International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 07, July-2015

Performance Evaluation of Capon and Capon-like Algorithm for Direction of Arrival Estimation

M. H. Bhede
E&TC Dept.
SCOE, Pune,

D. G. Ganage
E&TC Dept.
SCOE, Pune,
Maharashtra, India

S. A. Wagh
E&TC Dept.
SITS, Narhe, Pune,
India

Abstract: **Wireless communications is one of the most active areas of technology development, since it is satisfying the demand for increasing system capacity.The system capability is improved using Direction-of-Arrival (DOA) estimation algorithm that corresponds to seek out the direction during which desired user and therefore the interference lie for antenna array. This paper investigates and compares Capon and Capon-like DOA estimation algorithm on the uniform linear array (ULA) which are used in design of smart antenna system. The Capon-like algorithm is based on Capon algorithm through the introduction of a new optimization problem, in order that which aims to maintain the array gain in the 'look direction' is constant, usually unity. To verify the performance of the proposed algorithm, simulations are performed and then the results obtained are compared with the Capon algorithm.**

***Keywords*—Wireless Communication, DOA,Capon, Capon-like, Smart Antenna System, ULA.**

I. INTRODUCTION

In array signal processing Direction of Arrival estimation (DOA) stands for estimating the angles of arrivals of received signals by an array of antennas [1].The applications of this DOA estimation are such as in audio processing, wireless communication, radar and sonar, seismology, and wireless emergency call locating [3]. A smart antenna, is a system that combines multiple antenna elements with a signal processing capability to optimize its radiation pattern automatically in response to the system signal environment.In smart antenna systems, DOA estimation is anecessary process to find out the direction of incoming signals and thus to direct the beam of the antenna array towards the estimated direction and placing null towards interference signals.

Many resolution algorithms for DOA estimation are proposed such as Conventional spectral-based method and sub-spaced based and statistical method [3]. Conventional method for DOA estimation is based on the beamforming and null-steering concept, is straightforward, depends on physical size of array and requires low computation complexity. This technique steer beams in all directions and look for the maximum peaks in the output power. The sum and delay or Bartlett and Minimum Variance Distortionless Response (MVDR) or Capon etc. are conventional spectral based methods. Conventional methods have some limited resolution leads to sub-spaced based methods. Higher angular resolutions Multiple Signal Classification (MUSIC)[8] and Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) [8] are sub-spaced based methods having higher accuracy than conventional based methods. In real applications, when the number of sources is incorrectly estimated and the coherent signals existed due to multipath fading, the performance of subspace-based methods will degenerate significantly. To avoid the problem of source estimation of high computational complexity, Capon algorithm can be applied in DOA estimation but with the cost of lower resolution compared with subspace-based method [3].

In this paper, Capon algorithm, which has less computational complexity than subspace-based methods, is used as the basis to derive the proposed algorithm (Capon-like) algorithm. The proposed algorithm is similar to the Capon algorithm in one aspect, which is to minimize power from all direction subject to specific gain in the 'look direction'; hence it is named Capon-like algorithm [3].

Capon and Capon-like algorithms were developed and simulated in MATLAB software. The organization of this paper is as follows- firstly receiving signal model is developed for direction of arrival estimation in Section II. The Capon algorithm is described in detail in Section III. The Proposed Capon-like algorithm is described in detail in Section IV. In section V simulation results and discussion of Capon and Capon-like are presented. Finally conclusions are presented in further Section.

II. SIGNAL MODEL

Figure1 shows a uniform linear array (ULA) of N equispaced sensors. The array consists in a set of antenna elements connected to a receiver through amplitude and phase shift weights.

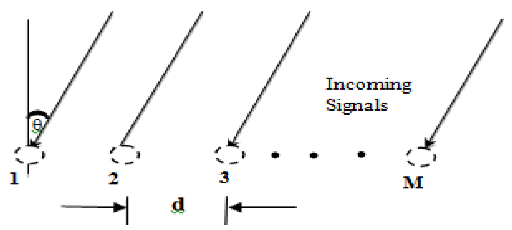

Figure1. Uniform Linear Array

Consider, D signals which are incident on ULA and the received input data vector at M-elements that are separated by a distance. Now, distance d can be expressed as a linear combination of N incident waveforms and noise. The signal vector u (t) can be defined as

$$x(t) = \sum_{l=0}^{D-1} a(\phi_l)\, s_l(t) + n(t) \qquad (1)$$

$$x(t) = [a(\phi_0)\,..\,a(\phi_{D-1})] \begin{bmatrix} s_l(t) \\ . \\ . \\ . \\ s_l(t) \end{bmatrix} + n(t) \qquad (2)$$

