INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD ISSN: 2455-0620 Volume - 7, Issue - 7, July – 2021
Monthly, Peer-Reviewed, Refereed, Indexed Journal with IC Value: 86.87 Impact Factor: 6.719
Received Date: 10/07/2021 Acceptance Date: 25/07/2021 Publication Date: 31/07/2021

Correlative Evaluation of various algorithms for Beamforming and DOA estimation in smart Antennas

[1] **Binod Kr. Choudhary,** [2] **Prashant Singh**
[1]Assistant Professor, [2]System Engineer
[1]Department of Engineering, School of Engineering & IT, ARKA JAIN University,
Jamshedpur, India
[2]Accenture, Bengaluru, India
Email - [1]dr.binod.c@arkajainuniversity.ac.in [2]prashantxiia2@gmail.com

Abstract: *The time period smart antenna consists of all conditions in which a device is the use of an antenna array and the antenna sample is dynamically adjusted by the machine required. Most important problems in smart antennas are direction of Arrival (DOA) estimation and beamforming. The path of Arrival of all of the incoming signals along with the interfering signals is envisioned using DOA algorithms. A number of the DOA algorithms are song ((Multiple Signal Classification), estimation of signal parameter through rotational invariance techniques (ESPRIT) and Matrix Pencil approach. A beam is recommended in the path of desired sign and the user is tracked as his movements whilst setting nulls at interfering sign guidelines via constantly updating the complicated weights. Based totally on the angle information the beamforming network computes the complicated weights required for beam steering. Some maximum typically used strategies are the steepest descent, MVDR and LMS algorithms. In this paper we simulated diverse DOA and beamforming algorithms the usage of MATLAB and compared their performances'*

Key Words: *smart antenna, Beam forming, ESPRIT, MUSIC, MVDR, LMS, direction of arrival.*

1. INTRODUCTION:

The demand for mobile communication resources has increased phenomenally over the past few years. Adaptive, or smart, antenna techniques have emerged as a key way to achieve the ambitious requirements introduced for current and future mobile systems. A smart antenna is commonly defined as a multi-element antenna where the signals received at each element are intelligently and adaptively combined to improve the overall performance of the wireless system, with the reverse performed on transmit [1].Smart antennas have the property of spatial filtering, which makes it possible to receive energy from a particular direction while simultaneously blocking it from another direction. The benefit of smart antennas is that they can increase range and capacity of systems while helping to eliminate both interference and fading [2]. For optimal processing, the typical objective is maximizing the output signal-to-noise ratio (SNR). For an array with a specified response in the direction of the desired signal, this is achieved by minimizing the mean output power of the processor subject to specified constraints. In the absence of errors, the beam pattern of the optimized array has the desired response in the signal direction and reduced response in the directions of unwanted interference [3]. The weights of the array system determine system performance. The selection process of these weights depends on the application and leads to various types of beamforming schemes [4].

Organization of this paper is as follows. Section II provides an overview of smart antenna. Section III presents a description of DOA algorithms. Section IV presents the adaptive beamforming algorithms.

2. SMART ANTENNA:

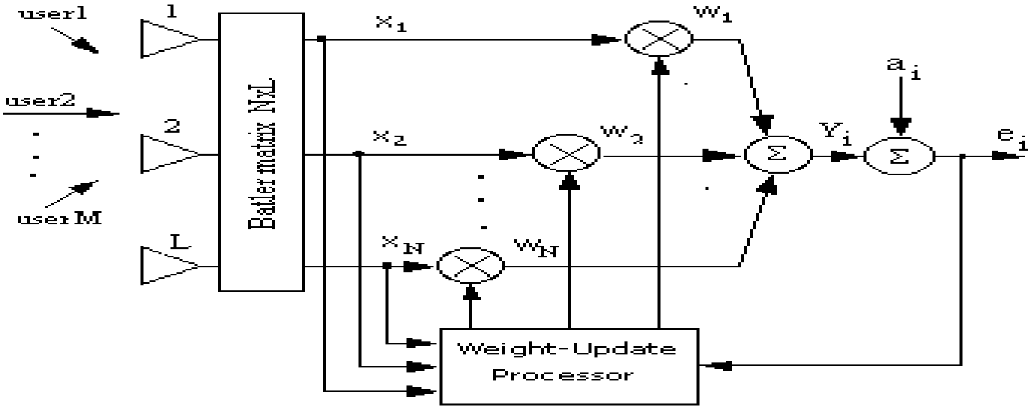


Figure 1

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. "Fig. 1," shows the functional block diagram of smart antenna system.

