ISSN 2320 - 2599
Volume 5, No.2, March – April 2016
International Journal of Microwaves Applications
Available Online at http://www.warse.org/IJMA/static/pdf/file/ijma01522016.pdf

Direction of Arrival Estimation in Smart Antenna Using MUSIC and Improved MUSIC Algorithms at Noisy Environment

Anwesha Dhar, Anupama Senapati, Jibendu Sekhar Roy
School of Electronics Engineering, KIIT University
Bhubaneswar, Odisha, India
Anwesha.dhar100@gmail.com, senapati.anupama@gmail.com, drjsroy@rediffmail.com

ABSTRACT

The performance of smart antenna in mobile network depends on the accuracy of determination of angle of arrival (AOA) or direction of arrival (DOA). In this paper, the performances of multiple signal classification (MUSIC) algorithm and improved MUSIC algorithm are used for DOA estimation. In improved MUSIC algorithm modification is done by the conjugate reconstruction of the data matrix of the MUSIC algorithm. From simulation results it is found that the improved MUSIC algorithm gives appropriate angular resolution with increasing number of antenna sensors compared to MUSIC algorithm in different noisy environment.

Key words: Coherent signal, direction of arrival, MUSIC algorithm, non-coherent signal, smart antenna.

1. INTRODUCTION

A smart antenna composed of various antenna sensors, whose signal is diagnosed automatically in order to use the mobile radio channel's spatial domain. By locating the main beam in the user direction and forming nulls towards the interference signal direction, smart antennas can provide higher signal-to-noise ratio (SNR), minimum co-channel interference and multipath fading with higher the system capacities in mobile network. The smart antenna employs antenna arrays along the units of digital signal processing to enhance transmission and reception of antenna patterns for the signal environment response [1]. The block diagram of a smart antenna is shown in Figure 1.

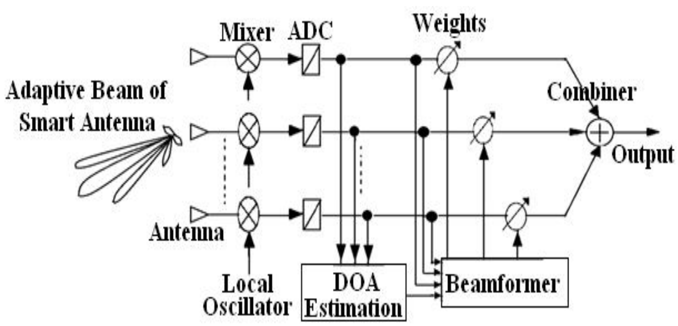

Figure 1: Block diagram of a smart antenna system

In smart antenna [2], [3], firstly, the DOA of incoming signal is estimated along with multipath signals and interference signals angle of arrival. Then the required user signal is identified and separated from the rest of unwanted incoming signals. Afterward a radiation pattern is generated in the desired direction to the user and producing nulls in the direction of interference signals. The received signal is a combination of transmitted signal, interferer's signal, multipath component and noise at the receiver's side. Hence, the recognition of required signal is difficult.

The main objective of direction of arrival (DOA) estimation is to use the information received by antenna array elements to determine the directions of the signals from the users as well as the directions of interference signals [4], [5]. Some of the DOA estimation algorithms are delay-and-sum method, Capon's minimum variance technique [6], multiple signal classification (MUSIC) algorithm, estimation of signal parameter via rotational invariance technique (ESPRIT) [7]. The DOA algorithm considering SNR is also reported [8]. The target of DOA estimation techniques is to plot a pseudospectrum, by searching the peak to find the angle of arrival of signal [9], [10]. Among different DOA estimation utilized algorithms, MUSIC algorithm is depended on decomposition of received signal's covariance matrix [11] and has good estimation accuracy and reduced complexity of system as compared to other DOA algorithms. Due to decomposition of received signal's covariance matrix, it is partitioned into two subspace matrices such as signal subspace and noise subspace [12]. MUSIC algorithm gives appropriate impinging signal direction and more stable [13] resolution compared to ESPRIT. The high resolution of direction of arrival has achieved by MUSIC algorithm in case of non-coherent or uncorrelated signal. The effectiveness of MUSIC is lost for AOA estimation of correlated or coherent signal [14]. Therefore, direction finding of coherent signal has been an active area of research and various improved and modified version of MUSIC algorithm has been proposed [14], [15] which are efficient while angle detection of coherent signal by removing the correlation between the signals.

