Indian J.Sci.Res. 13 (1): 241-244, 2017 ISSN: 0976-2876 (Print)
ISSN: 2250-0138 (Online)

SMART ANTENNA SYSTEM FOR DOA ESTIMATION USING 2D-ULA

VEERENDRA[a1] AND MD. BAKHAR[b]

[ab]Department of E&CE, Guru Nanak Dev Engineering College, Bidar, Karnataka, India

ABSTRACT

In this paper, we designed a smart antenna system based on multiple signal classification (MUSIC) algorithm for direction of arrival (DOA) estimation using two dimensional uniform linear array (2D-ULA). Antenna array configurations namely, ULA and uniform rectangular array (URA) show the inability for direction finding of desired (user) signal at grazing incidence. This problem can be solved by using this 2D-ULA. This configuration consists of doubly crossed horizontal and vertical ULAs with the computational load of 2L element–ULA. Here 'L' is the number of antenna elements used in the array. In this work, the proposed 2D-MUSIC presents improvement of about 20-22 dBs in noise floor as compared to classical method. Hence 2D-MUSIC is accurate, robust and efficient and is a suitable candidate for future mobile communications.

KEYWORDS: DOA, MUSIC, Smart Antenna, URA, ULA

Smart antenna systems have been an attractive solutions to the problem related to spectrum estimation and detection [B.Gershman, 1997]-[Barabell, A. J, 1983]. The future wireless applications are characterized by a superior performance and adaptive nature. Generally fixed beam framing is utilized at base station of wireless communication system which has a drawback of system performance and adaptive techniques [Cheng Qian, 2014],[M.Max and J.Sheinvald,1994] One methodology for expanding these necessities utilizes spatial processing with adaptive antenna array [Ming-Yang Cao et al, 2015].

As the need of remote correspondence applications are expanding the accessible electromagnetic spectrum band is getting swarmed step by step [R.O.Schmidt, 1986]. From the numerous inquiries, it has been found that the allocated range (licensed spectrum) is not used appropriately in light of spectrum. It has turn out to be most hard to discover empty groups either to set up another administration or to upgrade the current one. One solution to such kind of issues is the '*element spectrum management*' which enhances the use of range [S.Jeng et al, 1997]. In cognitive radios the spectrum detection is the major challenge [Veerendra et al, 2015]. This problem can be solved using the smart antenna technology. Smart antenna uses numerous DOA algorithms, namely, Bartlett, maximum Eigen value, maximum likelihood and MUSIC [Veerendra et al, 2014]. Among these, MUSIC is the most popular and widely used algorithm for spectrum estimation. In this work we studied this algorithm using 2D-ULA.

Array Signal Model

Consider an array of L elements with L potential weights. Let it receives **M** narrow band source signals S_M from desired users arriving at directions $\theta_1, \theta_2 \ldots \theta_M$ as Z Shown in Fig. 1. The array also receives I narrow band source signals Si from undesired (or interference) users arriving at directions $\theta_1, \theta_2 \ldots \theta_I$. At a particular instant of time $t=1,2\ldots K$, where K is the total number of snapshots taken. The desired user signal vector $x_M(t) = X_M$ can be defined as

$$\mathbf{X_M} = \sum_{m=1}^{M} a(\theta_m)\,\mathbf{S_M} \tag{1}$$

Where, $\mathbf{a(\theta_m)}$ is the $L \times 1$ array steering vector which represents the array response at direction θ_m and is given by

$$\mathbf{a(\theta_m)} = [\exp(j(n-1)\varphi_m]^T; \quad 1 \le n \le L \tag{2}$$

Where $[(.)]^T$ is the transposition operator, and φ_m represents the electrical phase shift from element to element along the array [Veerendra et al, 2016]. This can be defined by

