

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/341041334>

EFFECT OF FAULTY SENSORS ON ESTIMATION OF DIRECTION OF ARRIVAL AND OTHER PARAMETERS

Article in JOURNAL OF MECHANICS OF CONTINUA AND MATHEMATICAL SCIENCES - April 2020

DOI: 10.26782/jmcms.2020.04.00014

CITATIONS

2

READS

85

5 authors, including:



[La Sandhu](#)

Central South University

22 PUBLICATIONS 42 CITATIONS

[SEE PROFILE](#)



[Ebrahim Shahzad Awan](#)

Western Sydney University

14 PUBLICATIONS 40 CITATIONS

[SEE PROFILE](#)



EFFECT OF FAULTY SENSORS ON ESTIMATION OF DIRECTION OF ARRIVAL AND OTHER PARAMETERS

Laeq Aslam¹, Fawad Ahmad², Sohail Akhtar³, Ebrahim Shahzad Awan⁴
Fatima Yaqoob⁵

^{1,2,4}Department of Electrical Engineering, International Islamic University, Islamabad
Pakistan

³University of Engineering and Technology, Lahore, Pakistan

⁵University of Sargodha, Sargodha, Pakistan.

Email: ¹laeeq.msee424@iiu.edu.pk, ²fawad_sahar@yahoo.com,
³mustaqeel@gmail.com, ⁴ebrahimawan@gmail.com,
⁵moonafatimal1@gmail.com

Corresponding author: Laeeq Aslam

<https://doi.org/10.26782/jmcms.2020.04.00014>

Abstract

This paper proposes an approach to study the effect of faulty array element on the accuracy of the parameter estimation of direction of arrival of the plane waves and their amplitudes from sources that are considered to be far field sources. In this approach we require only one snapshot. The cost function is developed for heuristic computation using genetic algorithm (GA). Cost function is based on L_2 norm of the difference between actual observation vector and the constructed vector plus the correlation between the two normalized vectors. The results have been given for different length of array i.e. 10, 15 and 20. Longer array is able to minimize the effect of faulty array element.

Keywords: Direction of Arrival, Uniform Linear Array, Parameter Estimation, Faulty Array.

I. Introduction

Beam forming is a technique that uses array of sensors for directional signal transmission and reception. In directional transmission and reception we focus our main beam in only one direction and setting nulls in for unwanted signals such as jammers as discussed in [XV], [VII], [VIII], [IX]. Against this background Direction of Arrival (DOA) is the first and the foremost requirement. Direction of arrival mainly deals with the estimation of azimuth and elevation angle. However, sometimes the frequency and amplitude are of interest. Some of the most common techniques include MUSIC, ESPRIT and others are discussed in [X], [I], [XI], [XII]. In [XIV],

Copyright reserved © J. Mech. Cont.& Math. Sci.
Laeq Aslam et al

authors proposed algorithm to for reducing computational load of the scheme proposed in [XII]. We also find in literature techniques called as heuristic techniques to find direction of arrival (DOA). These techniques are Genetic algorithm, Particle swarm optimization (PSO), Differential Evolution (DE) and proposed in [II],[XIII]. Heuristic computation techniques offer more accuracy and reliability when they are mixed with any other algorithm such as, active search algorithm, pattern search (PS) and interior point algorithm as discussed in [VI],[III],[IV]. The different geometric of array used by researchers has been Linear arrays ,1-L & 2- L Shaped array, Planar array, Circular arrays and Even elliptic arrays

The most common problems encountered during estimation of these parameters has been the element failure, estimation failure, pair matching, ambiguity problem, computation complexity. In our paper we have dealt with the array element failure when one or more element has failed partially or fully. This is a practical issue that can occur at any time and need to be addresses. In this we have seen that element position and array length both are important.