In this paper an improved MUSIC algorithm is utilized for better performance of MUSIC and the detection of coherent signal direction at different noisy environment with low SNR. Better resolution is achieved using improved MUSIC algorithm.

2. MUSIC ALGORITHM

The widely used algorithm for DOA estimation is MUSIC algorithm [9], [11], [14]. MUSIC algorithm gives the knowledge about impinging signal strengths, number of impinging signals and cross-correlation between noise power and impinging signals. Suppose that a sensors array which is linear with Q sensors and they are apart from each other by distance 'b' which is lower than half of signal wavelength and also assume that S number of impinging signals, sticking at angles $\phi_1, \phi_2, ..., \phi_S$, are collected by array sensors. Now it is considered that the number of impinging signals (S) to be below the number of sensors (Q) i.e. S<Q and the distance 'b' separated the two consecutive sensors of the sensors array is expressed as a space matrix [$b_1\ b_2 \dots \dots b_{Q-1}$].

The signals data collected by all array sensors at the 't' samples is represented by [12]

$$x(t) = \sum_{k=0}^{S-1} a(\theta_k) h_k(t) + e(t) = Ah(t) + e(t) \tag{1}$$

Where $e(t) = [e_0(t), e_1(t), ...e_{S-1}(t)]$ is the white Gaussian noise matrix, $h^T(t) = [h_0(t), h_1(t)......., h_{S-1}(t)]$ is the impinging signals matrix and A is the steering matrix. The assumption of uncorrelated noise in MUSIC algorithm makes the nature of covariance matrix diagonal.

The covariance matrix (V_{xx}) of signal's data can be illustrated as

$$\begin{aligned} V_{xx} &= E[x.x^H] = E[(Ah+e)(h^H A^H + e^H)] \\ &= AE[h.h^H]A^H + E[e.e^H] \\ &= AR_{s11}A^H + R_{n11} \end{aligned} \tag{2}$$

Where R_{s11} states signal covariance matrix of S x S sensors, $R_{n11} = \sigma^2 I$ states noise covariance matrix of Q x Q sensors, I states identity matrix of Q x Q sensors and A is the steering vector of Q x S sensors. The decomposition of covariance matrix is resulted in the number of Q eigen values along with relative eigen vectors P. Among Q eigen values, S largest eigen values associates to the source signals and the rest smaller eigen values of Q-S are corresponded to noise subspace. If T_N and T_S denote noise and signal subspaces respectively, then the finale decomposed covariance matrix is

$$V_{xx} = T_S \sum T_S^H + T_N \sum T_N^H \tag{3}$$

Orthogonality condition in MUSIC algorithm between steering matrix and noise matrix gives

$$a^H(\phi) T_N T_N^H a(\phi) = 0 \tag{4}$$

at different angles of arrival $\phi_1, \phi_2, ..., \phi_S$

Therefore, the pseudospectrum of MUSIC to evaluate the impinging signal direction is

$$B_{MUSIC}(\phi) = \frac{1}{a^H(\phi) T_N T_N^H a(\phi)} \tag{5}$$

3. IMPROVED MUSIC ALGORITHM

MUSIC algorithm is limited to uncorrelated or non-coherent signals. This failure of MUSIC algorithm is due to the signal covariance matrix (R_{xx}) which does not satisfy the full rank condition required by the MUSIC for Eigen decomposition. The improvement of MUSIC algorithm is possible by improved MUSIC [14], [15] algorithm for better estimation of coherent and non-coherent signals. The improved MUSIC algorithm is modified by the conjugate reconstruction of the data matrix of the MUSIC algorithm. To estimate the coherent signal DOA, improved MUSIC algorithm removes the correlation between signals.

The improvement of MUSIC algorithm is done by introducing a transformation matrix K. K is an M-th order transition matrix, represented by [12]

$$K = \begin{bmatrix} 0 & 0 & \dots & 1 \\ 0 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 1 & 0 & \dots & 0 \end{bmatrix} \tag{6}$$

So that the new received signal matrix z is represented as

$$z = Kx^* \tag{7}$$

where x* is the complex conjugate of x.