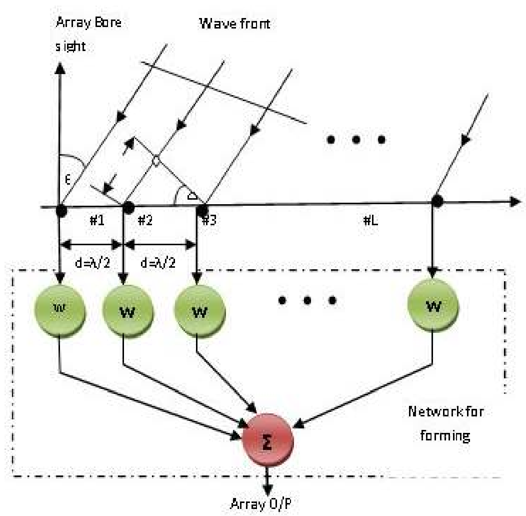

Figure 1: Geometry of ULA

[1]Corresponding author

$$\varphi_m = 2\pi\left(\frac{d}{\lambda}\right)\sin(\theta_m) \quad (3)$$

where **d=λ/2** is the inter-element spacing and **λ** is the wavelength of the received signal. The desired users signal vector $\mathbf{X_M}$ of (1) can be written as

$$\mathbf{X_M} = A_M \mathbf{S_M} \quad (4)$$

Where $\mathbf{A_M}$ is the *L x M* matrix of the desired users signal direction vectors and is given by

$$\mathbf{A_M} = [a(\theta_1), a(\theta_2), ...a(\theta_M)] \quad (5)$$

And **S** is the *M x 1* desired users source waveform vector defined as

$$\mathbf{S} = [S_1 \quad S_2 \quad ...... \quad S_M]^T \quad (6)$$

The undesired (or interference) user signal vector $\mathbf{X_I}$ is

$$\mathbf{X_I} = \mathbf{A_I}\, i \quad (7)$$

Where $\mathbf{A_I}$ is the *L x 1* matrix of the undesired users signal direction vectors and is given by

$$\mathbf{A_I} = [a(\theta_1) \quad a(\theta_2) \quad ...... \quad a(\theta_I)]^T \quad (8)$$

And ***i*** is the *I x 1* undesired (or interference) users source waveform vector defined as

$$\boldsymbol{i} = [i_1 \quad i_2 \quad .... \quad i_I]^T \quad (9)$$

The overall received signal vector **X** can be written as

$$\mathbf{X} = \mathbf{X_M} + n_t \mathbf{X_I} \quad (10)$$

Where, 'n_t' represents white Gaussian noise with zero mean and σ^2 variance. The conventional estimate of the correlation matrix is defined as

$$\Re = E[\mathbf{X}\,\mathbf{X^H}] \quad (11)$$

where **E{.}** represents the ensemble average; and $(.)^H$ is the Hermitian operator. The above equation can be approximated by applying temporal averaging over ***K*** snapshots (samples) taken from the signals incident on the sensor array. This leads to forming a spatial correlation matrix $\Re$ given by

$$\Re = \frac{1}{K}\sum_{k=1}^{K} X\,X^H \quad (12)$$

Substituting for **X** from (10) in (12) gives

$$\Re = A_M \Re_{ss} A_M^H + n_k n_k^H + A_I \Re_{ii} A_I^H \quad (13)$$

where $\Re_{ss} = E\{ss^H\}$ is an *M x M* desired users source waveform correlation matrix; $\Re_{ii} = E\{ii^H)\}$ is an *I x I* undesired users source waveform correlation matrix.. Finally, equation (13) can be rewritten as

$$\Re = \frac{1}{K}\sum_{k=1}^{K} A_M [SS^H] A_M^H + \sigma^2 I + \frac{1}{K}\sum_{k=1}^{K} A_I [ii^H] A_I^H \quad (14)$$

Here, *I* is an identity matrix of size *L x L*.