3. DIRECTION OF ARRIVAL (DOA) ESTIMATION:

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 and Matrix Pencil method.

3.1. *DOA Estimation Using MUSIC Algorithm:*

MUSIC algorithm is a high resolution Multiples **Si**gnal **C**lassification technique based on exploiting the eigenstructure of the input covariance matrix. It provides information about the number of incident signals, DOA of each signal, strengths and cross correlations between incident signals, noise power, etc. input data vector at an M-element array can be expressed as a linear combination of the D incident waveforms and noise

$$u = \sum_{I=1}^{D} a(\emptyset 1)S1 + n = AS + n$$

Where A is the matrix of steering vectors,

$$A=[a(\emptyset 1)a(\emptyset 2)\ldots\ldots a(\emptyset D)]$$

Where S= [s1... sD]' is the signal vector, and n= [n1… nM] is a noise vector with components of variance.
The received vectors and the steering vectors can be visualized as vectors in an M-dimensional vector space. The input covariance matrix is

$$R_{vv} = E[uu^H] = AR_{ss}A^H + \sigma_n^2$$

Where Rss is the signal correlation matrix. \
The DOA's of the multiple incident signals can be estimated by locating the peaks of a MUSIC spatial spectrum.

$$P(\emptyset) = \frac{1}{a^H(\emptyset)V_n V_n^H a\emptyset}$$

3.2. DOA ESTIMATION USING ESPRIT ALGORITHM:

ESPRIT is another parameter estimation technique, based on the fact that in the steering vector, the signal at one element has a constant phase shift from the previous element. ESPRIT is a subspace based estimation technique where the poles are computed using Covariance matrix. The data model consists of *M* signals. By using the data model, the correlation matrix of *y* can be written as

$$R = \varepsilon[yyH] = \varepsilon[(x+n)(x+n)^H]$$

3.3. DOA Estimation Using MATRIX PENCIL METHOD

The narrowband sources located in the far field of auniformly spaced array consisting of isotropic omni-directional point sensors radiating in free space is considered. This results in a uniform linear array (ULA). The focus here is to use the unitary transform to convert the complex matrices used in the MP formulation to real matrices and use these matrices to estimate the DOA of multiple signals simultaneously impinging on the ULA. The vector x(n) is the set of voltages measured at the feed point of the antenna elements of the ULA. Therefore, x(t) can be modeled by a sum of complex exponentials, i.e.,

$$y(t) = x(t) + n(t) = \sum_{i=1}^{M} Re^{s_{i_t}} + n(t)$$

where
y (t)= observed voltages at a specific instance t.
n (t)= noise associated with the observation
x(t)= actual noise free signal

Now, let us consider the matrix pencil

$$Y_b - \lambda Y_a = Z_a R_0 [Z_0 - \lambda I] Z_b$$

$$Y_a^{+} = \{Y_a^H Y_a\}^{-1} Y_a^H$$

The DOA is obtained from

$$\theta_i = \sin^{-1}\left(\frac{Im(log z_i)}{\pi d}\right)$$

where,

$$z_i = e^{j\frac{2\pi}{\lambda} d \sin(\theta)}$$

For noisy data, the Singular Value Decomposition is useful to reduce some of the noise effect.

4. BEAMFORMING

A beam former is a set of sensors (antennas), arranged either in a linear or circular fashion, with outputs that can be steered electronically. The goal of beamforming is interference cancellation, that is, to isolate the signal of the desired user, contained in overall signal from interference and noise. The weights of the filter are continuously changed i.e. adapted according to the received signal. Such adaptive filters attempt to filter out jammer signals. Jammer signals are received by the sensors from directions other than the selected signal source.

4.1. IMPLEMENTATION OF MVDR ALGORITHM:

Fig.2 shows a uniform linear array (ULA) of N-Equi-spaced sensors.