The new covariance matrix V_{xx} is defined as

$$V_{zz} = E[zz^H] = KVx^*K \tag{8}$$

The reconstructed conjugate matrix V can be formed from the summation of V_{xx} and V_{zz}

$$V = V_{xx} + V_{zz} = AR_{S11}A^H + K[AR_{S11}A^H]^* K + 2\sigma^2 I \tag{9}$$

Because of the matrix summation rule, the matrices V_{xx},V_{zz} and V will have the same noise subspace. The decomposition of V give its eigen values and eigen vectors, after sorting of eigen values one can divide the eigen vectors into two subspaces to obtain the new noise subspace. This new noise subspace is used to construct pseudo spectrum to find the estimated DOA value by searching the peaks.

4. DIRECTION OF ARRIVAL ESTIMATION

The DOA estimations using MUSIC and improved MUSIC are simulated in MATLAB. The efficiency of both the algorithms has analyzed by taking number of samples 210, additive white Gaussian noise of 0,-5,-10,-15 dB, array sensors spacing 0.5λ and varying number of array sensors in all simulations. The DOA estimation is done for two angles -20^0 and 20^0.

First, the effect on resolution of MUSIC algorithm with increasing array sensors in different noisy environment is investigated. Figure 2, Figure 3, Figure 4 and Figure 5 represent the DOA estimation using MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=0dB, SNR=-5dB, SNR=-10dB, SNR=-15dB respectively.

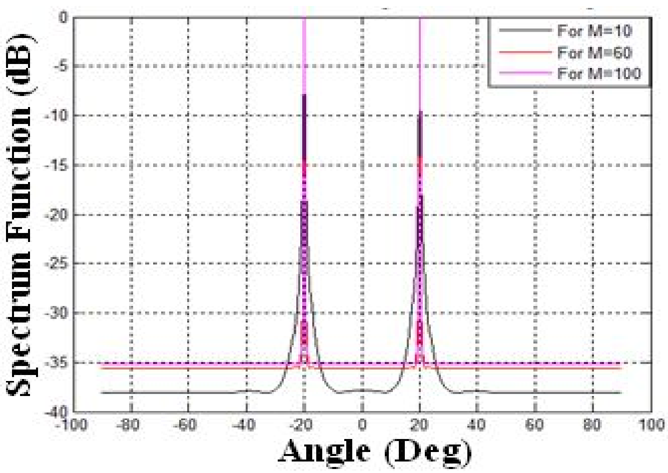

Figure 2: DOA estimation of MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=0dB

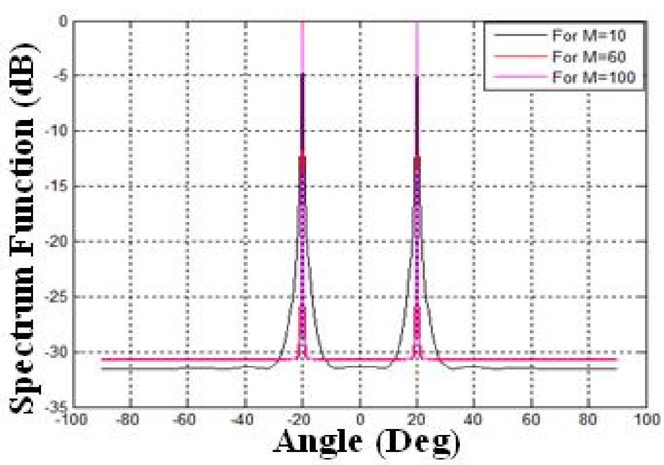

Figure 3: DOA estimation of MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-5dB

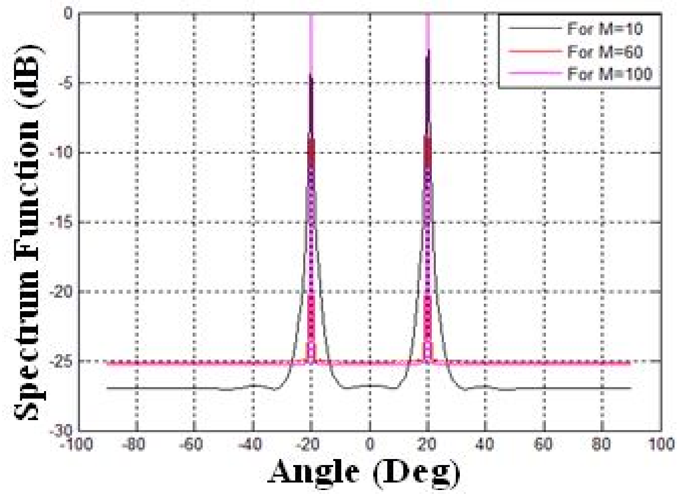

Figure 4: DOA estimation of MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-10dB

