KIET IJCE KIET International Journal of Communications & Electronics
Volume. No. 6, Issue No. 1, Jan-June 2018, ISSN: 2320 – 8996

A Comparison of Sub Array Beam forming Technique with others Directions of Arrival Estimation Techniques

Balram Tamrakar[#1], Krishna Singh[*2], Parvin Kumar Kaushik[#3]
Guru Gobind Singh Indraprastha University, New Delhi, India.
GB Pant Government Engineering College, okhala, New Delhi, India
Electronics & Communication Engineering Department, KIET Group of Institution, Ghaziabad, India
[1]balramtamrakar11@gmail.com,
[2]singhkrishna5@gmail.com,
3parvin.kaushik@kiet.edu

Abstract: There are different Directions of Arrival (DOA) techniques by which we can estimate the incoming signals. In this research paper, I proposed the comparison between different Directions of Arrival techniques such as Sub Array beam forming based DOA, Capon & MUSIC (Multiple Signals Classification) DOA. Sub Array Beam forming based Direction of Arrival Estimation (SBDOA) technique is used & then comparison with other existing techniques. In this technique the antennaarray is decomposed in to two equal size virtual sub array. Two virtual sub arrays are used to form a signal whose phase relative to the reference signal & it is a function of the DOA.The DOA is then estimated based on the computation of the phase shift between the reference signal and its phase-shifted version. The phase-shifted reference signal is obtained after interference rejection through beam forming; the effect of interference on the process is significantly reduced by the use of this technique. SBDOA technique gives the best results than other existing techniques.

Index terms: Beam forming, Direction of Arrival (DOA), Estimation, Uniform Linear Array (ULA), Pilot signal.

INTRODUCTION

There are various techniques by which we can estimate the direction of arrival such as multiple signal classification (MUSIC) and estimation of signal parameters via rotational invariance technique (ESPRIT) and CAPON technique. I amdiscussingonlythree techniques as SBDOA (SubArray Beam forming based Direction Of Arrival), MUSIC and CAPON, further i will compare all the three techniques. In MUSIC-class techniques, the DOAs are determined by finding the directions for which their antenna response vectors lead to peaks in the MUSIC spectrum formed by the eigenvectors of the noise subspace,the capacity of DOA estimation using MUSIC is no more than M-1 where, M is the number of antenna elements in the antenna array [2]. In the capon technique we are using the minimum variance distortion less response algorithm to find out the estimated DOA, in the capon technique we are try to minimize the output power of the system except that the desired signal directions [3]. MUSIC DOA estimation gives more accurate result than capon method for two closely located signals, with small array element number; the capon method results give more error than MUSIC method results. Generally these techniques are not very effective to find out the better resolute estimated DOA. Further, using these techniques in the presence of multiple signal sources, the DOAs of the target signals and interference are all estimated, and as a consequence, these techniques cannot identify which signal source corresponds to which estimated DOA. To find out a better result in DOA estimation, a new sub array beam forming-based DOA (SBDOA) estimation technique that uses a reference signal (pilot signal) is used; the major difference between the used SBDOA estimation technique and existing techniques is that in the SBDOA estimation technique, the target DOA is estimated after interference rejection using Beam forming.

In other existing techniques, the DOA estimation is based on either computing the spatial signatures or antenna response vectors, as a result, a DOA is estimated in the presence of many other signals from sources other than the target one and, therefore, the performance of DOA estimation algorithms is significantly degraded by the interference.

In the used SBDOA estimation technique, the target DOA is estimated from the phase shift introduced in the actual signal by sub array beam forming, which is a function of the target DOA. Since the phase shift is estimated after sub array beam forming, all signals and interference other than the target one can be efficiently rejected or separated before DOA estimation. Thus their interference on the DOA estimation is reduced. In this way, the estimation resolution and accuracy of the used SBDOA technique are better than those of other existing techniques. The capacity of DOA estimation using SBDOA technique can be far larger than the number of antenna elements. The SBDOA technique is computationally simpler and can be easily implemented in terms of hardware. Further, the use of a reference signal that can be either a pilot signal or a decision - directed signal enables the used SBDOA technique to identify which signal source corresponds to which estimated DOA
.