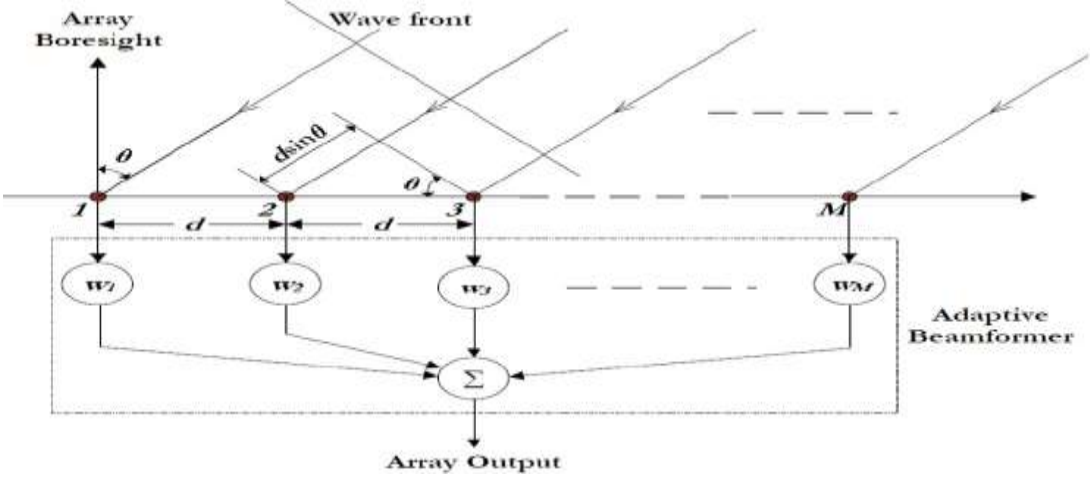


Figure 2 Uniform Linear Array with M- Element

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

$$W = \frac{R^{-1}A}{A^H R^{-1} A}$$

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

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

4.2. IMPLEMENTATION OF LMS ALGORITHM:

The LMS bam former configuration is shown in Fig. 3.

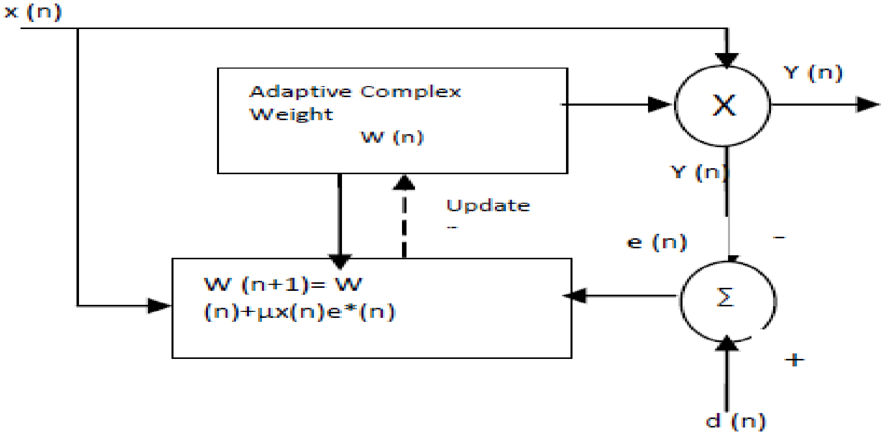


Figure 3: LMS beam former

The output of the array is given by,

$$y(t) = w^H x(t)$$

The reference signal d(t) generated at the receiver is usually assumed to have similar statistical properties as the transmitted signal.

This give ua a simple expression for weight updating:

$$W[n+1] = w[n] + \mu X[n](d[n] - X^H[n]W[n])$$

The larger the value of µ, the faster the convergence but the lower the stability around the minimum value.

LMS algorithm can be summarized in following equations:

Output, $y(n) = w^H(n)$
Error, $e(n) = d(n) - y(n)$
Weight, $w(n+1) = w(n) + \mu x(n)e(n)$

4.3. Method of steepest descent

The method of steepest descent is the simplest of the gradient methods. Imagine that there's a function *F*(*x*), which can be defined and differentiable within a given boundary, so the direction it decreases the fastest would be the negative gradient of *F*(*x*). To find the local minimum of *F*(*x*), The Method of The Steepest Descent is employed, where it uses a zigzag like path from an arbitrary point *X*0 and gradually slide down the gradient, until it converges to the actual point of minimum.