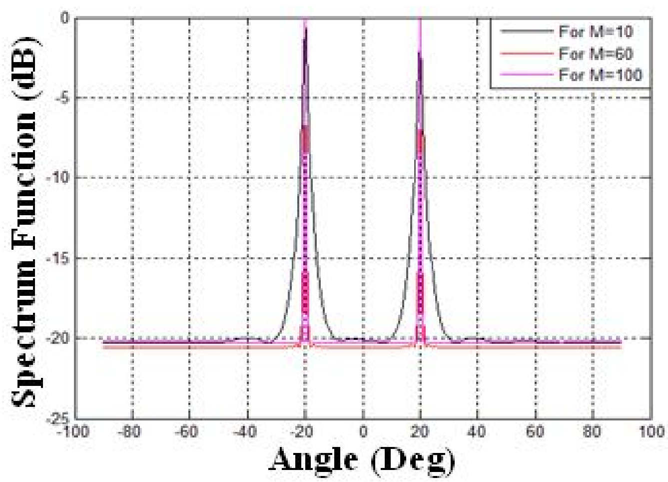

Figure 5: DOA estimation of MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-15dB

From the above figures, it is observed that due to increase in number of array sensors, MUSIC algorithm using non-coherent signal, can precisely determine the DOA of impinging signals in different noisy environment.

Figure 6, Figure 7, Figure 8 and Figure 9 represent the DOA estimation using MUSIC algorithm using coherent signal for varying antenna sensors with SNR=0dB, SNR=-5dB, SNR=-10dB, SNR=-15dB respectively.

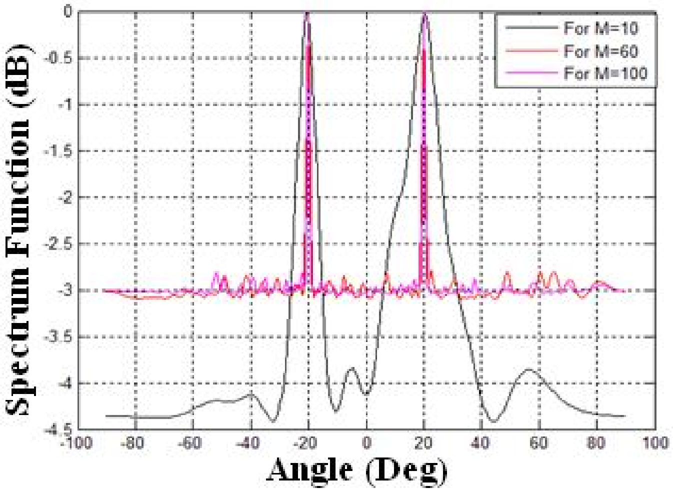

Figure 6: DOA estimation of MUSIC algorithm using coherent signal for varying antenna sensors with SNR=0dB

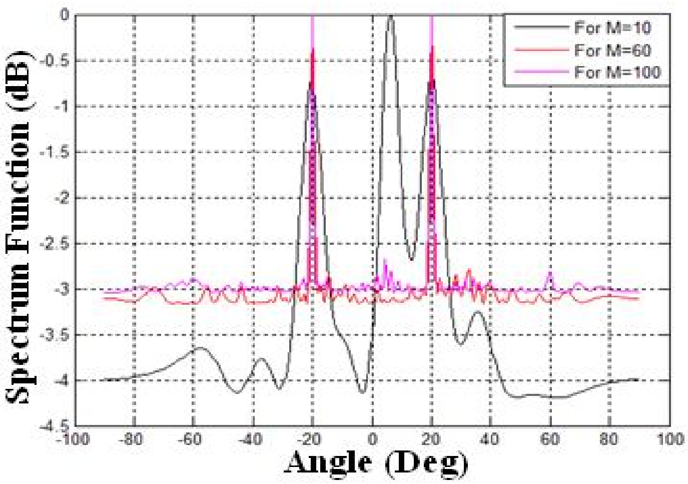

Figure 7: DOA estimation of MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-5dB

