Available at
www.ElsevierComputerScience.com
POWERED BY SCIENCE DIRECT

Signal Processing 84 (2004) 1359–1365

SIGNAL PROCESSING

www.elsevier.com/locate/sigpro

Performance analysis of joint DOA/TOA estimator

F. Mrabti[a], M. Elhajjami[b], M. Zouak[a,b,*]

[a] UFR, Automatique et Analyse des Systèmes, Faculté des sciences Fès-Dhar El Mehraz, BP 1796, Fes, Atlas 30000, Morocco
[b] University of Sidi Mohammed Ben Abdellah, UFR, Laboratory Signaux, Systèmes et Composants, Faculté des Sciences et Techniques, Fès, BP 2202, Fès, VN 30000, Morocco

Received 20 June 2003; received in revised form 21 April 2004

Abstract

In many applications such as radar and mobile communication, the multipath propagation effects are described as a sum of contributions of a large number of wavefronts that arrives at the sensor array in clusters of rays, distributed around a nominal direction of the signal sources. Based on this observation and on the work of Bengtsson and Ottersten (Proceeding of Norsig-98, IEEE Nordic Signal Processing Symposium, April 1998), this paper jointly estimate the directions of arrival and the times of arrival of scattered sources. A theoretical performance analysis is given in terms of asymptotic error variance and illustrated by a simulation study.

Keywords: Sensor array processing; Parameter estimation; Mobile communication; Scattered sources

1. Introduction

For several years, many algorithms have been proposed to resolve the problem of signal parameter estimation in sensor array processing. In fact, the signal can be separated at the array based on the knowledge of their spatial and/or temporal "signatures".

Traditionally, the studies assume that the received signals originate from far-field point sources and give rise to planar wavefronts which impinge on the array from a fixed direction of arrival (DOA). However, in some radio propagation scenarios, especially in urban areas, this assumption is clearly inappropriate. The array receives many rays from the vicinity of the source and the assumption on number of paths becomes restrictive [1,10]. This scattering situation, is modelised by a spatial distribution function of the DOA and times of arrival (TOA).

In [3], the authors treated each scattered source as the superposition of two point sources under the assumption that the delay between the different rays is small and can be treated as shift in the gain factors. However, a joint estimation of the DOA and TOA can be used to enhance the power of the received signal and a good separation of rays.

In this contribution, we confirm the approximation in [3] where the time delay was introduced in the model. A spatio-temporal processing

* Corresponding author. University of Sidi Mohammed Ben Abdellah, UFR, Laboratory Signaux, Systèmes et Composants, Faculté des Sciences et Techniques, Fès, BP 2202, Fès, VN 30000, Morocco.

E-mail addresses: f_mrabti@yahoo.fr (F. Mrabti), elhajjami@caramail.com (M. Elhajjami), mohcine_zouak@yahoo.fr (M. Zouak).

0165-1684/$ - see front matter
doi:10.1016/j.sigpro.2004.05.010

technique, MUSIC, is used for channel parameters estimation.

This paper is organised as follows: In Section 2, a modelling framework is presented for the space-time processing. The algorithm MUSIC, to estimate the parameters channel, is investigated in Section 3 followed by a Monté Carlo simulations in Section 4. The paper is concluded in Section 5.

2. Data model

In an urban area, the signal received by the base station from a mobile terminal can be considered as resulting mainly from reflections of the radiowaves. None of these different signal paths will dominate, unless there is free sight between the mobile and the base station. The source can be modelled as a number of scatterers spreading out on a circle surrounding it (Fig. 1), [1,4].

Assume a large number of wavefronts impinging on a uniform linear array (ULA), emanating from reflections close to the source [1,2,10]. The authors of [3], under the assumption that the time delays is modelled as phase shifts, approximate each cluster by two point sources at θ_1 and θ_2, (Fig. 2). This approximation permits us to use the formulation of the DOA estimation problem which requires that the number of impinging signals is less than the number of sensors in the array.

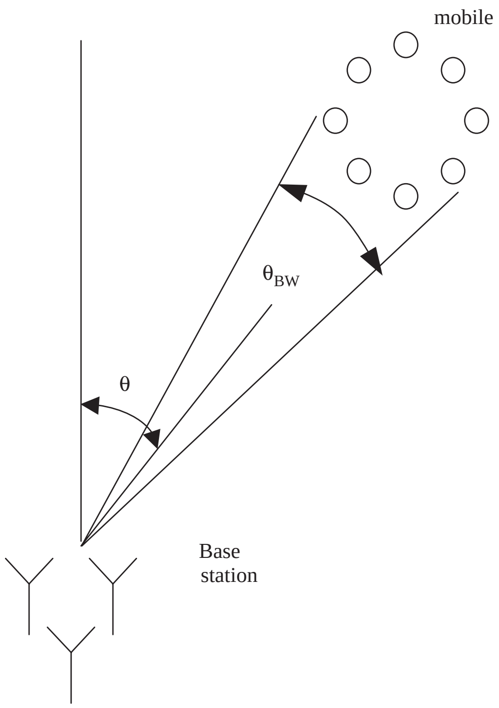

Fig. 1. Model of base station received scattered source.

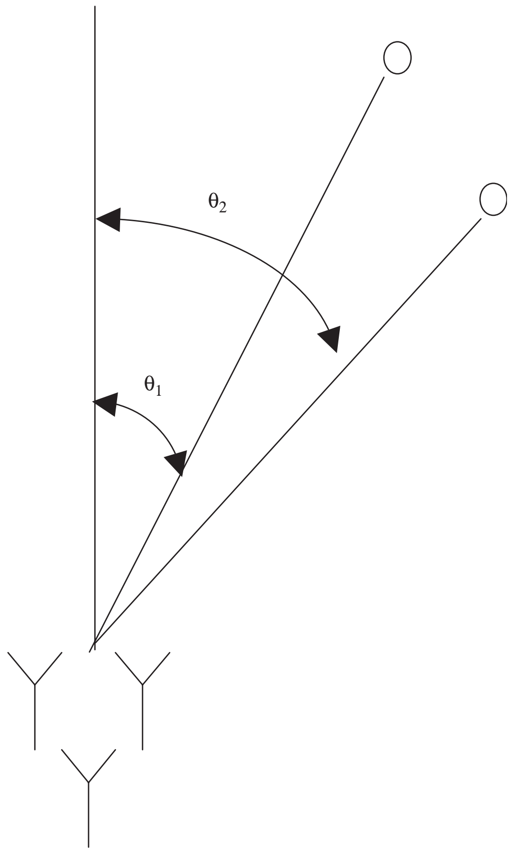

Fig. 2. Approximation by two points sources.

This approximation can be justified. In [1,4] the authors assume that the scatterers are spread out on a circle surrounding a mobile with DOA's given by

$$\theta_m = \theta + \tfrac{1}{2}\,\theta_{\mathrm{BW}} \sin\left(\frac{2\pi m}{M-1}\right), \tag{2.1}$$

where θ denotes the DOA from a mobile to the base station, θ_{BW} symbolizes the width of the "cluster" as seen from the base station and $m=1,\ldots,M$, M is the number of scatterers.