I. Problem formulation

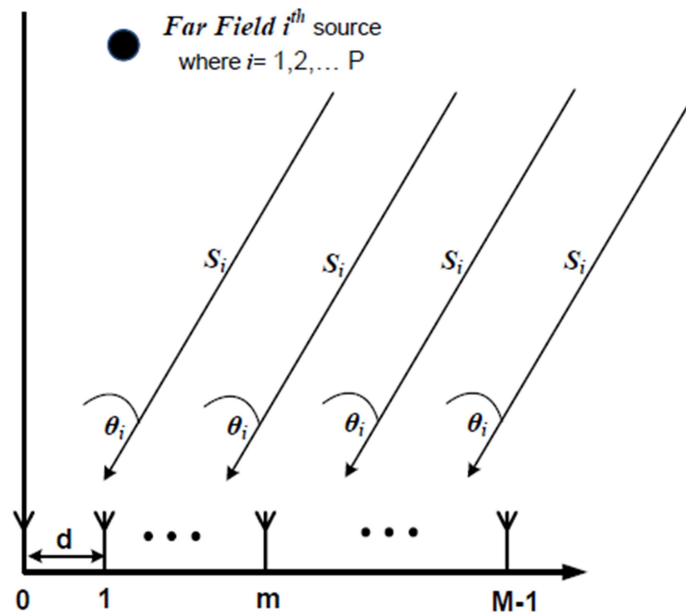


Fig.1 Signal Model for far field sources.

Let there be N sources which are considered as far field sources. Assuming that signal from source i falls on an array sensor $[1 \ 2 \ 3 \ \dots \ M]$. They are given as $[A_i, A_i e^{j\varphi_i}, A_i e^{j2\varphi_i}, \dots, A_i e^{j(m-1)\varphi_i}]$. Where φ_i an electrical angle due to the extra distance covered by the array and is given by

Copyright reserved © J. Mech. Cont.& Math. Sci.
Laeq Aslam et al

$$\varphi_i = \frac{2\pi}{\lambda} d \sin \theta_i \quad (1)$$

If $d = \frac{\lambda}{2}$, eq.1 can be written as $\varphi_i = \pi d \sin \theta_i$. On any m^{th} element, the signal from N sources are given by

$$X_m = \sum_{i=1}^N A_i e^{j(m-1)\varphi_i} \quad (2)$$

where $m = 1, 2, \dots, M$ & the net array vector signal is given as follows

$$\vec{X} = [x_1 \ x_2 \ \dots \ x_M]$$

II. Cost Function

On the receiver side we receive array vector signal $\vec{X}$ containing information about amplitude and Angles of the all N number of targets. We define our Cost function as

$$E = E_1 + E_2 \quad (3)$$

Where,

$$E_1 = \|\vec{X} - \hat{\vec{X}}\|_2^2 \quad (4)$$

$$E_2 = \left| \frac{\|\vec{X}\|}{\|\hat{\vec{X}}\|} - 1 \right| \quad (5)$$

$\hat{\vec{X}}$ Is the estimate of $\vec{X}$ generated using randomly generated amplitudes and angles of N number of targets and is optimized using “Genetic Algorithm”.

III. Genetic Algorithm

Genetic algorithm works through following steps

Initialization

We generate S number of chromosomes randomly. As we have only considered two targets therefore, each chromosome is of the length equal to 4. Where first two genes represent amplitudes whereas, the next two represents the angles.

Evaluation

Based on these angles and amplitudes we calculate $\hat{\vec{X}}$ and evaluate the error of each chromosome. If the least error is below a certain threshold level we move to step 6 otherwise go to step 3.

Selection

Select the best chromosome to be a part of next generation of chromosomes.

*Copyright reserved © J. Mech. Cont.& Math. Sci.
Laeq Aslam et al*

Crossover

Producing new children from parents is crossover. One can formulate a new generation from the old parents and new children.