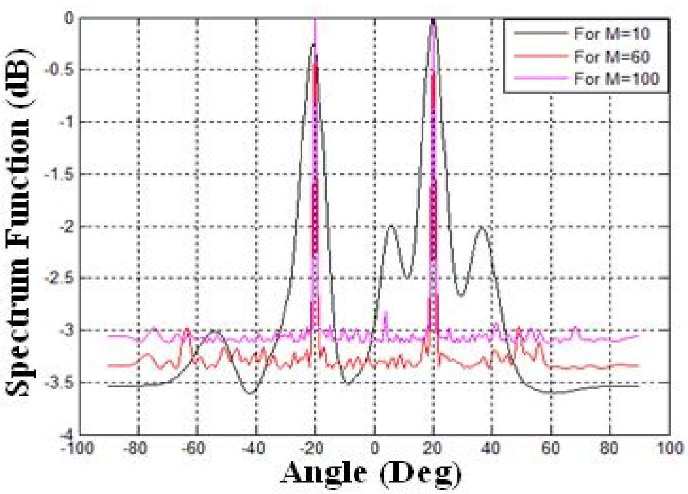

Figure 8: DOA estimation of MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-10dB

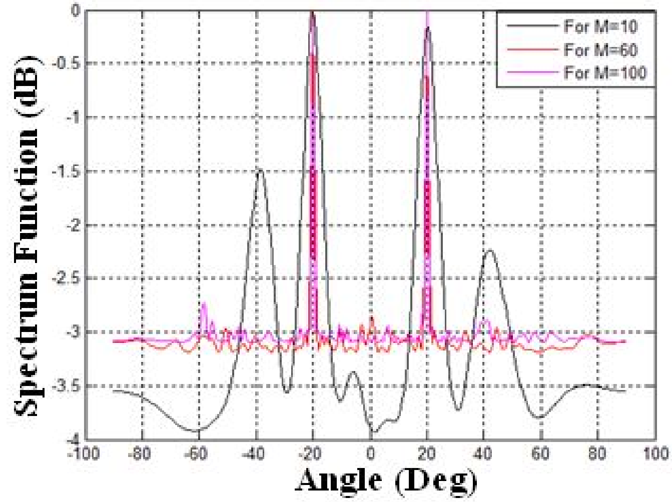

Figure 9: DOA estimation of MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-15dB

From simulation results it is found that by increasing number of antenna sensors the resolution can be improved and the extraction of direction of arrival of coherent signal becomes easier.

Now, the effect on resolution of improved MUSIC algorithm with increasing array sensors in different noisy environment is studied. Figure 10, Figure 11, Figure 12 and Figure 13 show the DOA estimation using improved MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=0dB, SNR=-5dB, SNR=-10dB, SNR=-15dB respectively.

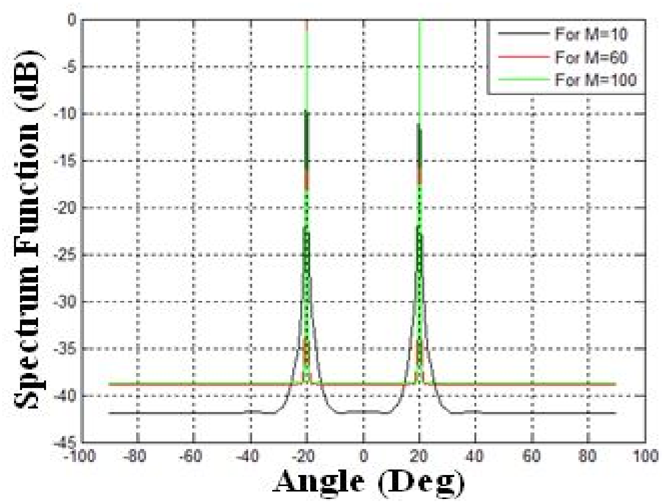

Figure 10: DOA estimation of Improved MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=0dB