Where $a(\phi)$, $s_l(t)$ and $n(t)$ are the steering vector, desiredsignal and noise signal respectively

$$u(t) = A\, s(t) + n(t) \qquad (3)$$

Where, $s^T(t) = [s_0(t) s_1(t) \ldots\ldots s_{D-1}(t)]$ is the vector of incident signals, $n(t) = [n_0(t) n_1(t) \ldots\ldots n_{D-1}(t)]$ is the noise vector, and $a(\phi_j)$is the array steering vector. In terms of the above data model, the input covariance matrix R_{uu} can be expressed as [6]

$$R_{uu} = A\, E[ss^H]A^H + E[nn^H] \qquad (4)$$

Where R_{ss} is the signal correlation matrix $E[ss^H]$.

III. CAPON ALGORITHM

Introduced by J. Capon [3], Capon algorithm is a conventional spectral-based method which is used to improve resolution of Bartlett Algorithm.The main idea of Capon algorithmis to minimize the received power of the incoming signal in all direction while maintaining a unity gain in look direction [3].The constrained imposed on this algorithm is given as:

$$\min_w E[|y(k)|^2] = \min_w w^H R_{uu} w$$

Subject to $w^H a(\phi_0) = 1$(5)

The weight w vector obtained by solving (5) is often called Capon beam former weights or minimum variance distortion less response (MVDR). Applying Lagrange optimization method to the constraint yields the optimized weight,

$$w = \frac{R_{uu}{}^{-1} a(\phi)}{a^H(\phi) R_{uu}{}^{-1} a(\phi)} \qquad (6)$$

The output power of the array as a function of DOA is as shown below.

$$P_{Capon}(\phi) = \frac{1}{a^H(\phi) R_{uu}{}^{-1} a(\phi)} \qquad (7)$$

By computing and plotting MVDR spectrums over the whole range ofϕ, the DOA can be estimated by locating the peaks in the spectrum [12].

VI. CAPON-LIKE ALGORITHM

The proposed algorithm is based on modified Capon algorithm; the steering vector can be expressed asfollows

$$A(\phi) = [g(\phi_1)a(\phi_1)\; g(\phi_2)a(\phi_2)\,..\,a(\phi_N)g(\phi_N)]^T \qquad (8)$$

Where $g(\phi)$ is the array gain in a specific direction ϕ. Since the array response is affected by the gainpattern in a 'look direction', the constraint in Capon-likealgorithm can be given by [3] -

$$\min_w E[|y(k)|^2] = \min_w w^H R_{uu} w$$

Subject to $w^H a(\phi_0) = g(\phi)$(9)

Applying Lagrange optimization technique to the constraint yields the Lagrange multiplier λ, and the optimized weight w given by,

$$\lambda = -\frac{g^H(\phi)}{a^H(\phi) R_{uu}{}^{-1} a(\phi)} \qquad (10)$$

$$w = \frac{R_{uu}{}^{-1} a(\phi) g^H(\phi)}{a^H(\phi) R_{uu}{}^{-1} a(\phi)} \qquad (11)$$

Finally, the power spectrum of the Capon-like algorithm is given as

$$P_{Caponlike}(\phi) = \frac{1}{a^H(\phi) R_{uu}{}^{-1} a(\phi)} \qquad (12)$$

VII. SIMULATION RESULTS

The Capon and Capon-like algorithm of DOA estimation are simulated using MATLAB. In these simulations, it is considered a uniform linear array antenna formed by elements with the equally spaced distance of $\lambda/2$. The noise is Gaussian white noise, SNR=20dB and number of snapshots is 500. The simulation has been run for three independent narrow band signals;angle of arrival is 20^0, 30^0 and 70^0. The performance has been analyzed for different array elementsand SNR.

A. SIMULATION RESULTS OF CAPON ALGORITHM

Case.1: Capon spectrum for varying number of array elements

The effect of varying the number of array elementswith two different values M_1=30, M_2= 100 and other condition remains unchanged are as shown in Figure2. It is clear that as number of array elements increases, the peaks of spectrum become narrower and if number of array element decreases, then angular resolution of Capon algorithm decrease.