FORMATION OF SIGNAL MODEL

In the SBDOA technique we are using the uniform linear array (ULA) antenna geometry; the antenna array is decomposed into two equal-sized sub arrays such that for each element in one sub array, there is a corresponding **element** in the other sub array displaced by a fixed translational distance. Here we discuss the commonly used uniform linear array (ULA) and the SBDOA technique can be easily applied to other kinds of antenna arrays. Consider an M-element ULA with adjacent element spacing D deployed at a base station. Let angle θ_k in radians denote the DOA of the signal from source k. The M dimensional column vector $a(\theta_k)$, known as the antenna-array response vector is given by [1]

$a(\theta_k) = [1 \; z(\theta_k) \ldots \ldots \ldots z(\theta_k)^{M-1}]^{T}$
Where $z(\theta_k) = e^{-j2\pi D \sin\theta_k/\lambda}$ and λ is the wavelength.
Figure 1 shows that general configuration for a ULA antenna having M elements arranged along a straight line with the distance between sensor elements, d, equal to one half of the incoming signal wavelength, λ. The angle of the incoming signal α is measured relative to the antenna bore sight. Here α angle can be taken as angle θ; it is just for the reference purpose.

KIET IJCE KIET International Journal of Communications & Electronics
Volume. No. 6, Issue No. 1, Jan-June 2018, ISSN: 2320 – 8996

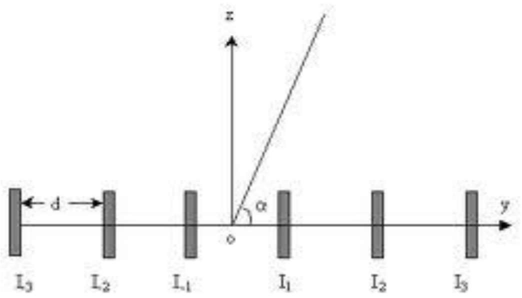

Fig1: Uniform Linear Array (ULA)

We assume that signals from different sources are uncorrelated or have negligible correlation with each other. If there are K signal sources and J unknown interference sources, then the received signal at the antenna array after down-converting to baseband can be represented by the M-dimensional vector as

$$u(t) = \sum_{k=1}^{K+J} s_k(t)a(\theta_k) + n(t)$$

Where $s_k(t)$ for k = 1, 2… K is a target signal component, $s_k(t)$ for k = K+1, 2…K+J is an unknown interference component, and $n(t)$ is a stationary background noise vector.

BEAM FORMING

Beam forming is signal processing technique that is used in sensor array to find out the directional signal transmission and reception. A Beam former is an array of sensors which can do spatial filtering, the objective is to estimate the signal arriving from the desired direction in the presence of noise and other interfering signals, a beam former does spatial filtering in the sense that it separates two signals with overlapping frequency content originating from different directions. Beam forming is the method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired, and nulling the pattern of the targets/mobiles that are undesired/interfering targets, this can be done with a simple FIR (Finite Impulse Response) filter. The weights of the FIR filter may also be changed adaptively, and used to provide optimal beam forming, in the sense that it reduces the MMSE between the desired and actual beam pattern formed.

SUB ARRAY BEAM FORMING BASED DIRECTION OF ARRIVAL ESTIMATION

The block diagram of the used SBDOA system is illustrated in Figure, two virtual sub arrays are used in conjunction with two sub array beam formers to obtain an optimum estimation of a phase-shifted reference signal whose phase relative to that of the reference signal is a function of the target DOA, the target DOA is then computed from the estimated phase shift between the phase-shifted reference signal and the reference signal [1]. Consider the case where θ_k for k = 1, 2,……,K is the target DOA to be estimated.

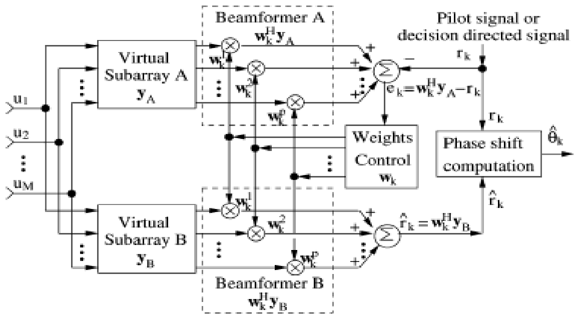

Fig2: Block Diagram of SBDOA

The function of the used DOA estimator is as follows. Two sub arrays signal vectors y_A and y_B are formed such that the phase shift between each signal component in y_A and its corresponding signal component from the same source in y_B is a function of the DOA, the two sub array signals are then fed into beam formers A and B. The weight vector w_k is obtained by minimizing the mean-square error (MSE) e_k between the output signal of beam former A and the reference signal r_k ,using the weight vector w_k obtained from beam former A, the sub array signal $y_B$is weighted and combined in beam former B.