MUSIC algorithm

MUSIC [6] is an acronym which stands for MUltiple SIgnal Classification. This algorithm was developed by Schmidt in 1986. This is a spectral estimation based method which exploits the orthogonality of the noise subspace with the array correlation matrix. It promises to provide unbiased estimates of the number of signals, the angles of arrival and the strengths of the waveforms.

From array correlation matrix $\Re$ can find *M* eigen vectors associated with the signals and *L-M* eigenvectors associated with the noise. Then we have to choose the eigen vectors associated with the smallest eigen values. Noise eigenvectors subspace of order *L x (L-M)* is constructed and is given as

$$\mathbf{E_N} = [e_1, e_1, e_1, ...e_{L-M}] \quad (15)$$

The noise subspace eigen vectors are orthogonal to the array steering vectors at the angles of arrivals θ_1, $\theta 2$.... θ_D. The pseudo-spectrum - a function that gives an indication of the angle of arrival based upon maxima versus angle for MUSIC is given as

$$P_{MU}(\theta) = \frac{1}{|\bar{a}(\theta) \quad \bar{E}_L \quad \bar{E}_L^H \quad \bar{a}(\theta)|} \quad (16)$$

Proposed MUSIC using 2D-ULA (2D-MUSIC)

It consists of doubly crossed ULAs, i.e., superposition of horizontal and vertical ULA and has identical size and computational load as compared to ULA. Fig. 2 shows the geometry of horizontal–vertical ULA.

Now, let us apply all components of the received signal (1) to the above geometry to analyse the performance. The user signal **X** can then be modelled for *k* snapshots as:

$$\mathbf{X} = \mathbf{X_h} + \mathbf{X_v} = \left[\sum_{m=1}^{M} a_h(\theta_m) + a_v(\theta_m)\right] \mathbf{S_M} \quad (17)$$

Here $a_h(\theta_m)$ and $a_v(\theta_m)$ are the $L \times 1$ array steering vectors of horizontal- and vertical array respectively. The expressions of these steering vectors are given by:

$$\mathbf{a_h(\theta_m)} = \left[\exp\left(j(n-1)2\pi\left(\frac{d}{\lambda}\right)\right)\sin\theta_m \right]^T \qquad (18)$$

$$\mathbf{a_v(\theta_m)} = \left[\exp\left(j(n-1)2\pi\left(\frac{d}{\lambda}\right)\right)\cos\theta_m \right]^T \qquad (19)$$

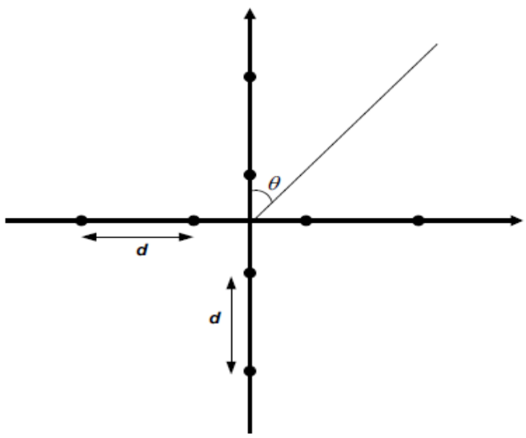

Figure 2: Geometry of horizontal–vertical ULA.

RESULTS AND DISCUSSION

The proposed algorithms are simulated using the parameters tabulated in Table I. In our simulation we considered four mobile users with DOA=[-60° 10° 40° 60°] using 10 and 100 antenna elements. Figs. 3 and 4 show the spectrum of proposed and classical MUSIC algorithm for antenna elements, L=10 and 100 respectively. Figs. 5 and 6 show the eigen value magnitude (EVM) for all the eigen values using L=10 and 100 respectively.

