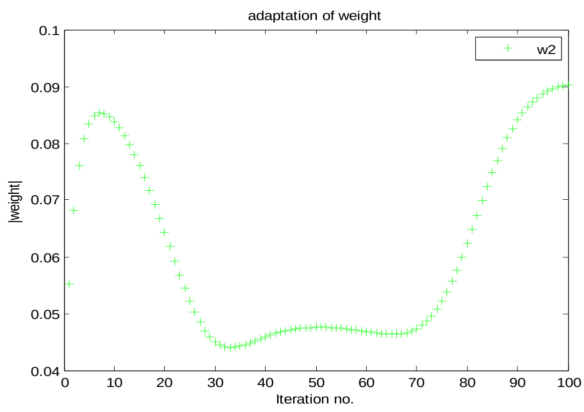


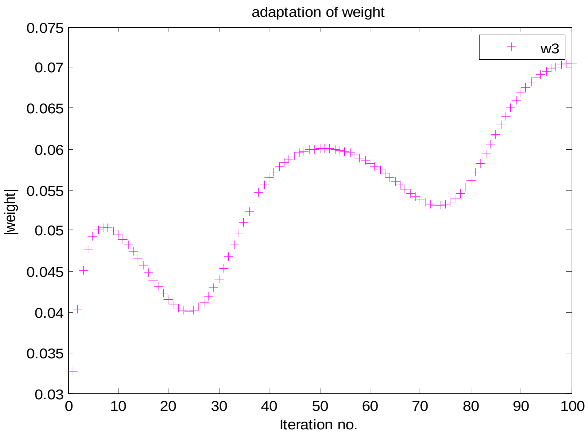
IX. EXPECTED RESULT

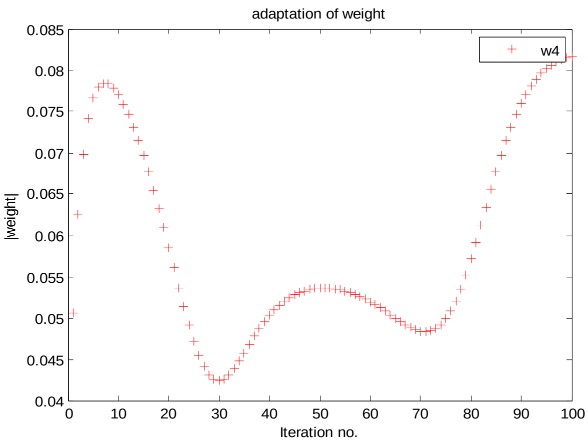


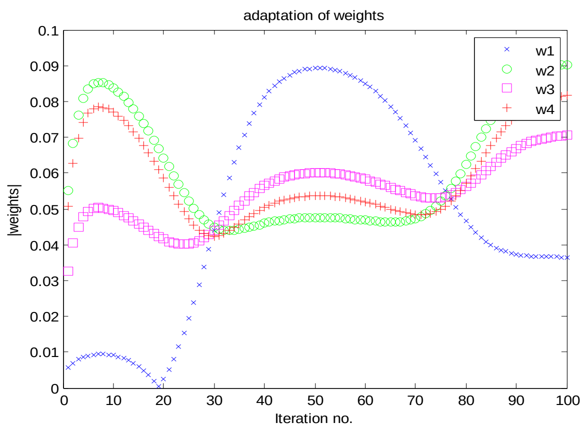


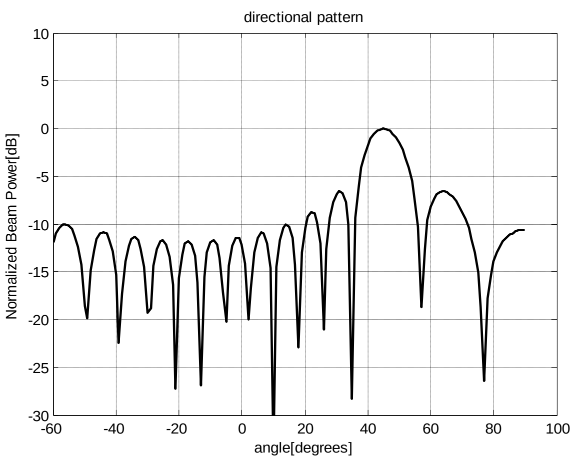












X. CONCLUSION

This topic will provide an effective solutions to major problems of wireless networks where spectral congestion is a common problem and where strong interferences are present. These systems of antennas include a large number of techniques that attempt to enhance the received signal, increase range coverage, suppress all interference, and increase capacity.The system will also be able to select radio channel for best quality of service.

REFERENCES

1. Yikun Huang, "Design of a Dynamic Beamforming Antenna for Wimax Radio Systems," IEEE, 2008.
2. Mariel Rivas, Shuguo **Xie, Donglin Su," A Review of** Adaptive Beamforming Techniques for Wideband Smart Antennas", School of Electronic Information Engineering Beijing University of Aeronautics & Astronautics,
3. Mohammad Ghavami," Wideband Smart Antenna Theory Using Rectangular Array Structures", IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 50, NO. 9, SEPTEMBER 2002
4. P. H. Lehne, and M. Pettersen, "An overview of smart antenna technology for mobile communications systems," IEEE Communication Surveys, vol.2, pp.2-13, 1999
5. E. M. Ardi, R M Shubair., and M. E. Mualla," Adaptive Beamforming Arrays for Smart Antenna Systems: A Comprehensive Performance Study", Etisalat College of Engineering,2004.
6. Suchita W.Varade , K. D. Kulat, "Robust Algorithms for DOA Estimation and Adaptive Beamforming for Smart Antenna Application", Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09, 2009 IEEE.
7. Chris Loadman, Dr. Zhizhang Chen, Dylan Jorgensen, "An Overview of Adaptive Antenna Technologies For Wireless Communications", *CNSR 2003 Conference*, May 15-16, 2003, Moncton, New Brunswick, Canada
8. E Mal-Ardi, R Mshubair, And ME Al-Mualla, Performance Evaluation Of The Lms Adaptie Beamforming Algorithm Used In Smart Antenna Systems, 2004 IEEE,Page No.432,433
9. Y. Huang, and M. Panique, "Performance analysis of a null steering algorithm," IEEE APS International Symposium, June, 2007.
10. C. Loadman, Z. Chen, and D. Jorgensen, "An overview of adaptive antenna technologies for wireless communications," Communication networks and services research conference. A3, pp.15- 19, 2003

AUTHORS PROFILE

1. **Chhaya Singh**, was born in Azamgarh, Uttar Pradesh, India on January 14, 1989. She received B.E (Electronics) degree in 2011 from Mumbai University, Maharashtra and pursuing M.E.(Electronics) from 2012 to 2014. Research areas include wireless communication. She is working as lecturer in the department of Electronics Engineering in Yadavrao Tasgaonkar Institute Of Engineering and Technology , Bhivpuri, Mumbai, India.

2. **Dr. B.G.Hogade** , earned Ph.D. in Smart Antenna from NMIMS, Mumbai, 2014. Research areas include wireless communication, smart antenna. He is working as Associate Professor in the department of Electronics Engineering in Terna Engineering, Nerul, Navi Mumbai, India.