The output of beam former B, i.e., r_k is an optimum estimation of the phase-shifted reference signal and, further, the phase of r_k relative to that of the reference signal r_k is a function of the target DOA,θ_k, finally, the estimation $\hat{\theta}_k$of the target $\theta_k$is obtained based on the computation of the phase shift between the phase-shifted reference signal r_k and the reference signal r_k.

SUB ARRAY SIGNAL FORMATION

The ULA is deployed at the receiver, and two kinds of antenna element multiplexing geometries can be used to obtain two virtual sub arrays as:

(1) Maximum Overlapping Sub arrays (MOSs)
(2) Conjugate Sub arrays (CSs).

Consider an M-element ULA deployed at a receiver, MOSs have two sets of (M-1)-element virtual sub arrays, A and B. Sub array A consists of the first M-1 elements of the M-element antenna array deployed at the receiver and sub array B consists of the last M-1 elements. In CSs, each virtual sub array has the same number of elements as the antenna array deployed, Using the SBDOA technique, CSs lead to more efficient sub array beam forming and provide higher estimation accuracy and resolution of the DOA than MOSs

COMPUTATION OF DOA

Let $\hat{r}_k(t) = (w_k^B)^H y_B(t)$ denote the output signal of beam former B. Since $\hat{r}_k(t)$ is an optimum estimation of the phase shifted reference signal $e^{j\emptyset_k} r_k(t)$ in the MMSE (Minimum Mean Square Error) sense, it can be written as

$$\hat{r}_k(t) = e^{j\emptyset_k} r_k(t) + n_k(t)$$

This represents the reference signal shifted by $\emptyset_k$ plus an estimation error.

$\hat{r}_k = [r_k(1) r_k(2) \dots\dots\dots\ r_k(L)]^T$
$r_k = [\hat{r}_k(1)\hat{r}_k(2) \dots\dots\dots\ \hat{r}_k(L)]^T$

Let denote vectors with samples of the reference signal and the estimated phase-shifted reference signal in a snapshot interval, respectively, if $\hat{\emptyset}_k$denotes an estimate of $\emptyset_k$, it can be computed using the least square method such that the square error between the two signal vectors $\hat{r}_k$ and $r_k$is minimized, i.e.,

$$\underset{\hat{\emptyset}_k}{minimize} \left\| \hat{r}_k - e^{j\hat{\emptyset}_k} r_k \right\|$$

If, $e^{j\emptyset_k} = p + jq$ where,$p^2 + q^2 = 1$, the optimization problem in the above equation can be written as

$$\underset{p,q}{minimize}\ f(p,q) = \| \hat{r}_k - (p + jq) r_k \|$$
$$subjected\ to\ \ p^2 + q^2 = 1$$

This optimization problem can be easily solved using the Lagrange multipliers method and the solution $\hat{\emptyset}_k$ can be obtained as

$$\hat{\emptyset}_k = \arg(p + jq) = \arg(r_k^H \hat{r}_k)$$

This is the angle of the complex inner product of the reference signal vector and its phase-shifted version, an estimation of the target DOA can then be obtained as

$$\hat{\theta}_k = \begin{cases} \arcsin\left(\frac{-\lambda\hat{\emptyset}_k}{2\pi D}\right), & for\ MOSs \\ \arcsin\left(\frac{\lambda\hat{\emptyset}_k}{2\pi D}\right), & for\ CSs \end{cases}$$

In the used technique, the DOA is estimated from the phase shift between the reference signal and its phase-shifted version, thus, the capacity of DOA estimation is no longer bounded by the number of antenna elements as in existing techniques. Most importantly, the DOAs are estimated after interference rejection through sub array beam forming and, therefore, the effect of interference on DOA estimation is reduced.

KIET IJCE KIET International Journal of Communications & Electronics
Volume. No. 6, Issue No. 1, Jan-June 2018, ISSN: 2320 – 8996

SIMULATION RESULTS

In this section, the resolution, capacity, and accuracy of the SBDOA technique will be evaluated and compared with the other existing techniques through simulations. Here I am using Matlab tool to obtain simulation results.

The term resolution of DOA estimation is used to denote the minimum angle difference between two DOAs that can be resolved by the estimation technique. The term capacity is used to denote the maximum number of signal sources that a DOA estimation technique is capable of detecting. Firstly we compare the resolution of the SBDOA estimation using the MOS and CS and then after we will compare the resolution and capacity of the SBDOA estimation with the other existing techniques.

