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Multi-Dimensional Angle of Arrival Estimation by Circular Phased Adaptive Array Antennas

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Abstract

In this paper the use of a circular array antenna with adaptive system in conjunction with modified Linearly Constrained Minimum Variance Beam forming (LCMVB) algorithm is proposed to meet the requirement of Angle of Arrival (AOA) estimation in 2-D as well as the Signal to Noise Ratio (SNR) of estimated sources (Three Dimensional 3-D estimation), rather than interference cancelation as it is used for. The proposed system was simulated, tested and compared with the modified Multiple Signal Classification (MUSIC) technique for 2-D estimation. The results show the system has exhibited astonishing results for simultaneously estimating 3-D parameters with accuracy approximately equivalent to the MUSIC technique (for estimating elevation and azimuth angles), and it has privilege to estimate SNR for sources which are under the estimation process.

Finally, the proposed system needs less computational time and hardware complexity when it is compared with Eigen value decomposition techniques used by MUSIC technique. Also, it has cost effectiveness with respect to (3-D) active detecting means such as radars.

Keywords: *Angle of Arrival Estimation, MUSIC, Adaptive Array Antenna System.*

1. Introduction

Over the last decade, the AOA estimation or guesstimate the direction and location of the transmitting sources is the most desirable activities used in electronic ware-fare and security activities [1-4].

The AOA estimations of the received signals by anarray antennas has gained a great attention in the array signal processing subject such as radar and wireless communication system [5]. Most of new directions finding techniques such as Multiple Signal Classification (MUSIC), Estimation of Signal Parameter via Rotational Invariance (ESPRIT) and others [6] had been studied in contexts of one dimensional 1-D (azimuth angle) cases. These techniques are based on Eigen value decomposition of the covariance matrix to the sampled input $x(k$ of the array. These techniques need intensive computation process so that they might not be suited for real time application (where the required signals are to be trucked on line).

One dimension is sufficient for estimating AOA for the land and sea transmitting sources, assuming that the elevation angle is very small. For airborne transmitting means, the AOA estimation of these sources needs a two Dimensional (2-D) real time estimator (elevation θ and azimuth φ).

Adaptive array antenna with fast convergence algorithm and less computational time process offers an effective passive means tool rather than active means (like radars) to estimate the elevation and azimuth of the platform that carried these transmitting sources.

This use is very important in a real war environment because it is a passive and secured activity from the point of view of the electronic ware fare missions(reconnaissance activity). Unlike the active systems(radars) which can be detected and jammed by electronic means or destroyed by weapons. The adaptive array antenna is mainly used for suppressing the interference, multipath and jammer signals, while very few researches talks about the ability of using adaptive array antenna system as angle of arrival estimator [7]. Most of the previous researchers discuss the use of linear array antenna to estimate azimuth angles only. Simultaneous (2-D) estimation needs to use a circular array antenna. Figure (1) shows a circular array antenna mounted on x-y plane and parallel to the z-y plane with elevation angle θϵ[0,/2π] and azimuth angle φϵ[0,2π]. A covariance matrix R_{xx} of the received signals is now carrying complete information about the elevation and azimuth angles as well as the input levels of the received signals. We can explore this information in conjunction with the adaptive processors and algorithms to simultaneously extract the (elevation θ, azimuth φ as well as the SNR).

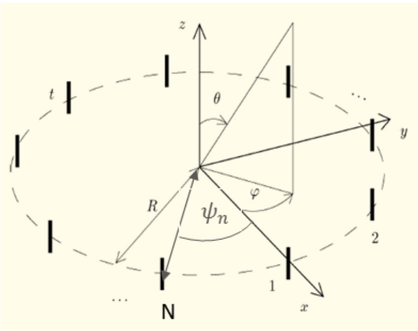

Fig. 1. Uniformly circular array system.

2. Two-Dimension Mathematical Formulation

The Uniform Circular Array (UCA) geometry is shown in Figure (1), the antenna elements assumed to be identical, omnidirectional, and uniformly distributed over a circumference of a circle of radius R in the x-y plane. A spherical coordination system is used to represent the angle of arrival of the incoming plane wave, the origin of the coordination system located at the center of the array.

