



HAL
open science

Comment on 'Conjugate ESPRIT (C-SPRIT)'

Jean-Pierre Delmas

► **To cite this version:**

Jean-Pierre Delmas. Comment on 'Conjugate ESPRIT (C-SPRIT)'. IEEE Transactions on Antennas and Propagation, 2007, 55 (2), pp.511 - 511. 10.1109/TAP.2006.889995 . hal-01320676

HAL Id: hal-01320676

<https://hal.science/hal-01320676v1>

Submitted on 24 May 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Comment on "Conjugate ESPRIT (C-SPRIT)"

Jean-Pierre Delmas

GET/INT, Département CITI, UMR-CNRS 5157,
Institut National des Télécommunications,
9 rue Charles Fourier, 91011 Evry Cedex, FRANCE.
Fax: +33-1-60 76 44 33,
e-mail: jean-pierre.delmas@int-evry.fr

Abstract

It is shown that in the above paper by N. Tayem and H.M. Kwon, the Esprit-like algorithm was derived from a rather unrealistic assumption, and therefore, this conjugate Esprit algorithm will have little utility in practice.

Index terms: Antenna array, direction of arrival (DOA) estimation, non circular signals.

In [1], the authors present an Esprit-like algorithm to estimate the directions of arrivals (DOA) from noncoherent one-dimensional (1-D) signal sources such as binary phase shift keying (BPSK) and M-ary amplitude shift keying (MASK). The proposed algorithm provides more precise DOA estimates and can detect more signals than well-known classical subspace-methods MUSIC and ESPRIT for 1-D signals. The paper has been read with great interest; however, it appears to be based on a key assumption that is never satisfied in practice. In this note, we explain the correct model that must be used for estimation of DOA of narrowband (1-D) signal sources.

The authors consider a uniform linear array composed of M elements that receives K noncoherent and narrowband 1-D signals from different DOAs θ_k , $k = 1, \dots, K$. The $M \times 1$ received signal satisfies the following standard model

$$\mathbf{y}_t = \sum_{k=1}^K \mathbf{a}(\theta_k) s_{k,t} + \mathbf{n}_t,$$

where the first component of all the steering vectors $\mathbf{a}(\theta_k)$ is equal to one, and where it is assumed in [1] that $s_{k,t}$, $k = 1, \dots, K$ are real-valued for 1-D signals such as BPSK and MASK. The two assumptions

$$[\mathbf{a}(\theta_k)]_1 = 1 \quad \text{and} \quad s_{k,t} = s_{k,t}^*, \quad \text{for } k = 1, \dots, K \quad (0.1)$$

are key assumptions that allow the authors to prove the following relation [1, rel. (15)]

$$\begin{pmatrix} \mathbf{y}_{t,1} \\ \mathbf{y}_{t,2} \end{pmatrix} = \begin{pmatrix} \mathbf{A} \\ \mathbf{A}\Phi^* \end{pmatrix} \mathbf{s}_t + \begin{pmatrix} \mathbf{n}_{t,1} \\ \mathbf{n}_{t,2} \end{pmatrix}$$

on which the proposed conjugate ESPRIT is devised.

We prove in the following that the two constraints (0.1) are not consistent for one-dimensional signals. In practice, the DOA estimation is made after frequency down conversion: The analog received BPSK or MASK modulated signals are bandpass filtered and after down-shifting the signal to baseband, the in-phase and quadrature components are matched-filtered, sampled and paired to obtain complex signals $s_{k,t}$. The output of the matched filter associated with the first element of the array is represented as a sum $\sum_{k=1}^K s_{k,t}$ of 1-D signals with

$$s_{k,t} = \alpha_{k,t} e^{i\phi_k},$$

where $\alpha_{k,t}$ are real-valued and where ϕ_k are *arbitrary phase shifts* that can be different for each signal but constant with time. Consequently, the *amplitudes* $s_{k,t}$ are *complex-valued*. This model has been used by numerous authors who have studied DOA estimation of non-circular sources (see e.g., [2, rels.(5),(7)], [3, rel.(28)], [4, rel. (2)], [5, Subsection II.A], [6, bottom of p.2]). Note that in these references all emphasize

that the phases ϕ_k are arbitrary phase shifts (denoted natural phases in [2, 3]) that can be different for each signal.

The frequency offsets can be naturally neglected, but the phases are *intrinsic to the model if the first component of the steering vector is normalized to one*. The assumption that $s_{k,t}$ are all real-valued would correspond to the case where all the K source signals with the same carrier frequency would be located at distances d_k from the reference element, which in turn would be a multiple of the wavelength associated with the carrier frequency: It is clear that this assumption is completely unrealistic.

This assumption cannot be circumvented because if phases were introduced into relations (12) of [1], the proposed algorithm would no longer be valid. Finally we note that this assumption (0.1) has been also used in very numerous papers of the authors dedicated to non-circular signals (see e.g., [7, 8, 9] for coherent non-circular sources for which the different signals are phase delayed amplitude weighted replicas on one of them), [10] for 2-D root MUSIC algorithms and [11] for Toeplitz based matrix pencil. Consequently all the nice results given in these papers are misleading because they do not apply in practice.

References

- [1] N. Tayem and H.M. Kwon, "Conjugate ESPRIT (C.SPRIT)," *IEEE Trans. on Antennas and Propagation*, vol. 52, no. 10, pp. 2618-2624, Oct. 2004.
- [2] P. Chargé, Y. Wang and J.Saillard "A non-circular sources direction finding method using polynomial rooting," *Signal processing*, vol. 81, pp. 1765-1770, 2001.
- [3] A. Zoubir, P. Chargé and Y. Wang, "Non circular sources localization with Esprit," *European Conference on Wireless Technology*, Munich, Oct. 2003.
- [4] M. Haardt and F. Römer, "Enhancements of unitary Esprit for non circular," *International Conference on ASSP*, Montreal, May 2004.
- [5] P. Chevalier, F. Pipon, "New insights into optimal widely linear array receivers for the demodulation of BPSK, MSK and GMSK signals corrupted by non circular interferences - Application to SAIC", *IEEE Transactions on Signal Processing*, vol.54, no.3, pp. 870-883, March 2006
- [6] H. Abeida, J.P. Delmas, "MUSIC-like estimation of direction of arrival for non-circular sources," *IEEE Transactions on Signal Processing*, vol. 54, no. 7, pp. 2678-2690, July 2006
- [7] A. Salamech and N. Tayem, "Conjugate MUSIC for non-circular sources," submitted to *IEEE Trans. on Antennas and Propagation*, 2006.
- [8] N. Tayem, A. Salamech, "Angle of arrival estimation for non-circular signals," *IEEE Sarnoff Symposium*, Princeton, March 2006.
- [9] A. Salamech and N. Tayem, "Conjugate MUSIC for non-circular sources," *IEEE International Conference of ASSP*, Toulouse, May 2006.
- [10] A. Salamech, N. Tayem and H.K. Kwon, "Improved 2-D Root MUSIC for non-circular signals," *workshop on Sensor Array and Multichannel (SAM)*, Waltham, Massachusetts, USA, July 2006.
- [11] N. Tayem, A. Salamech and H.K. Kwon, "Toeplitz based matrix pencil for non-circular signals," *IEEE Vehicular Technology Conference*, Montreal, September 2006.