RESOLUTION OF SBDOA ESTIMATION FOR MOS & CS

This simulation result deals with a case where the DOAs of three signals and interference sources are closely distributed. A five-element ULA with a spacing of D = λ/2 deployed at the receiver was considered, three target signal components and one interference components with a pilot signal were assumed to be received at the antenna array with equal power. A snapshot length of 200 samples was used for both MOS and CS techniques. The vertical axis represents the occurrences as the number of times that a certain value of estimated DOA was obtained and the horizontal axis represents the estimated DOA in degree.

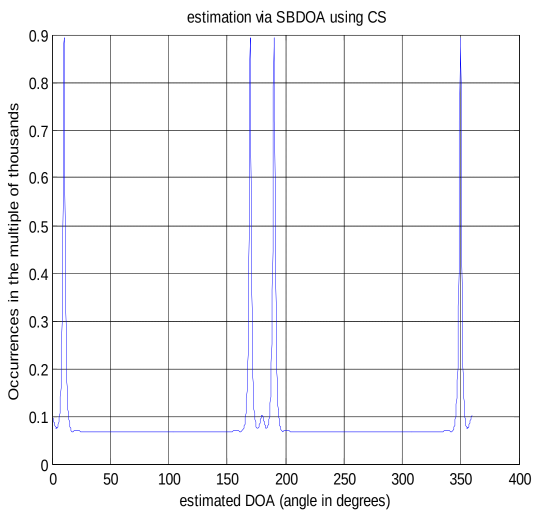

Fig3: Estimation via SBDOA using CSs.

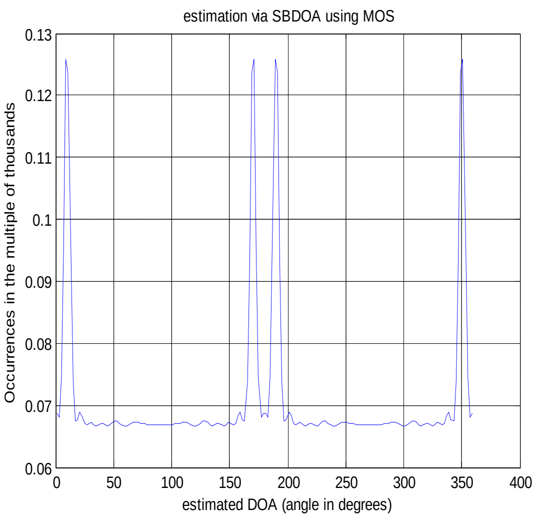

Fig4: Estimation via SBDOA using MOSs.

In this simulation result the actual DOA of the target signal is set at 170, 180 and 350 degree angles, and one interference is set at 10 degree angle, from the simulation results we can say that the resolution of the SBDOA technique using CSs is better than using MOSs, this is due to the fact that CSs have one more antenna element than MOSs in each sub array, which will lead to higher SINR (Signal to Interference plus Noise Ratio) at the beam former output for CSs. Because MOSs contains only M-1 elements of the sub array then its SINR is less than the SINR of CSs, an increase in SINR leads to better estimation accuracy.

COMPARISON OF THE RESOLUTION & CAPACITY OF DOA ESTIMATION

In this simulation result we compare the resolution and capacity of the SBDOA technique with the other existing techniques like MUSIC and CAPON; here we are taking the Comparison of resolution and capacity of DOA estimation when the number of signal and interference sources is larger than the number of antenna elements, all the simulation conditions kept the same as in the previous section of simulations. Here we have simulation result of (1) SBDOA technique using CSs, (2) SBDOA technique using MOSs. (3) MUSIC, (4) Capon techniques.

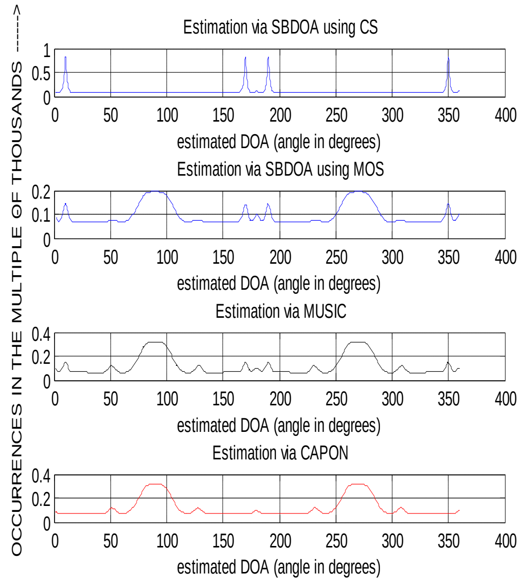

Fig5: Comparison between different DOA estimation techniques.