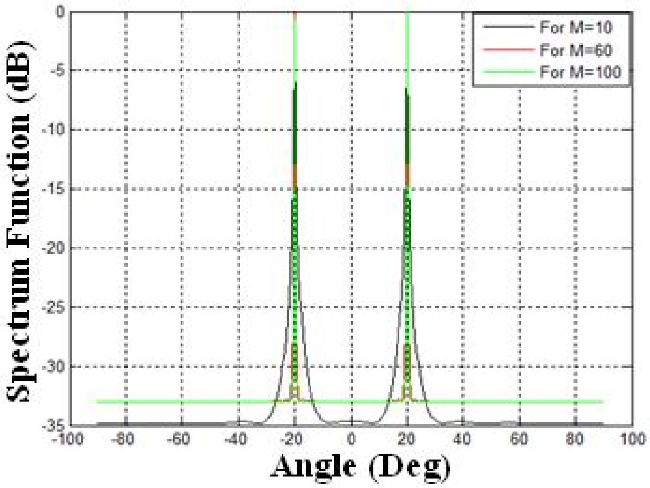

Figure 11: DOA estimation of Improved MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-5dB

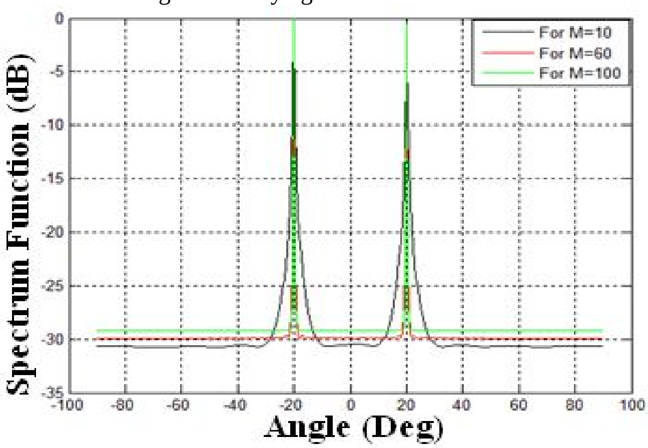

Figure 12: DOA estimation of Improved MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-10dB

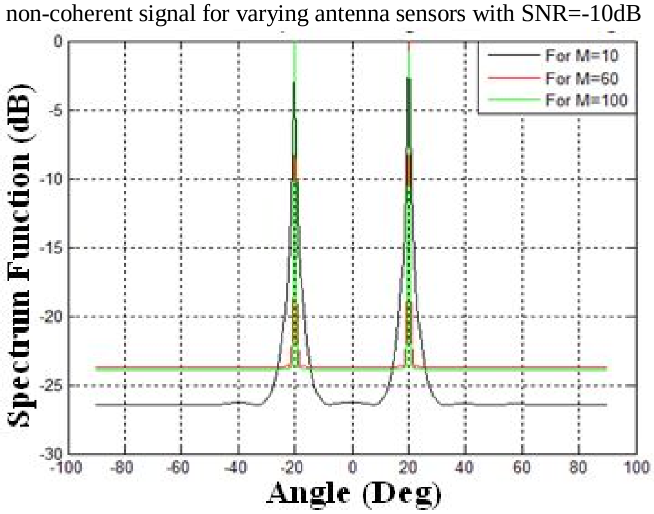

Figure 13: DOA estimation of Improved MUSIC algorithm using non-coherent signal for varying antenna sensors with SNR=-15dB

Figures indicate that as antenna sensors increases from 10 to 100, peaks become sharper in spectrum and hence increase the improved MUSIC algorithm's resolution capability in different noisy environment.

Figure 14, Figure 15, Figure 16 and Figure 17 show the DOA estimation using improved MUSIC algorithm using coherent signal for varying antenna sensors with SNR=0dB, SNR=-5dB, SNR=-10dB, SNR=-15dB respectively.

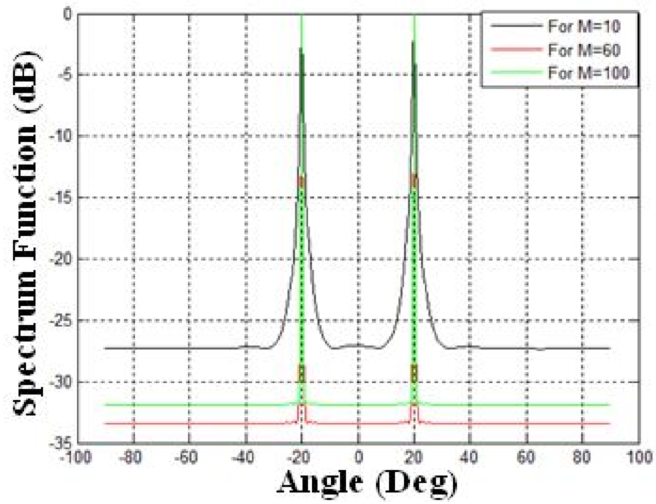

Figure 14: DOA estimation of Improved MUSIC algorithm using coherent signal for varying antenna sensors with SNR=0dB