Source elevation angles $\theta\epsilon\left[0,\frac{\pi}{2}\right]$ are measured up from y-axis toward the z-axis and the azimuth angles$\varphi\epsilon[0,2\pi]$ are measured from x-axis toward the y-axis, the elements N of the array is displaced by an angle of [6]

$\psi_n = \frac{2\,\pi\,n}{N}$ $\quad for\ n = 1,2,\dots,N$and the radius R will be

$$R=N*d*\lambda/2\pi \qquad \dots (1)$$

Where d is the inter element spacing and λ is the wave length of the operating frequency.

For k snapshot the received signal vector will be

$$x(k,\theta,\varphi) = \sum_{i=1}^{D} x_{(i)}(k,\theta,\varphi) + x_{n(i)}(k) \quad \dots (2)$$

Where $x_{(i)}(k,\theta,\varphi)\,, x_n(k)$ are the i[th] received signal and the thermal noise vectors of a length (1×N) respectively. D is the number of received signals under angle of arrival estimation process.

If the received signal is incident from elevation angle θ and azimuth φ, then received signal vector is given by [8]

$$X(k,\theta,\varphi) = A\, e^{j(w_\circ kT+\psi)}U \qquad \dots (3)$$

Where A is signal amplitude, $w_\circ$ center frequency, ψ is arbitrary carrier phase angle distributed [0, 2π] and Uis the array vector corresponding to the incident angles of the received signals and defined by [8]

$$U = \left[g_E(\theta,\ \varphi)\left(e^{j\frac{2\pi}{\lambda}*R*\sin(\theta)\cos(\varphi-\psi_n)}\right)\right]^T \dots (4)$$

Where $g_E(\theta,\ \varphi)$ is the element field pattern and T is denotes to the vector transpose.

The thermal noise voltages in the array channels are assumed to be mutually uncorrelated random signals with zero mean and σ^2variance and it can be expressed as [7]

$$X_n(k) = [X_1(k), X_2, \dots X_N(k)]^T \qquad \dots (5)$$

The adapted array output of Figure.2 is performed by multiplication of the received signals with the adapted weight vector [W]and it can be expressed as

$$y(k) = \sum_{i=1}^{N} w_i x_i \qquad \dots (6)$$

and in the vector form

$$Y(k) = W^T X = X^T W \qquad \dots (7)$$

Where W and X vectors are given by

$$W = [w_1, w_2, \dots., w_N]^T \qquad \dots (8)$$

$$X = [x_1, x_2, \dots\dots, x_N]^T \qquad \dots (9)$$

Signal and noise in the adaptive array antenna system may be described in the terms of the statistics properties, so this make possible to evaluate the system by its statistical average$E[\cdot]$, where $E[.]$ is the expected value of any random signal, the evaluation of statistical average leads directly to interested quantities related to the second statistical moment such as covariance matrix, which is closely related to correlation matrix for stationary signals.

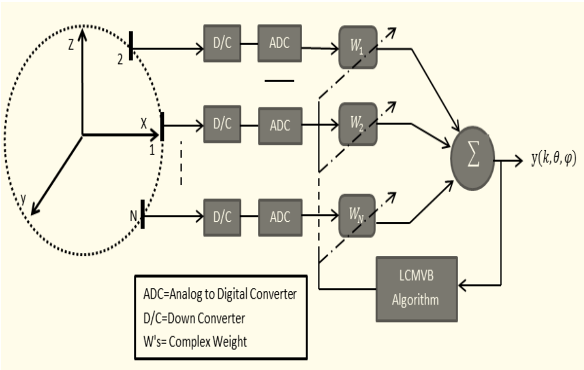

Fig. 2. Adaptive array antenna model.

The covariance correlation matrix of received signals vector is defined as [6]

$$\boldsymbol{R}_{xx} = E[\boldsymbol{X}^*\boldsymbol{X}^T] = \overline{[\boldsymbol{X}^*\boldsymbol{X}^T]} \quad \dots (10)$$

Where $\boldsymbol{R}_{xx}$ is $N \times N$ autocorrelation matrix of received signal and it is Hermitian (i.e.$\mathbf{R_{xx}} = \mathbf{R_{xx}^{*T}}$).