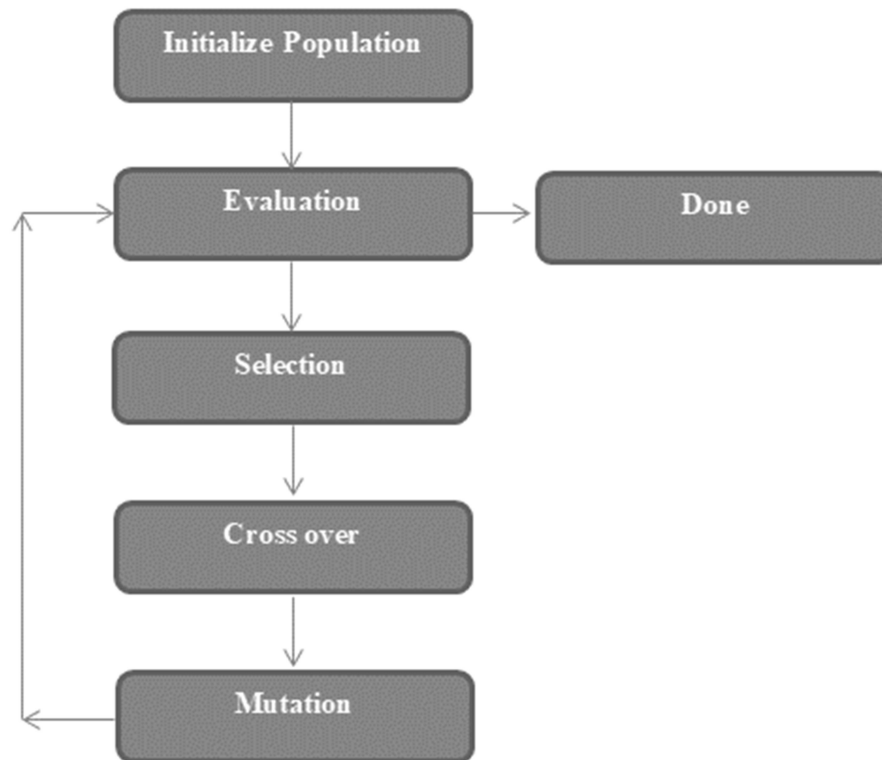


Fig. 1 Flow chart for genetic algorithm.

Mutation

In case crossover does not bring a substantial change, we mutate a gene at random of any chromosome taken at random.

Termination

If the error is below a threshold we choose the chromosome with least error as our solution and quit the process.

IV. Simulation and result

We have assumed two sources in the far field zone with amplitudes $A_1 = 1, A_2 = 5$ and respective angles $\theta_1 = 50^\circ, \theta_2 = 65^\circ$ from the broad sides.

We have used different number of array element ($M = 10, 15, 20, 25$). All the elements one by one have been made 100 % faulty starting from 1 to M . The result reveal that, the effect of the faulty element is position dependent. In general the effect of the faulty element is more pronounced if element is toward the end of the array. Also we note that if the number of elements increases, the fault $|\Delta\theta_1|$ and $|\Delta\theta_2|$ decreases. Moreover, the variances in the fault decreases as the number of elements increases.