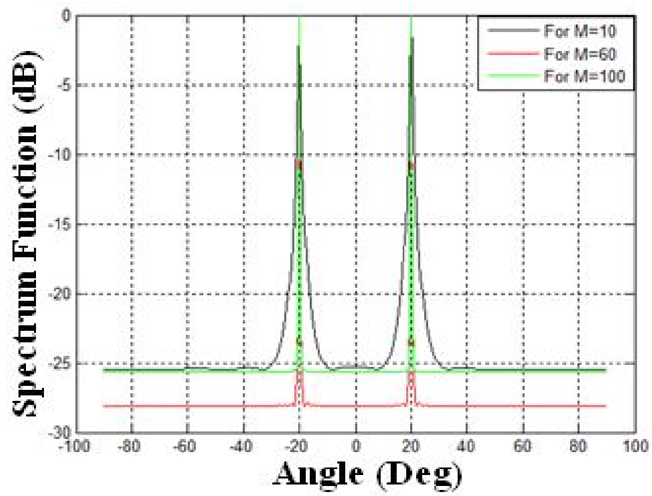

Figure 15: DOA estimation of Improved MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-5dB

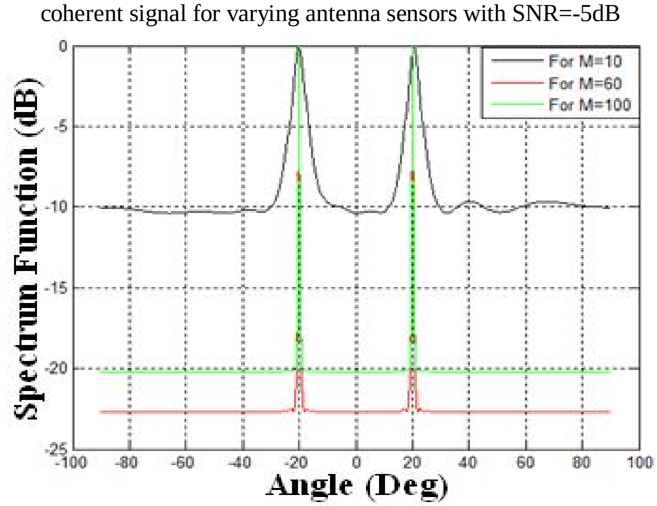

Figure 16: DOA estimation of Improved MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-10dB

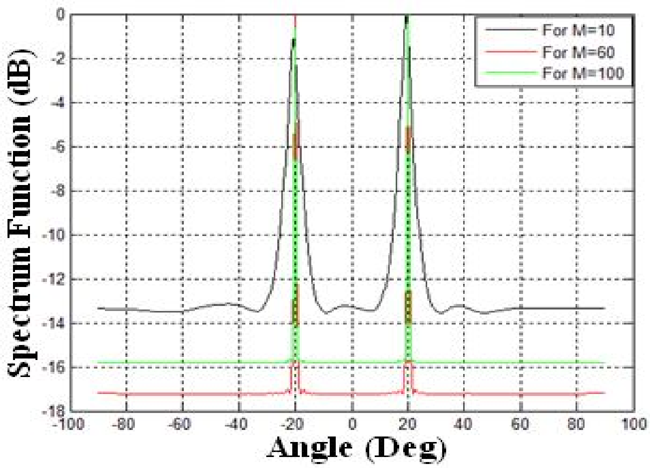

Figure 17: DOA estimation of Improved MUSIC algorithm using coherent signal for varying antenna sensors with SNR=-15dB

Results show that with increase in number of antenna sensors, spectral beamwidth of DOA estimation becomes narrow in different noisy environment. In all simulation, effect of varying number of antenna sensors gives the information about performance of MUSIC and improved MUSIC algorithms by reducing the beamwidth. Resolution is better for improved MUSIC compared to MUSIC. From simulation results, one can find that the beamwidth is almost similar for antenna sensors 60 and antenna sensors 100.