3. Two Dimensional (2D) MUSIC Estimator

The MUSIC technique is a simple, popular, high resolution and efficient Eigen structure method for angle of arrival estimation. In order to estimate $(\theta,\ \varphi)$ by MUSIC, a circular array antenna system is used. The MUSIC spatial spectrumfor$(\theta,\ \varphi)$ is given by [6]

$$DF(\theta, \varphi) = \frac{1}{\boldsymbol{C^T}(\theta,\varphi)\, \boldsymbol{Q}_n \boldsymbol{Q}_n{}^H \boldsymbol{C}^*(\theta,\varphi)} \quad \dots (11)$$

Where $\boldsymbol{C}(\theta,\varphi)$ is a spatial vector given by

$$\boldsymbol{C}(\theta,\varphi) = \left[g_z(\theta,\varphi) e^{-jz*\frac{2\pi}{\lambda}*R*sin\theta*\, cos(\varphi-\psi_z)}\right]^T \quad \dots (12)$$

$for\ z = 1{,}2 ...\ N$ and $g_z(\theta,\varphi)$is the z^th element pattern. $\boldsymbol{Q}_n$ is a noise subspace set matrix composed from (N-D) Eigen vector associated with the channel thermal noise components.

4. Mathematical Model for Proposed 3-D Estimator

A circular array antenna with radius R in the x-y plane is used in conjunction with the Linearly Constrained Minimum Variance Beam forming (LCMVB) algorithm as a proposed system to estimate elevation angle (θ) and azimuth angle (φ) of received signals as well as signal to noise ratio (SNR) (i.e.3-D estimation).

The adaptive array output of Figure. (2) can be expressed as[8].

$$E|y(k,\theta,\varphi)|^2 = E|\boldsymbol{W}^T\boldsymbol{X}^*(k,\theta,\varphi)|^2 = \boldsymbol{W}^T\boldsymbol{R}_{xx}(k,\theta,\varphi)\boldsymbol{W}^* \quad \dots (13)$$

It is required to minimized the array output power according to the following cost function given by

$$min_w \boldsymbol{W}^T\boldsymbol{R}_{xx}(k,\theta,\varphi)\boldsymbol{W}^* \quad \dots (14)$$

Subjected to$\boldsymbol{C}^T\boldsymbol{W} = \boldsymbol{C}^\dagger\boldsymbol{W}^* = 1 \quad \dots (15)$

Where (T)is the transpose notation, (*) is a complex conjugateand dagger (†) is a transpose conjugate notation $[*]^T$.

Finding $\boldsymbol{W}_{opt}(\theta,\varphi)$ to satisfy Eq. (14) and Eq. (15) can be accomplished by the method of Lagrange multipliers. Adjoining the constraint Eq. (15) to Eq. (14) performs the cost function. The minimization of this function is giving by

$$min_{w^*}\mathcal{B}(\boldsymbol{W},\boldsymbol{W}^*) = \boldsymbol{W}^T\boldsymbol{R}_{xx}(k,\theta,\varphi)\mathbf{W}^* + [\lambda\left(\boldsymbol{W}^\dagger\boldsymbol{C}^*(\theta,\varphi) - 1\right)] \dots (16)$$

The gradient of Eq. (16) with respect to$\boldsymbol{W}^*$leads to

$$\nabla_{W^*}\mathcal{B}(\boldsymbol{W},\boldsymbol{W}^*) = \boldsymbol{R}_{xx}(\boldsymbol{k},\theta,\varphi)\boldsymbol{W}^{\mathrm{T}} + \boldsymbol{C}^*(\theta,\varphi)\lambda \quad \dots (17)$$

The minimum value of Eq. (17) is given by

$$\boldsymbol{R}_{xx}(k,\theta,\varphi)\boldsymbol{W}_{opt}^{\boldsymbol{T}} + \boldsymbol{C}^*(\theta,\varphi)\lambda = 0 \quad \dots (18)$$

Therefore the optimal weight vector is

$$\boldsymbol{W}_{opt}^{\mathbf{T}}(\theta,\varphi) = -\boldsymbol{R}_{xx}^{-1}(k,\theta,\varphi)\boldsymbol{C}^*(\theta,\varphi)\lambda \quad \dots (19)$$

So the Lagrange multipliers λ may now be evaluated from the constraint given by Eq. (15).

$$\boldsymbol{C}^T(\theta,\varphi)\boldsymbol{W}_{opt}(\theta,\varphi) = 1$$

$$\boldsymbol{C}^T(\theta,\varphi)[-\boldsymbol{R}_{xx}^{-1}(\boldsymbol{k},\theta,\varphi)\boldsymbol{C}^*(\theta,\varphi)\lambda] = 1 \quad \dots (20)$$