To put this step into a function, one can get:

xk+1 = *xk* ¡ ¸*krF*(*xk*) = *xk* ¡ ¸*kg*(*xk*) (1)

In the above iterative form, the term *g*(*xk*) is the gradient at a given point. It is obvious that in order tonod the point where *F*(*x*) is a minimum, the directional derivative at that point would be zero, and in this case, the directional derivative is given by:

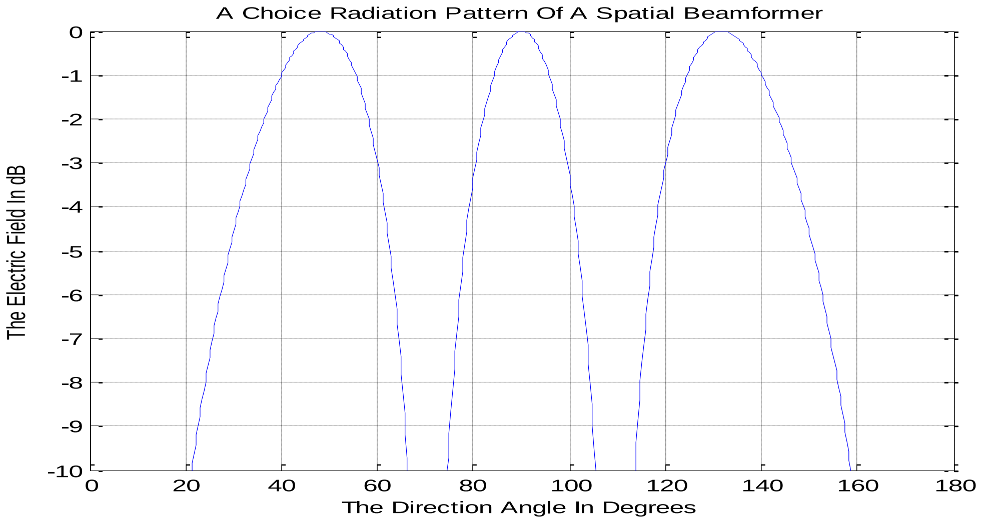
d=*d*¸*kF*(*xk*+1) = *rFxk*+1*Td*=*d*¸*kxk*+1 = ¡*rF*(*xTk*+1)*g*(*xk*)

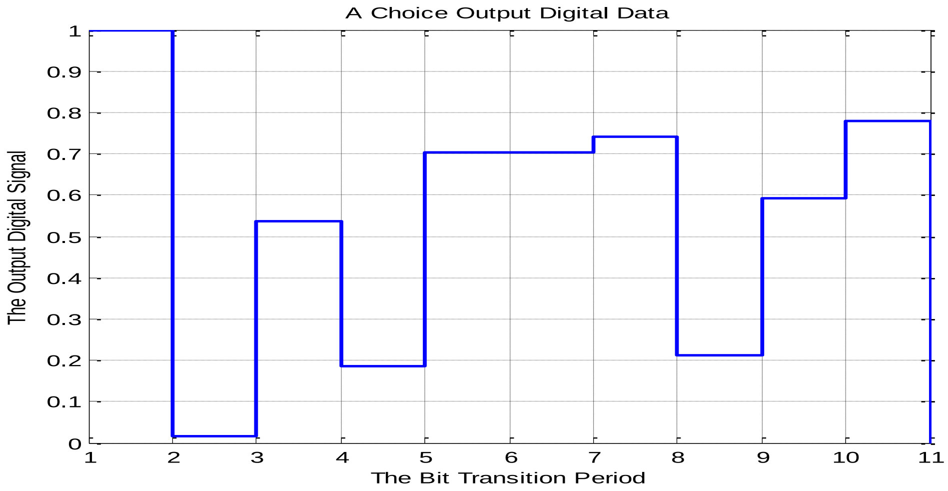
By setting the above equation equal to zero, it is clear that the term ¸*k* should be used as the step taken in the gradient direction so that *rF*(*xk*+1) and *g*(*xk*) become orthogonal. By taking steps in this direction of the negative gradient, this essentially is a minimization problem along a line for different values of ¸*k*. It is not hard to see why the method of steepest descent is so popular among many mathematicians: it is very simple, easy to use, and each repetition is fast. But the biggest advantage of this method lies in the fact that it is guaranteed to find the minimum through numerous times of iterations as long as it exists. Thus the convergence speed is pretty slow, this process can literally take forever! Although a larger step size will increase the convergence speed, but it could also result in an estimate with large error.