Table I: Experimental Parameters

S. No	Parameters	Values
1	Type of Antenna Array	2D-ULA
2	Number of array elements (L)	10 and 50
3	Pass band frequency Range	(3-4)GHz
4	Inter element spacing (d)	d = λ/2
5	Number of snapshots (K)	100 and 200
6	Signal to Noise Ratio (SNR)	20 dB
7	Base band frequency	1 KHz

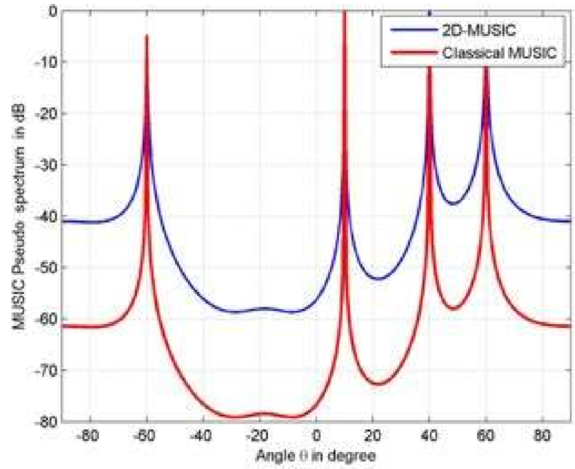

Figure 3: MUSIC spectrum for L=10, K=200, DOA[-60° 10° 40° 60°]

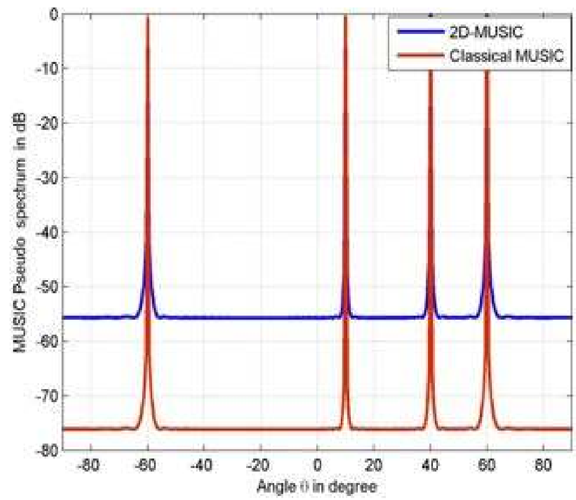

Figure 4: MUSIC spectrum for L=50, K=200, DOA[-60° 10° 40° 60°]

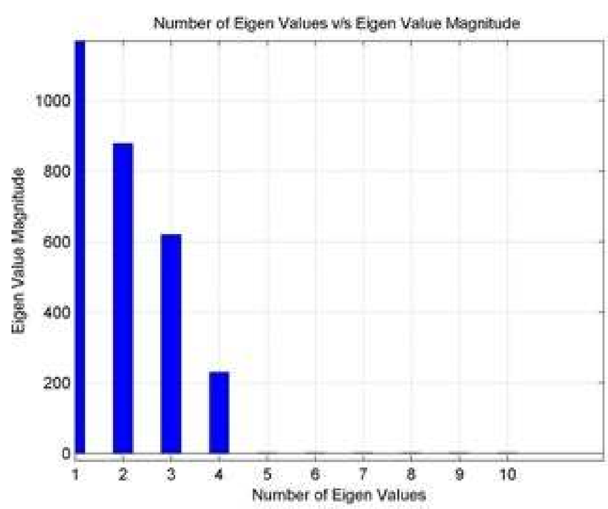

Figure 5: Number of eigen values versus EVM for L=10

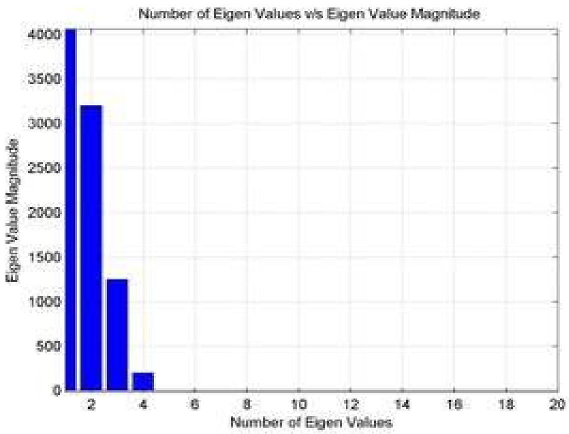

Figure 6: Number of eigen values versus EVM for L=50

Following points are observed from the simulation results.