It then follows that λ is given by

$$\lambda(\theta,\varphi) = -[\boldsymbol{C}^T(\theta,\varphi)\boldsymbol{R}_{xx}^{-1}(\boldsymbol{k},\theta,\varphi)\boldsymbol{C}^*(\theta,\varphi)]^{-1} \quad \dots (21)$$

Combining Eq. (19) and Eq. (21) then yields to the optimum constrained weight vector

$$\boldsymbol{W}_{opt}(\theta,\varphi) = \frac{\boldsymbol{R}_{xx}^{-1}(\boldsymbol{k},\theta,\varphi)\boldsymbol{C}^*(\theta,\varphi)}{[\boldsymbol{C}^T(\theta,\varphi)\boldsymbol{R}_{xx}^{-1}(\boldsymbol{k},\theta,\varphi)\boldsymbol{C}^*(\theta,\varphi)]} \quad \dots (22)$$

If $\boldsymbol{W}_{opt}\,(\theta,\varphi)$is substituted into Eq. (3), the output of the array system $y(\theta,\varphi)$will be optimum when the azimuth angle (φ) and elevation angle $(\theta)$of constrain vector $\boldsymbol{C}(\theta,\varphi)$ is coincide with the azimuth and elevation of any received signals in the range of $\theta\epsilon\left[0,\frac{\pi}{2}\right]$, and $\varphi\epsilon[0,2\pi]$ and it can be expressed as

$$y(k,\theta,\varphi)=\boldsymbol{W}_{opt}^{T}(\theta,\varphi)\boldsymbol{X}(k,\theta,\varphi) \quad \ldots (23)$$

It can be seen from Eq. (22) that for each received signals we have an optimum weight vector $\boldsymbol{W}_{opt}\,(\theta,\varphi)$ related to the incident angles of these signals. This weight vector is updated (i.e. changes its value) according to the received environments.

5. Signal to Noise Ratio SNR($\boldsymbol{\theta},\boldsymbol{\varphi}$) Estimation

Since we calculate the optimum weight vector $\boldsymbol{W}_{opt}\,(\theta,\varphi)$ according to Eq. (22), this weight vector maximized the output of the array in the direction of received signals according to the constraint condition Eq. (15). So the output voltage of the proposed array system due to i^{th} received signal is $y_i(k,\theta,\varphi)$ and due to the n^{th}channel thermal noise voltage is $y_n(k)$ and they can be expressed as

$$y_i(k,\theta,\varphi)=\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{X}_i(k,\theta,\varphi) \quad \ldots (24)$$

$$y_n(k)=\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{X}_n(k) \quad \ldots (25)$$

Then the output powers for signals and noise can be written as

$$E|y_i(k,\theta,\varphi)|^2=|\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{X}_i^{*}(k,\theta,\varphi)|^2$$

$$=\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{R}_{ii}(k,\theta,\varphi)\boldsymbol{W}^{*}(\theta,\varphi) \quad \ldots (26)$$

Where $R_{ii}(k,\theta,\varphi)$ is a covariance matrix of ith received signal under angle of arrival estimation and it is equal to

$$R_{ii}(k,\theta,\varphi)=\boldsymbol{X}_i^{*}((k,\theta,\varphi)*\boldsymbol{X}_i^{T}(k,\theta,\varphi) \quad \ldots (27)$$

Similarly the out power due to thermal noise is

$$E|y_n(k)|^2=|\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{X}_{\boldsymbol{n}}(k,\theta,\varphi)|^2$$

$$=\boldsymbol{W}^{T}(\theta,\varphi)\boldsymbol{R}_{nn}\boldsymbol{W}^{*}(\theta,\varphi) \quad \ldots (28)$$

$\boldsymbol{R}_{nn}=\boldsymbol{\sigma}_n^2\boldsymbol{I}$, where $\boldsymbol{\sigma}_n^2$ is the second moment of noise signals (noise power) and $\boldsymbol{I}$ is an identity matrix of dimensions (N×N). $\boldsymbol{R}_{nn}$is diagonal matrix due to thermal noise voltages in the channels, they are uncorrelated signals (random signals).