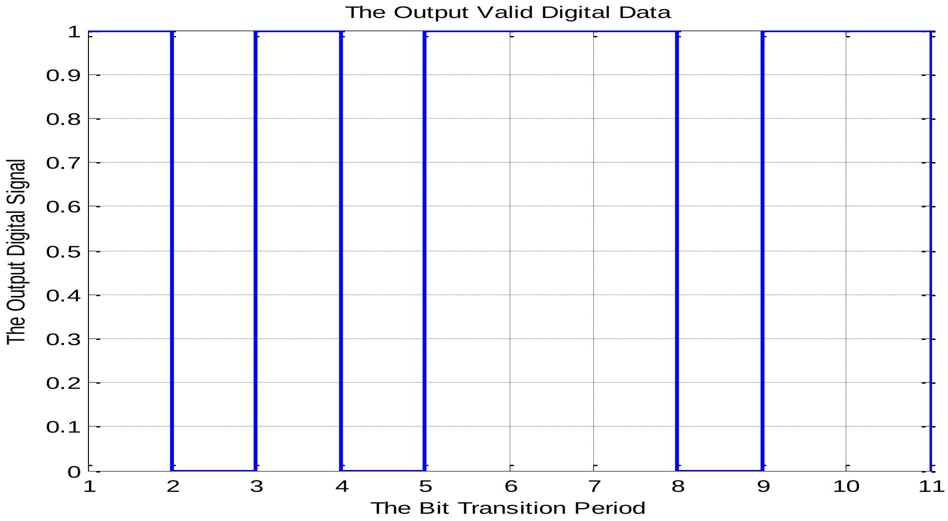
5. SIMULATION RESULTS:

We set the following parameters The channel to signal noise ratio:10.The signal arrival phase angles:[10,25].

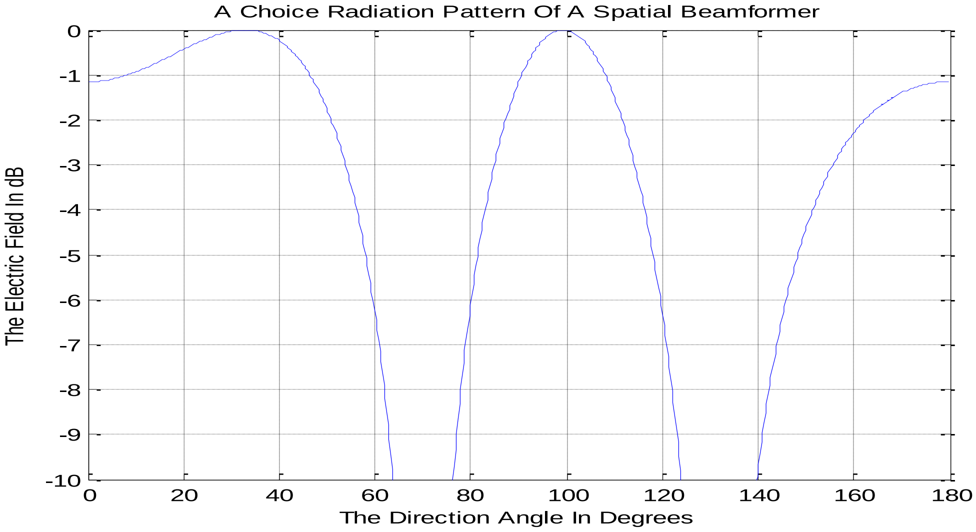
5.1 simulation result for music algorithm