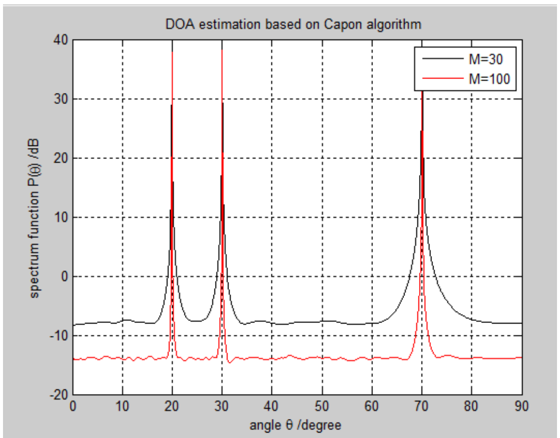

Figure2. MVDR spectrum for varying number of array elements

Case.2: Capon spectrum for varying signal to noise ratio.

The effect of varying the signal to noise ratio with two different values SNR_1= -10, SNR_2= 20 and other condition remains unchanged are as shown in Figure3. It is clear that as the value of SNR increases, precise detection of incoming signal and angular resolution capacity increases also the spectral beam width becomes narrower. The value of SNR can affect the performance of the Capon algorithm.

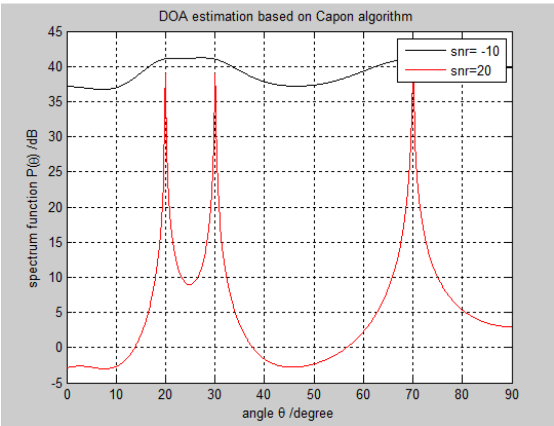

Figure3. MVDR spectrum for varying SNR

B. SIMULATION RESULTS OF CAPON-LIKE ALGORITHM

Case.1: MUSIC spectrum for varying number of array elements

The effect of varying the number of array elements with two different values M_1=30, M_2= 100 and other condition remains unchanged are as shown in Figure4. It is clear that as number of array elements increases, the peaks of spectrum become narrower and if number of array element decreases, then angular resolution of Capon algorithm decrease.

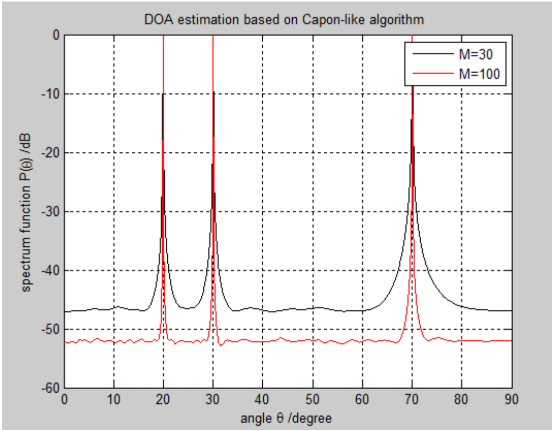

Figure4. MUSIC spectrum for varying number of array elements

Case.3: Capon-like spectrum for varying signal to noise ratio.

The effect of varying the signal to noise ratio with two different values SNR_1= -10, SNR_2= 20 and other condition remains unchanged are as shown in Figure5. It is clear that as the value of SNR increases, precise detection of incoming signal and angular resolution capacity increases also the spectral beam width becomes narrower. The value of SNR can affect the performance of the Capon-like algorithm.

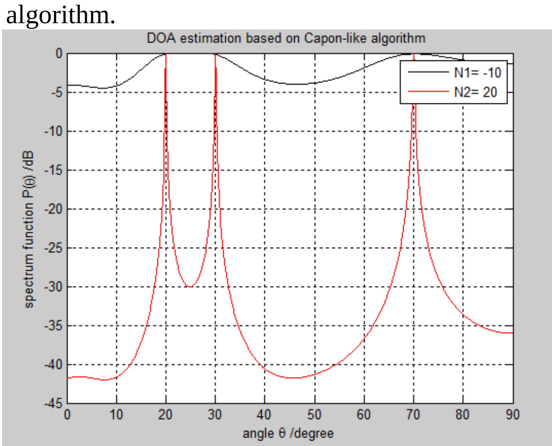

Figure5. Capon-like spectrum for varying SNR

C. SIMULATION RESULTS FOR COMPARISON OF ALGORITHM

In these simulations, it is considered a linear array antenna formed by 10 elements that are equally spaced with the distance of λ / 2. The noise is Gaussian white noise, SNR=20dB and number of snapshots is 500. The simulation has been run for threeindependent narrow band signals;direction of arrival is 20^0, 30^0 and 70^0.