Now the output SNR(θ,φ)which can be estimated to each received signal to perform (3-D) estimation (i.e. elevation, azimuth and SNR estimation) is equal to

$$SNR(\theta,\varphi)=\frac{E|y_i((k,\theta,\varphi)|^2}{E|y_n(k)|^2}$$

$$=\frac{\boldsymbol{W}^{\dagger}{}_{opt}(\theta,\varphi)\boldsymbol{R}_{ii}(k,\theta,\varphi)\boldsymbol{W}_{\boldsymbol{opt}}(k,\theta,\varphi)}{\boldsymbol{W}^{\dagger}{}_{opt}(k,\theta,\varphi)\boldsymbol{R}_{nn}\boldsymbol{W}_{\boldsymbol{opt}}(k,\theta,\varphi)} \ldots (29)$$

6. Simulation Results

All simulation programs were written in MATLAB 7.10 and the following assumption are considered:-

a) The number of array elements are taken to be ten (N=10), isotropic and circularly distributed on a circumference of circle in x-y plane.
b) The radius of the circle (R) of ten elements array with inter-element displacement 0.5λ is equal to 0.8 λ according to Eq. (1).
c) The received signals are considered to be statistically independent and uncorrelated.

The proposed 3-D adaptive array antenna estimator in conjunction with (LCMVB) algorithm is tested, evaluated and compared with MUSIC DF technique according to the following scenarios.

A- Senario1:- A two airborne transmitters are cosidered to be transmittedon a same frequency
with equal output powers.The received signals are assumed to be arrived from different elevation and azimuth angles.$\theta_1=45^o$, $\varphi_1=150^o$, $\theta_2=60^o$, and $\varphi_2=200^o$.The input received powers areassumed to be equals and equal to 5dB.

Figures(3,4,5)show the result of estimating elevation and azimuth angles in 2-D (θ **or** φ versus SNR) and estimating in 3-D (θ **and** φversus SNR) of the two transmitters by the use of proposed adaptive system. It can be seen that the estimated angles in both planes are coincide with the true angles of arrival of received signals.

Since the input received powers are assumed to be equales (5 dB), it can be seen that the proposed system gives equal output SNR (14.1 dB) for both received signals, which means that the proposed system cansimultaneously estimate(θ,φ and SNR) parameters for all received signals.

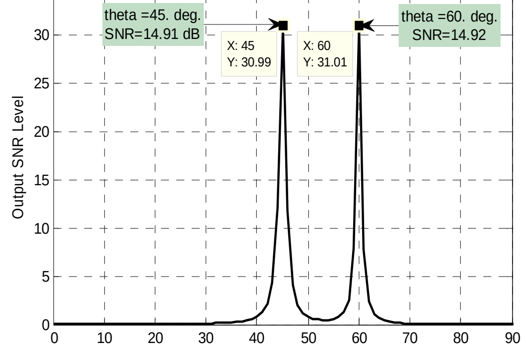

Fig. 3. Elevation angle θ estimation by proposed model.

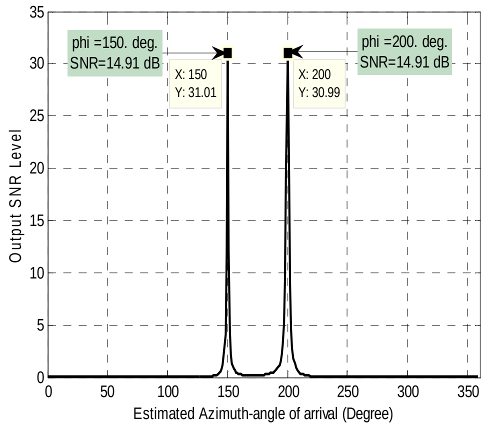

Fig. 4. Azimuth angle φ estimation byproposed model.

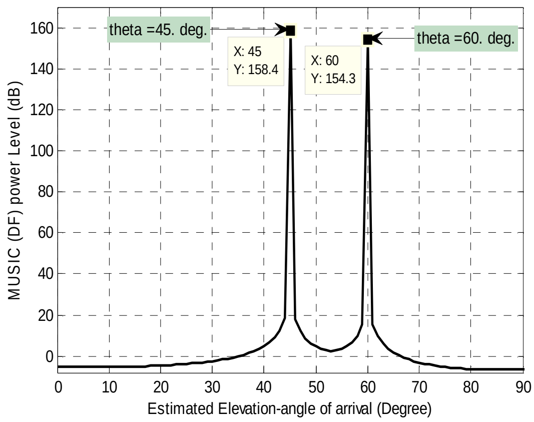

Fig. 6. Elevation angle θ estimation by MUSIC.