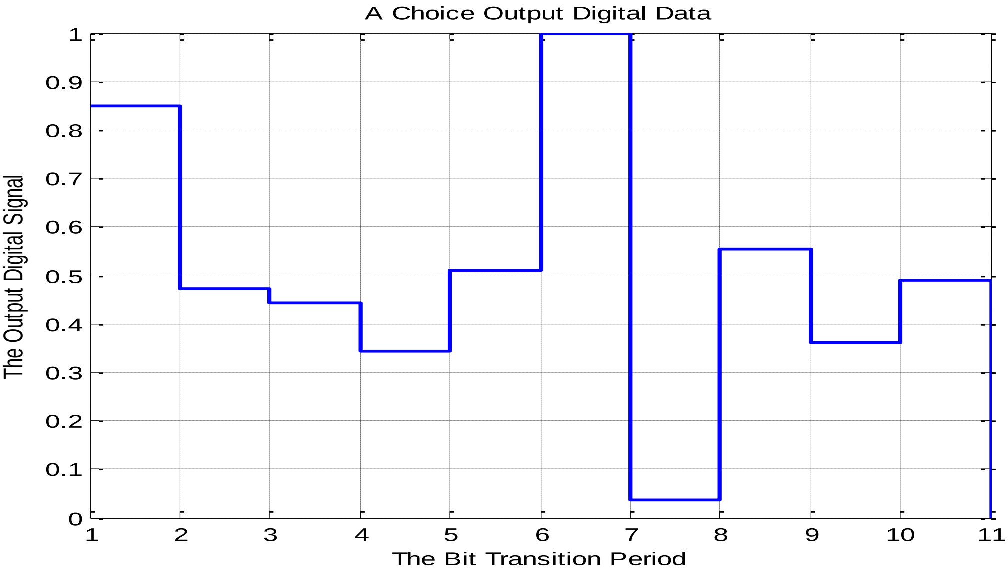


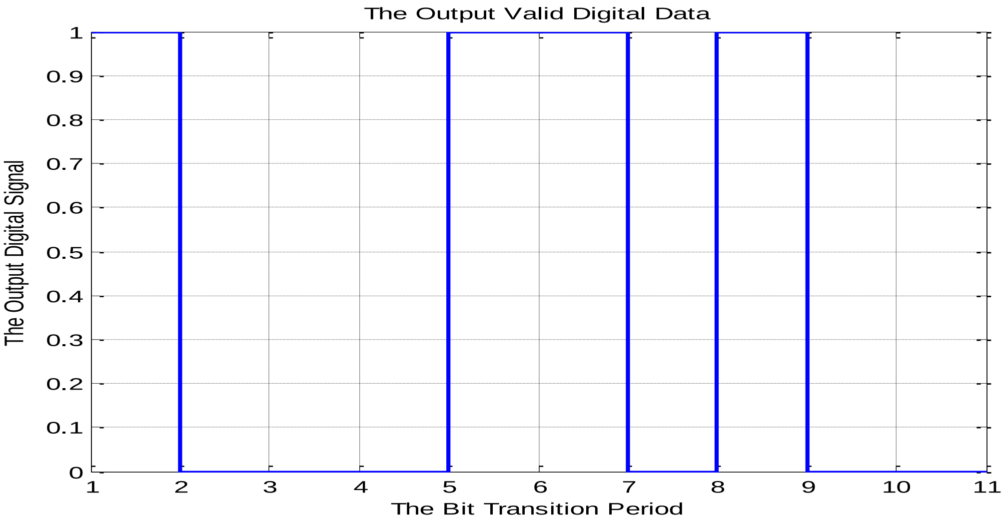




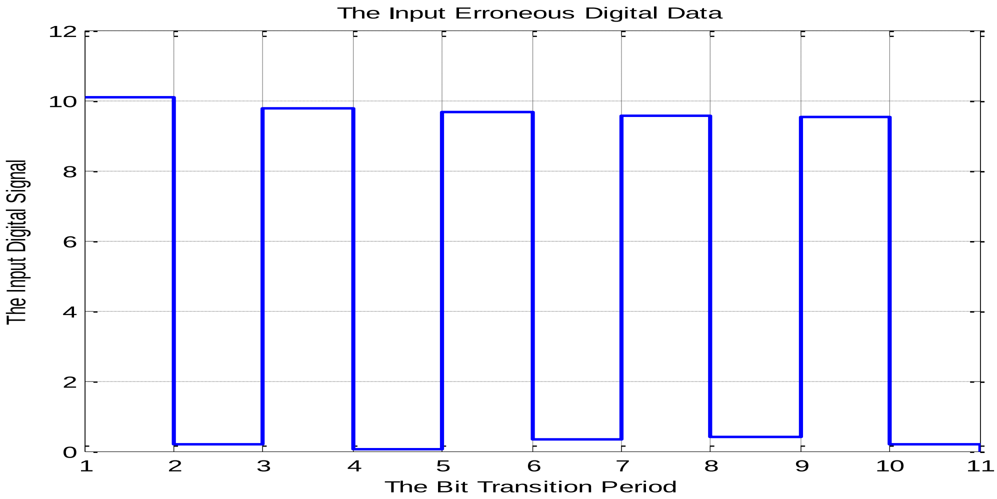
5.2 simulation result for ESPRIT algorithm