5. CONCLUSION

The impact on MUSIC and improved MUSIC algorithm using coherent and non-coherent signal for changing number of antenna sensors are analyzed in different noisy conditions and found that the estimation accuracy of MUSIC and improved MUSIC improve with increment in number of antenna sensors. The increase in number of antenna sensors make the peaks more sharp, more definite and corresponding direction of arrival accurately in the spectrum of MUSIC and improved MUSIC and also array directivity becomes good. Therefore, increase the antenna sensors to get DOA estimation accurately, but more number of antenna sensors, more data needs to be processed and increase the computational complexity which leads to lower speed for the execution of algorithms. The resolution is better for improved MUSIC algorithm as compared to MUSIC algorithm.

REFERENCES

1. J. H. Winters. **Smart antennas for wireless systems**, *AT&T Lab Research, IEEE Personal Communications*, vol. 5, no. 1, pp. 23-27, February1998.
2. L. Lazovic, and A. Jovanovic. **Comparative performance study of DOA algorithm applied on linear antenna array in smart antenna systems**, *2nd Mediterranean Conference on Embedded Computing, MECD* - 2013.
3. C. Balanis. ***Antenna Theory, Analysis and Design***, 3rd edition, John wiley and Sons, Hoboken, USA, 2005.
4. L. Godara. **Application of Antenna Arrays to Mobile Communications, Part II: Beam-Forming and Direction-of-Arrival Considerations**, *Proceedings of the IEEE*, vol. 85, no. 8, pp. 1195–1245, August 1997.
5. F. Li, H. Lui, and R. J. Vaccaro. **Performance analysis for DOA estimation algorithms: unification, simplification, and observations**, *IEEE Transactions on Aerospace and Electronic Systems*, vol. 29, no. 4, pp. 1170 – 1184, October 1993.
6. H. Elkamchouchi, and M. *A.* E. Mofeed. **Direction-of-arrival methods (DOA) and time difference of arrival (TDOA) position location technique**, *Twenty Second National Radio Science Conference (NRSC)*,March 15-17,2005.
7. K. K. Kumari, B. Sudheer, and K.V. Suryakiran. **Algorithm for direction of arrival estimation in a smart antenna**, *International Journal of Communication Engineering Applications-IJCEA*, Vol. 02, No. 04, pp.144-149, July 2011.
8. L. C. Godara. **Application of antenna arrays to mobile communications, part II: beam-forming and direction-of-arrival considerations**, *Proceedings of the IEEE*, Vol. 85, No. 8, pp. 1195–1245, August 1997.
9. R.O. Schmidt. **Multiple emitter location and signal parameter estimation**, *IEEE Transactions on Antennas and Propagation*, vol. AP-34, issue 3, pp. 276-280, March 1986.
10. R. Roy, and T. Kailath. **ESPRIT – estimation of signal parameters via rotational invariance techniques**, *IEEE Trans. On Acoustic, Speech, and Signal Processing*, vol.37,pp. 984-995, July 1986.
11. M. M. Abdalla, M. B. Abuitbel, and M. A. Hassan. **Performance evaluation of direction of arrival estimation using music and esprit algorithms for mobile communication systems**, *Proceedings of IEEE Wireless and Mobile Networking Conference(WMNC)*, pp 1-7, April 2013.
12. S. S. Balabadrapatruni. **Performance evaluation of direction of arrival estimation using MATLAB, Signal & Image Processing**, *(SIPIJ)*, vol. 3, no.5, pp. 1-7, October 2012.
13. T. V. Lavate, V. K. Kokate, and A. M. Sakpal. **Performance analysis of MUSIC and ESPRIT DOA estimation algorithms for adaptive array smart antenna in mobile communication**, *IEEE 2nd International Conference on Computer and Network Technology*, 2010.
14. Y. Gao, W. Chang, Z. Pei, and Z. Wu. **An improved music algorithm for DOA estimation of coherent signals**, *Sensors & Transducers*, vol. 175, no. 7, pp. 75-82, July 2014.
15. K. F. A. Tabatabaie. **A new Improved-MUSIC algorithm for high resolution direction of arrival detection**, *Journal of Theoretical and Applied Information Technology*, vol.72, no.1, pp. 101-105, February 2015.