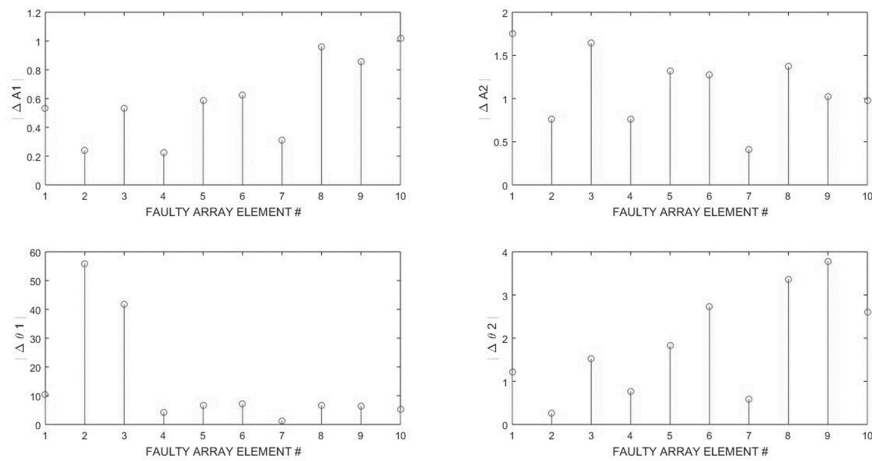


Fig. 2 Antenna array with 10 elements

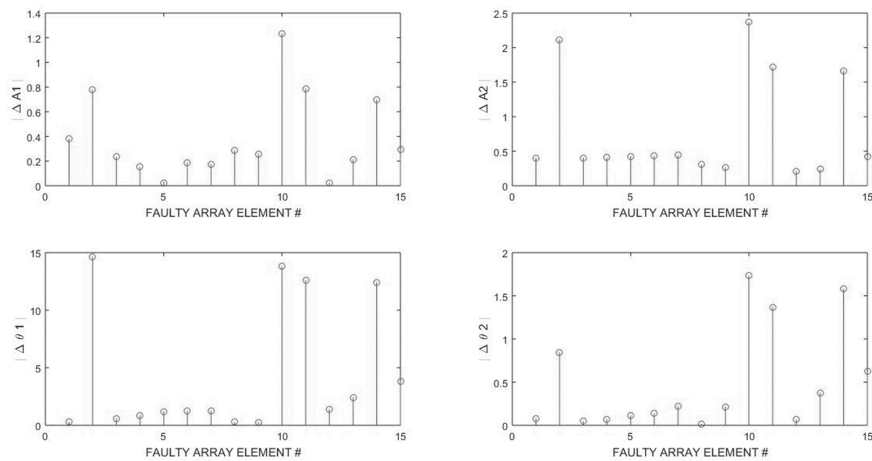


Fig. 3 Antenna array with 15 elements

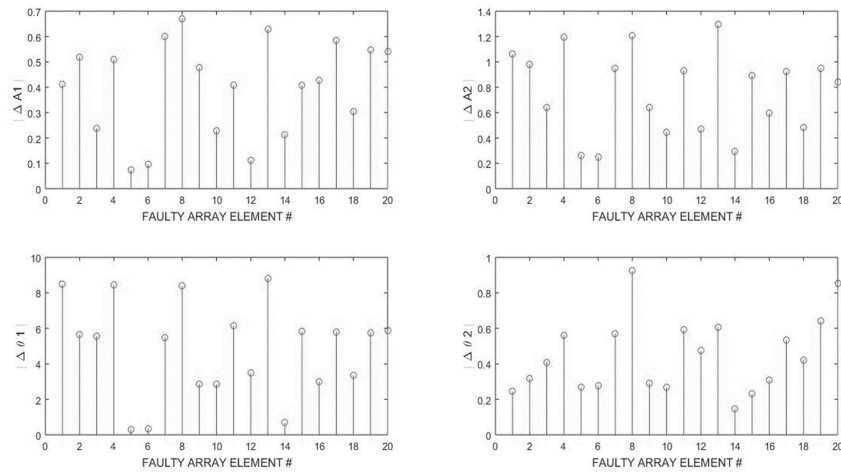


Fig. 4 Antenna array with 20 elements

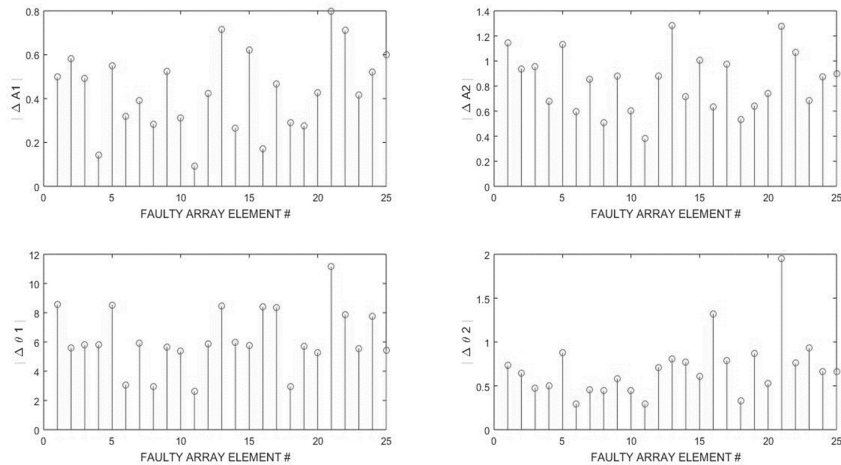


Fig. 5 Antenna array with 25 elements

V. Conclusion

The main purpose of this contribution was to make a critical study of the effect of faulty array elements on the estimation of direction of arrival and amplitude of far field sources. As we see situation is improved in general if number of elements is increased. Moreover, the entire faulty element does not have the same effect on the error, it is position dependent. As the fault is decreasing with the increase in the number of arrays therefore, it is recommended to use antenna array of large sizes for encountering the problem of faulty array.