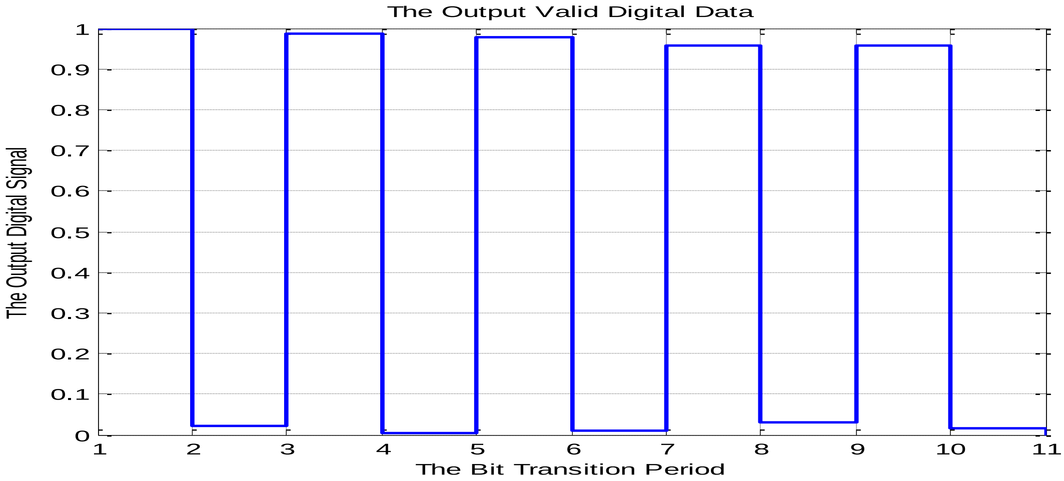


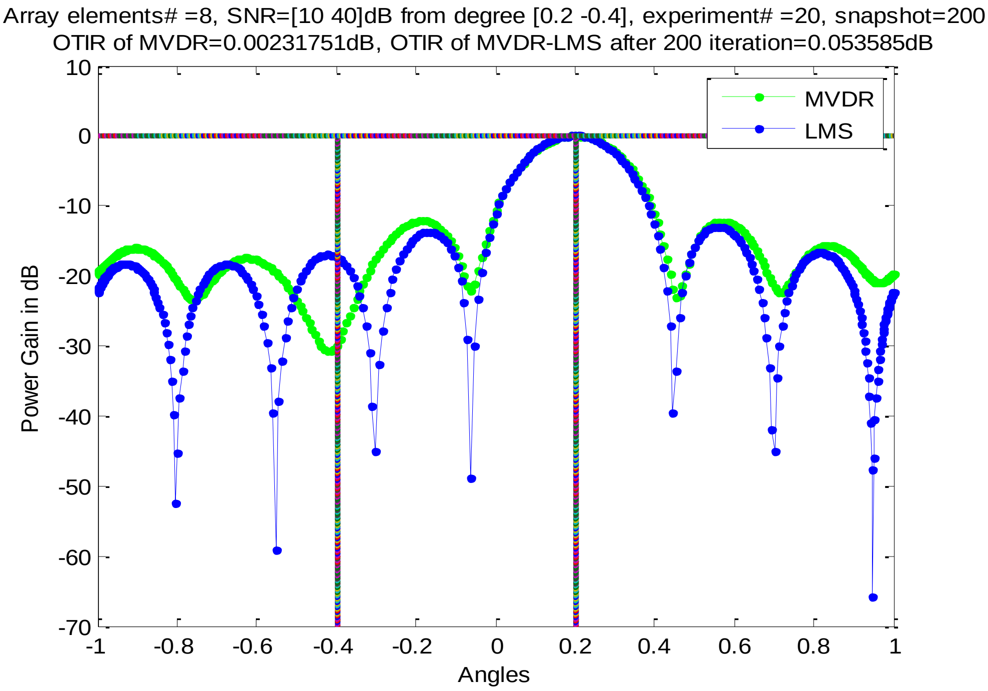




5.3 Simulation result for MATRIX PENCIL algorithm







6. CONCLUSION:

This paper presents results of direction of arrival estimation using MUSIC, ESPRIT and MATRIX PENCIL algorithms. These three methods have greater resolution and accuracy than the other considered (Bartlett, CAPON) and hence they are investigated much in detail. The simulation results show that performance of MUSIC, ESPRIT and MATRIX PENCIL improves with more elements in the array, with higher number of snapshots of signals and greater angular separation between the signals. These improvements are analyzed in the form of sharper peaks in MUSIC spectrum and smaller errors in angle detection. Results indicate that as number of snapshots increases, the MSE decreases, which results in accurate detection of closely spaced signals. For MUSIC, the ideal value of number of snapshots is 700, which gives MSE as zero. The performance of the three algorithms has been evaluated for different value of SNR, which results in giving the highest ranking to MUSIC, as the most stable and accurate algorithm, which provides high resolution despite lower value of SNR. Thus, this study adds a new possibility of user separation through SDMA and can be widely used in the design of smart antenna system. A versatile simulation tool that implements the MVDR, LMS and Steepest descent algorithms for adaptive beamforming was developed with a user-friendly GUI. It has been observed that there is a sharp peak in an angular spectrum of MVDR algorithm and a lower noise floor compared to the LMS algorithm. The developed simulation tool can be used to improve and accelerate the design of wireless networks. Results of numerical simulation are useful for the design of smart antennas systems with optimal performance.

REFERENCES:

1. Nuri Yilmazer, Tapan K. Sarkar, Magdalena Salazar-Palma" DOA Estimation using Matrix Pencil and ESPRIT Methods",URSI International Symposium on Electromagnetic theory 2010.
2. Tanuja S. Dhope(Shendkar)" Application of MUSIC, ESPRIT and ROOT MUSIC in DOA Estimation",Faculty of Electrical Engineering and Computing,University of Zagreb,Croatia.
3. W.Varade,K. D. Kulat" Robust Algorithms for DOA Estimation andAdaptive Beamforming for Smart Antenna Application", Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09.
4. T.B. LAVATE, Prof. V.K. KOKATE, Prof. Dr. A. M. SAPKAL "Performance Analysis of MUSIC and ESPRIT DOA Estimation algorithms for adaptive array smart antenna in mobile communication", Second International Conference on Computer and Network Technology.
5. S.F. Shaukat, Mukhtar ul Hassan, R. Farooq, H.U. Saeed and Z. Saleem "Sequential Studies of Beamforming Algorithms for Smart Antenna Systems", World Applied Sciences Journal 6 (6): 754-758, 2009 ISSN 1818-4952 © IDOSI Publications, 2009
6. Khyati R.Zalawadia, Twinkle V. Doshi , Dr U D Dalal "Interference Rejection Performance of Adaptive Beam Forming through LMS Algorithm", Proceedings of Second International Conference on Signals, Systems & Automation (ICSSA-11)24-25 January.
7. Xu Wang, "Method of Steepest Descent and its Applications" ,Department of Engineering, University of Tennessee, Knoxville, TN 37996 (Dated: November 25, 2008).
8. Hak-Lim Ko, Yong-Hyun Seo, Kil-Yong Kim, Deok-Won Yun, Ok-Min Kim, Dae-Geon Cho, Seok-Hoon Lee, "Performance Analysis of Smart Antenna System for Mobile Terminals", Department of Information & Communications Engineering, Hoseo University.
9. Abdul Aziz, M.Ali Qureshi, M. Junaid Iqbal, S.Zeeshan A. Zaidi,"Performance and Quality Analysis of Adaptive Beam forming Algorithms (LMS,CMA, RLS & CGM) for Smart Antennas", 2010 3rd International Conference on Computer and Electrical Engineering (ICCEE 2010).