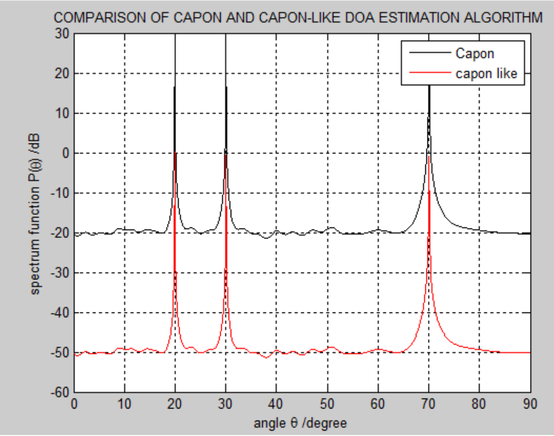

Figure6.Comparison ofCapon and Capon-like spectrum.

CONCLUSION

In this paper a new algorithmCapon-like is proposed from Conventional based Capon DOA estimation algorithm. The two algorithms are sensitive to the number of array elements and signal-to-noise ratio. The angular resolution of the algorithm is improved with increasing the number of array elements, number of snapshots, signal-to-noise ratio. Capon-like algorithm gives more accurate DOA estimation than Capon algorithm for same specification.

REFERENCES

[1] Youssef Khmou, Said Safi, MiloudFrikel,"Comparative Study between Several Direction of Arrival Estimation Methods", *International Journal of Telecommunications and Information Technology 2014.*
[2] L. C. Godara, "Application of Antenna Arrays to Mobile Communications, Part I: Performance Improvement, Feasibility, and System Considerations"*Proceedings of the IEEE, Vol. 85,* 1997.
[3] R. Sanudin, N. H. Noordin, A. O. El-Rayis, N. Haridas, "Capon-Like DOA Estimation Algorithm for Direction Antenna Arrays" *IEEE*, 2011.
[4] PetreStoica, Zhisong Wang, *Jian* Li, "Robust Capon Beamforming", *IEEE Signal Processing Letters*, Vol. 10, No. 6 June, *2003*.
[5] Ahmed KhairyAboul-Seoud, Ahmed Khairy Mahmoud, Alaa Hafez, and Ali Gaballa,"Minimum Variance Variable Constrain DOA Algorithm", *PIERS Proceedings, Guangzhou, China, August 25-28, 2014*
[6] EhsanMohammadi, MasoudMahzoon, and AzarMahmoudzadeh," A New Method to Improve Capon Algorithm", *International Journal of Modern Communication Technologies & Research (IJMCTR), Volume-2, Issue-11, November 2014*
[7] Richard Abrahamsson, Andreas Jakobsson,Petre Stoica," A Capon-Like Spatial Spectrum Estimator For Correlated Sources",*Signal Processing Conference, 2004 IEEE*
[8] N. P. Waweru, D. B. O. Konditi, P. K. Langat, "Performance Analysis MUSIC, Root-MUSIC and ESPRIT DOA Estimation Algorithm",*International Journal of Electrical, Robotics, Electronics and communications Engineering Vol:8 No:1, 2014*
[9] N. P. Waweru, D. B. O. Konditi, P. K. Langat, "Performance Analysis MUSIC, Root-MUSIC and ESPRIT DOA Estimation Algorithm",*International Journal of Electrical, Robotics, Electronics and communications Engineering Vol:8 No:1, 2014*
[10] M. Mohanna, M. L. Rabeh, E. M. Zieur, S. Hekala, "Optimization of MUSIC algorithm for angle of arrival estimation in Wireless communications" *National Research Institute of Astronomy and Geophysics, ELSEVIER*, 2013.
[11] Joseph C. Liberti, Jr., Theodore S. Rappaport, "Smart Antenna for Wireless Communications*", Prentice Hall PTR*, 1999, ISBN 0-13-719287-8.
[12] Frank Gross, "Smart Antennas for Wireless Communications" *McGraw-Hill*, 2005.
[13] C.A.Balanis, "Antenna Theory Analysis and Design", *Wiley Pvt. Ltd*, 2005.