In this case of SBDOA using CSs we have the three target DOA at 170 , 180 and 350 degree angles, and one interference at 10 degree angle, in the SBDOA using MOSs we have also three target DOA at 170, 180 and 350 degree angle, and interference at 10, 90 and 270 degree angle, in the MUSIC technique we have three target signal at 170, 180 and 350 degree angle and it have more number of interference than SBDOA at 10, 50, 90, 130, 270 and 310 degree angle, the capon technique does not provides any target DOA and also it have more number of interference than SBDOA and MUSIC techniques. As shown from the simulation result the resolution of the three target DOA in SBDOA technique using CSs and MOSs is much better than the MUSIC and CAPON techniques, the MUSIC and CAPON technique having low SINR than SBDOA therefore these techniques have poor resolution. In terms of capacity the SBDOA, and MUSIC estimation technique detecting three target signals but CAPON technique does not detecting any target signals.

CONCLUSION

The comparison between different estimation technique has been proposed, in Sub Array Beam Forming-based Direction of Arrival

Estimation (SBDOA) technique, the two sub array beam formers are used to obtain an optimum estimation of the phase-shifted reference signal whose phase is relative to the reference signal and which is a function of the target DOA, the target DOA is estimated from the phase shift between the reference signal and its phase-shifted version, and the DOA is estimated after the interference rejection through beam forming in this way, the effect of interference on DOA estimation is reduced and the number of detectable signal sources can exceed in terms of the number of antenna elements, means detectable signal sources does not depends on the number of antenna elements used. Performance analysis and extensive simulations show that the used technique SBDOA offers significantly improved resolution, capacity, and accuracy of the estimation relative to the other existing techniques.

REFERENCES

[1] Nanyan Wang, Panajotis Agathoklis, and Andreas Antoniou, Life Fellow," A new DOA estimation technique based on sub array beam forming (SBDOA)" IEEE transaction. On signal processing, vol. 54, no. 9, sep. 2006.

[2] R. O. Schmidt, "Multiple emitter location and signal parameter estimation," IEEE Trans. Antennas Propag., vol. AP-34, pp. 276–280, Mar. 1986.

[3] P. Handel, P. Stoica, and T. Soderstrom, "Capon Method for DOA Estimation: Accuracy and Robustness Aspects," IEEE winter workshop on Nonlinear Digital Signal Processing, 1993. pp: P_7.1-P_7.5.

[4] L. C. Godara, "Application of antenna arrays to mobile communications—II: Beam-forming and direction-of-arrival considerations," Proc. IEEE, vol. 85, no. 8, pp. 1195–1245, Aug. 1997.

[5] J. Capon, "High-resolution frequency-wave number spectrum analysis," Proc. IEEE, vol. 57, pp.1408-1418 Aug. 1997.

[6] M. L. McCloud and L. L. Scharf, "A new subspace identification algorithm for high-resolution DOA estimation," IEEE Trans. Antennas Propag., vol. 50, pp. 1382–1390, Oct. 2002.

[7] S. Lim, J. Lee, and J. Park, "Performance evaluation of adaptive beam forming using pilot and traffic channel in CDMA2000 reverse link," in Proc. IEEE Veh. Technol. Conf., Sep. 2002, vol. 4, pp. 2154–2157.

[8] Y. Wang and J. R. Cruz, "Adaptive antenna arrays for cellular CDMA communication systems," in Proc. Int. Conf. Acoustics, Speech, Signal Processing (ICASSP) 1995, Apr. 1995, vol. 3, pp. 1725–1728.

[9] P. Comon and G. H. Golub, "Tracking a few extreme singular values and vectors in signal processing," Proc. IEEE, vol. 78, pp. 1327–1343, Aug. 1990.

[10] A. L. Swindlehurst, S. Daas, and J. Yang, "Analysis of a decision directed beam former," IEEE. Trans. Signal Process, vol. 43, no. 12, pp. 2920–2927, Dec. 1995.

[11] A. Klouche-Djedid and M. Fujita, "Adaptive array sensor processing applications for mobile telephone communications," IEEE Trans. Veh. Technol., vol. 45, pp. 405–416, Aug. 1996.