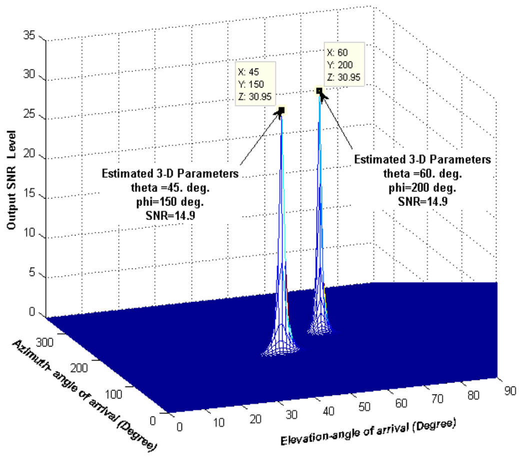

Fig. 5. Estimated θ and φ versus SNR by proposedmodel.

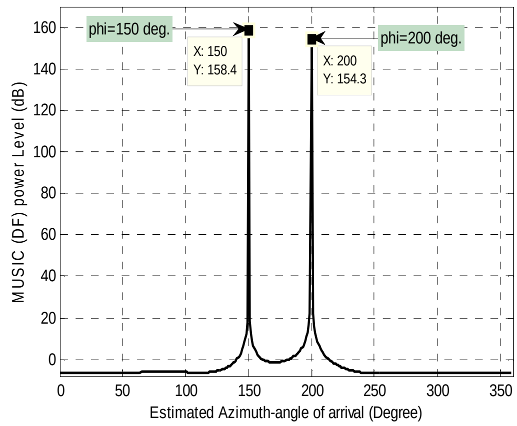

Fig. 7. Azimuth angle φ estimation by MUSIC.

While figures(6,7,8) for MUSIC technique show the estimation of θ *and* φ angles versus DF output level. It can be seen that the DFoutput level for the estimated signals are not related in any way to the received signals input powers, because the MUSIC DF output level which is given by Eq.(11) is related to the noise subspace Eigen vector set ($\boldsymbol{Q}_n$) and not to the input signals parameters.The accuracy of estimated angles are seemed to be identical for both cases.

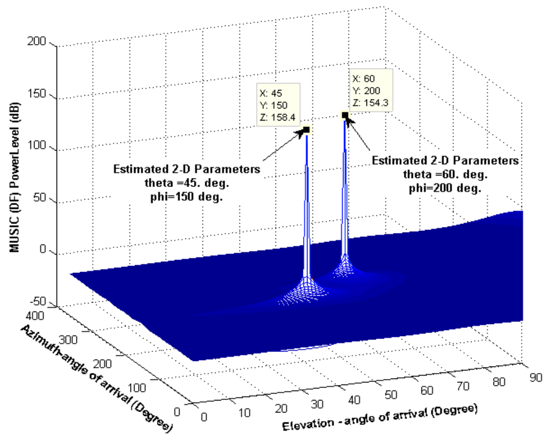

Fig. 8. Estimated(θand φ)versus DF level by MUSIC.

B- cenario 2:- two cases are considered.First, the two transmitters are transmitting from the same azimuth angles and from different elevation angles $\theta_1=30^o$, $\varphi_1=150^o$,$\theta_2=60^o$, and $\varphi_2=150^o$.Second,twotransmitters are transmitting from eqaul elevation angles and from different azimuth angles $\theta_1=50^o$,$\varphi_1=100^o$,$\theta_2=50^o$,and $\varphi_2=200^o$. The two sources transmit on the same frequency with different transmitting powers. The input received powers from sources are considered to6dB and 9dB

It can be seen from figures(9and10) that the proposed system estimate (θ, φ and SNR) for the two transmitter in both cases with a high accuracy although the two transmitters transmit from the same azimuth or same elevation angles with different transmitting powers.

It is also obvious that the output SNR's of received signals are directly related to the input received powers from sources. The (6 dB) input power gives (15.55 dB) output SNR while the (9 dB) input power gives (18.58) dB output SNR in both figures, which means that the proposed system are fulfill the designing requirments for estimating (3-D) parameters.