1. 2D-MUSIC algorithm presents about 20dBs improvement in noise floor for L=10 as shown in Fig. 4.
2. When antenna elements are increased to 50, it gives about 22 dBs improvement as shown in Fig. 4.
3. As antenna elements are increased, beam of algorithm increases and this gives high directivity.
4. As compared to classical MUSIC algorithm, proposed method gives sharper output indicating high directivity.
5. Both the methods are subspace based methods. Means separates the noise and signal subspace by decomposing the eigen values. Hence we find only four eigen values in Figs. 5 and 6 indicating four mobile users in different directions.
6. Samples or snapshots play a vital role in improving the resolution of DOA estimation. This fact is proved in Fig. 4. Sharper beams are produced in figure 4 because of more samples (200) as compared to figure 3 which uses only 100.
7. It is very important to note that, though samples are directly proportional to resolution and directivity, optimum numbers of samples are recommended to avoid the huge computational burden.

CONCLUSION

The smart antenna system for DOA estimation based on popular subspace based MUSIC algorithm using 2D novel ULA has been designed. Its performance is analyzed by varying various antenna parameters including, antenna elements, snapshots and signal to noise ratio. The proposed method is compared with the classical MUSIC algorithm using same parameters. Simulation results show that the proposed method presents about 20-22dBs improvement and the better angular resolution over the classical method. Hence the proposed method is more robust, stable and accurate and can be used in the advanced 4G-LTE and beyond mobile communications.

REFERENCES

Barabell A. J., 1983. Improving the Resolution Performance of Eigen structure-Based Direction Finding Algorithms, in IEEE Proc. of Int. Conf. on Acoustics, Speech, and Signal Processing, **8**:336–339.

Cheng Qian.,2014. Improved Unitary Root-MUSIC for DOA Estimation, IEEE Signal Process. Lett., **21**:140-144.

Gershman A. B., 1997. Improved DOA estimation of spatial spectrum, IEEE Signal Process. Lett., **4**:54–57.

Jeng S., Lin H., Okamoto G., Xu G. and Vogel W.J.,1997. Multipath direction finding with subspace smoothing, IEEE transaction on ASSP, **5**: 3485-3488.

Max M. and Sheinvald J., 1994. Direction finding of coherent signals via spatial smoothing for uniform circular arrays, IEEE transaction on antennas and propagation, **42**:613-620.

Ming-Yang C., Lei H.C., Qian., 2015. Jia-YinXu, H.C. So, Under determined DOA estimation of quasi-stationary signals via Khatri–Rao structure for uniform circular array, Elsevier Signal Processing, **106**:41– 48.

Schmidt R.O., 1986. Multiple emitter location and signal parameter estimation", IEEE Trans. Antennas Propagation, **34**:276–280.

Veerendra, Md. Bakhar and Vani R.M., 2015. Robust 2D-Novel Smart Antenna Array for MIMO Applications, International Journal of Advanced Research in Computer and Communication Engineering, **4**:271-274.

Veerendra, Md. Bakhar and Vani R.M., 2014. Implementation and Optimization of Modified MUSIC algorithm for High Resolution DOA Estimation, IEEE Proc. of Int. Conf. on Microwave and RF Conf., 193-197.

Veerendra, Md. Bakhar and Vani R.M., 2016. Robust Blind Beam formers for Smart Antenna System using Window Techniques, Procedia Computer Science, **93**: 713–720.