Copyright reserved © *J. Mech. Cont.& Math. Sci.*
Laeq Aslam et al

References

- I. B. Ottersten and T. Kailath, "Direction-of-arrival estimation for wide-band signals using the ESPRIT algorithm," *IEEE Trans. Acoust.*, vol. 38, no. 2, pp. 317–327, 1990.
- II. F. Zaman, I. M. Qureshi, A. Naveed, and Z. U. Khan, "Real time direction of arrival estimation in noisy environment using particle swarm optimization with single snapshot," *Res. J. Appl. Sci. Eng. Technol.*, vol. 4, no. 13, pp. 1949–1952, 2012.
- III. F. Zaman, I. M. Qureshi, A. Naveed, and Z. U. Khan, "Joint estimation of amplitude, direction of arrival and range of near field sources using memetic computing," *Prog. Electromagn. Res. C*, vol. 31, pp. 199–213, 2012.
- IV. F. Zaman, I. M. Qureshi, A. Naveed, J. A. Khan, and R. M. A. Zahoor, "Amplitude and directional of arrival estimation: comparison between different techniques," *Prog. Electromagn. Res. B*, vol. 39, pp. 319–335, 2012.
- V. F. Zaman, J. A. Khan, Z. U. Khan, and I. M. Qureshi, "An application of hybrid computing to estimate jointly the amplitude and direction of arrival with single snapshot," in *Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST)*, 2013, pp. 364–368.
- VI. J. A. Khan, M. A. Z. Raja, and I. M. Qureshi, "Numerical treatment of nonlinear Emden--Fowler equation using stochastic technique," *Ann. Math. Artif. Intell.*, vol. 63, no. 2, pp. 185–207, 2011.
- VII. M. Mouhamadou, P. Vaudon, and M. Rammal, "Smart antenna array patterns synthesis: Null steering and multi-user beamforming by phase control," *Prog. Electromagn. Res.*, vol. 60, pp. 95–106, 2006.
- VIII. M. Mukhopadhyay, B. K. Sarkar, and A. Chakraborty, "Augmentation of anti-jam gps system using smart antenna with a simple doa estimation algorithm," *Prog. Electromagn. Res.*, vol. 67, pp. 231–249, 2007.
- IX. M. A. Ur Rehman, F. Zaman, I. M. Qureshi, and Y. A. Sheikh, "Null and sidelobes adjustment of damaged array using hybrid computing," *Proc. - 2012 Int. Conf. Emerg. Technol. ICET 2012*, pp. 386–389, 2012.
- X. Cheng and Y. Hua, "Further study of the pencil-MUSIC algorithm," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 32, no. 1, pp. 284–299, 1996.
- XI. Y. Hua, T. K. Sarkar, and D. Weiner, "L-shaped array for estimating 2-D directions of wave arrival," in *Proceedings of the 32nd Midwest Symposium on Circuits and Systems*, 1989, pp. 390–393.
- XII. V. S. Kedia and B. Chandna, "A new algorithm for 2-D DOA estimation," *Signal Processing*, vol. 60, no. 3, pp. 325–332, 1997.
- XIII. Y. A. Sheikh, F. Zaman, I. M. Qureshi, and M. Atique-ur-Rehman, "Amplitude and direction of arrival estimation using differential evolution," in *2012 International Conference on Emerging Technologies*, 2012, pp. 1–4.
- XIV. Y. Wu, G. Liao, and H.-C. So, "A fast algorithm for 2-D direction-of-arrival estimation," *Signal Processing*, vol. 83, no. 8, pp. 1827–1831, 2003.
- XV. Z. U. Khan, A. Naveed, I. M. Qureshi, and F. Zaman, "Independent null steering by decoupling complex weights," *IEICE Electron. Express*, vol. 8, no. 13, pp. 1008–1013, 2011.