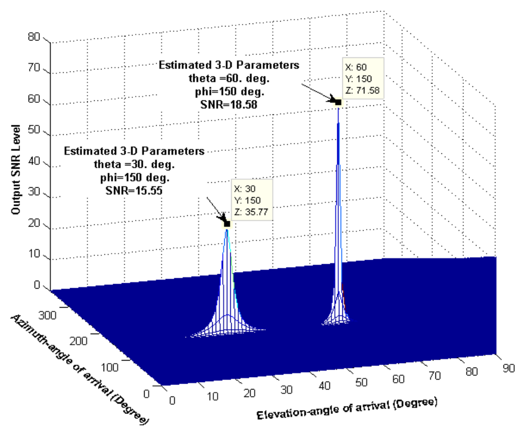

Fig. 9. Estimated (θ and φ) versus SNR by proposed system for equal azimuth and different elevation angles .

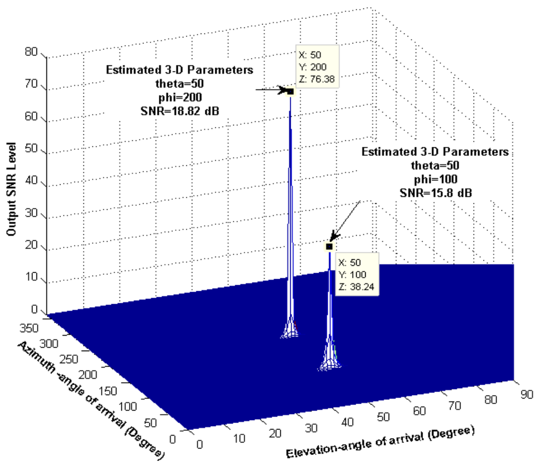

Fig. 10. Estimated (θ and φ)versus SNR by proposed system for different azimuth and equal elevation angles.

C- Scenario 3:- A three transmitters are transmitting on same frequency with different transmitting powers. The received signals are assumed to be from different elevation and azimuth angles$\theta_1=45^o$, $\varphi_1=150^o$, $\theta_2=60^o$,$\varphi_2=200^o$and $\theta_3=75^o$, $\varphi_3=250^o$.Theinput received powers from sources are cosidered to be 6, 9 and 12 dB.

Figure (11) shows (3-D) plot for proposed system.The result shows that the angle of arrival estimation for the three transmitters are quite accurate and identical to the angles of arrival estimated by MUSIC techniquesee Figure (12).

It can also be seen that the proposed system estimates the output SNR's for the received signals and shows different output SNR's levels,since the input powersof recived signals are assumed to be different while, a MUSIC technique hasn't this capability. Figure (12) shows that the DF level for the received signals which they have different input powers are equals this means that MUSIC technique can be considered a (2-D) estimator rather than (3-D) estimator as the case of proposed system.

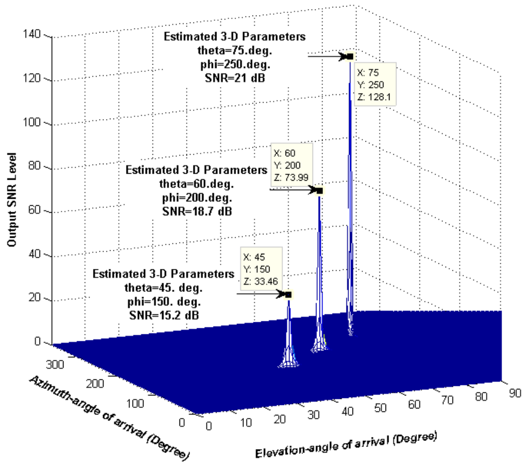

Fig. 11. Estimated (θ *and* φ) versus SNR by proposed model for three sources with different input levels.

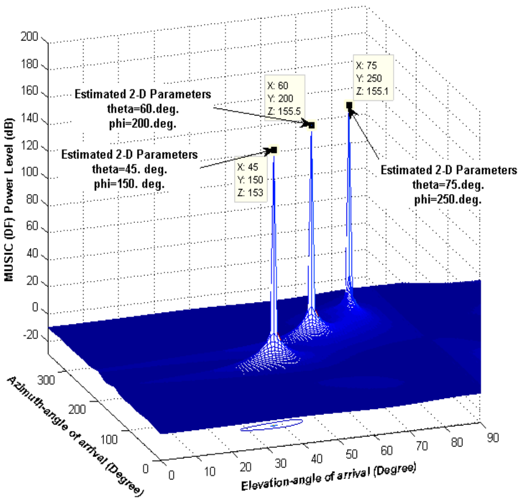

Fig. 12. Estimated (θ *and* φ) versus DF level by MUSIC for three sources with different input levels.

7. Conclusions

A uniformly circular array antenna with a modified adaptive algorithm is proposed to be used as an angle of arrival estimator in two planes (θ and φ) and output SNR estimator (i.e.3-D estimator).

The proposed (3-D) angle of arrival estimation results shows that the system is equivalent to the MUSIC technique from the point of angle of arrival estimation accuracy view and it has a privilege over MUSIC that it can estimate output SNR for the received signals under two planes angle of arrival estimation while MUSIC does not has this capability.

The estimated output SNR can be used to estimate the distance to the transmitting sources, since the estimated SNR is directly related to the transmitted power and distance between transmitting source and estimator (receiving side). Comparing the proposed model with the well know MUSIC technique shows that the proposed model does not need any hard ware or software orthogonality which is used by MUSIC to calculate noise subspace eigenvectors $\boldsymbol{Q_n}$. The orthogonality techniques which are based on Singular Value Decomposition (SVD) technique or eigenvalue decomposition technique are computationally intensive and they need more RAM size and more time processso that they might not be suited for real time application where the received signals must be tracked in real time.

The optimum adapted weight vector $\mathbf{W}_{optm}$ in the proposed system is directly calculated and used to estimate $\theta, \varphi$and SNR with minimum computing steps. This means that the proposed system can be used in a real time to track the received signals.

The proposed model also offers the capability to analyze and listen to the received signals(hearing and technical analyzing features) while performing angle of arrival estimation which is an important tools for supporting Electronic war-fare Counter Measures(ECM) and Electronic war-fare Supporting measures (ESM)activities against these sources.

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تخمين زاوية الوصول في مستويات متعددة بواسطة مصفوفة الهوائيات الدائرية الطورية المتكيفة

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الخلاصة

في هذا البحث تم اقتراح منظومة مصفوفة هوائيات طورية مع نظام متكيف وخوارزمية تشكيل انموذج الاشعاع لمصفوفة الهوائيات الدائرية بوساطة اقل قدرة ضوضاء مقيدة خطيا لتلبية متطلبات تخمين زاوية الوصول في مستويين (المستوى الافقي والمستوى العمودي) وكذلك تخمين مستوى الاشارة الى الضوضاء للاشارات الراديوية المستلمة في خرج المنظومة (اي التخمين المتوازي في ثلاثة مستويات)، بدلا من الاستخدام التقليدي لمصفوفة الهوائيات المتكيفة في تخميد اشارات التداخل والضوضاء المرافقة للاشارات المستلمة. النظام المقترح تم وضع انموذج رياضي له وتم بناء كيان برمجي تشبيهي له ، وفحصه في حالات محاكات متعددة ومختلفة.

اظهرت نتائج الفحص ان النظام المقترح اعطى نتائج رائعة في التخمين المتوازي (في الوقت نفسه) لزوايا الوصول للاشارات المستلمه في المستويين الافقي والعمودي وكذالك في تخمين مستوى الاشارة الى الضوضاء في خرج المنظومة (اي تخمين ثلاثي). دقة تخمين زوايا وصول الاشارات الراديوية المستلمة في المستويين الافقي والعمودي مكافئة لدقة التخمين المتحصلة من تقنية التصنيف المطور متعدد الاشارة المستخدم حاليا لتخمين زوايا الوصول، منظومتنا المقترحة لها افضلية على تقنية التصنيف المطور كونها تستطيع تخمين مستوى الاشارة الى الضوضاء للاشارات المستلمة في خرج المنظومة.

اخيرا النظام المقترح يحتاج الى عمليات حسابية والى وقت معالجة اقل وكيان مادي اقل تعقيداً من تقنية التصنيف المطور متعدد الاشارة والذي يحتاج الى حساب متجهات الايجن بطريقة التحليل المتسلسل لمصفوفات الاشارة والضوضاء . النظام المقترح يعد من الناحية الاقتصادية اقل تكلفة من الانظمة الفعالة المستخدمة في عمليات التخمين الثلاثي في وقت واحد مثل الرادار.