Chapter 5
EM-Source Localization in Indoor Environments by Using an Artificial Neural Network Performance Assessment and Optimization

Salvatore Caorsi
University of Pavia, Italy

Claudio Lenzi
University of Pavia, Italy

ABSTRACT

The localization of EM sources has become an interesting object of study in the past several decades. An important aspect is to reduce the search time and the maintenance of acceptable receiving levels between transmitters and receivers. The strong signal attenuation introduced by the transmission through walls plays a determinant role, as well as a suitable probing technique able to furnish good resolution. This chapter introduces a new probing technique based on artificial neural networks (ANNs) to detect and localize an ultra-wide band (UWB) pulsed EM source placed behind a wall. The main purpose is to study the performance of this technique in order to obtain a good compromise between two principal goals: accuracy on the reconstruction of the source position as high as possible and a probe dimension as small as possible. The use of ANNs for the resolution of the inverse scattering problem provides several advantages, such as short computation times, low computational burden, and the opportunity to reformulate the problem by considering only a few unknowns of interest.

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INTRODUCTION

In the past several decades, the detection and localization of electromagnetic (EM) sources has received a lot of attention and interest. Indeed, numerous papers and articles have been published on this topic, and these issues have interest for a lot of applications, such as radar systems, sonar, radio astronomy, seismology, satellite navigation, defence applications, and global positioning systems (GPS). Moreover, there is an increased need to locate EM sources for commercial purposes. For example, as reported in Chryssomallis (2000, pp. 129-136) and Hines et al. (2008), smart antenna (SA) technology has been studied a great deal and used in many mobile and wireless communication systems. When dealing with these antennas, the knowledge of the direction of arrival (DOA) of the desired signal is fundamental to modifying the radiation pattern for steering the maximum along the correct direction (Donelli, Viani, Rocca & Massa, 2009). Another problem, discussed in Tian, Tatematsu, Tanabe and Miyajima (2014) and Portugues et al. (2009), concerns how to find the source location of a spark discharge. This is important because the discharge may interfere with various telecommunication systems or damage the equipment. Recently, indoor detection and localization of EM sources has become an interesting object of study. In Alvarez, Las-Heras and Pino (2007), a method to locate an EM source, working in the very high-frequency (VHF) band and positioned inside an indoor location, is presented. In addition, in the case of emergency calls, essential information necessary to guide rescuers to the right place is knowing the location accurately. This has made necessary the development of devices and services to detect and locate survivors for their recovery and for the protection of human lives. These arguments are introduced and discussed in Patwari and Wilson (2010) and Ko and Lau (2009).

Up until now numerous methods have been proposed to locate EM sources, both of narrow band signals and ultra-wide band (UWB) pulses, that are positioned both in the far-field and near-field areas.

As discussed in Liggett (1973, pp. 327-345) and Schweppe (1968, pp. 294-305), one of the first was the maximum likelihood (ML) methods focused on estimating the DOA of narrow band signals with known a central frequency radiating from sources located in a far-field area. Nevertheless, especially in the case of multiple sources, the ML methods have not become very popular due to the high computational load needed by the nonlinear, multivaried maximization problem. In Chen, Hudson and Yao (2002), ML has been applied to detect wide band sources placed in a near field. As mentioned in Chen et al. (2002), the ML approach has been commonly accepted as one of the best and strongest schemes for coherent signal sources. However, in this case, the method also turned out to be computationally burdensome in the presence of several wide band sources. Two interesting alternative methods that provide the ability to locate multiple sources, both of narrow band signals and wide band pulses, are the alternating projection (AP), proposed in Ziskind and Wax (1988) and the expectation-maximization-based location algorithm, suggested in Mada, Wu and Iyengar (2009). Moreover, in the past several years, a great deal of attention has been paid to methods that estimate the DOA by using learning by examples (LBE) techniques. These approaches provide a good trade-off between accuracy and convergence time. In this context, in El Zooghby, Christodoulou and Georgiopulos (1997) the use of radial basis function neural network (RBFNN) is analyzed, and in Donelli, Viani, Rocca and Massa (2009), a procedure based on use of a support vector machine (SVM) is presented.

Other methods are able to find the EM source position using methods based on the time difference of arrival (TDOA). As proposed in Peck and Moore (2001) and Portugues et al. (2009), by using these methods, it is possible to estimate the DOA of pulsed EM waves and then obtain the source position through the intersection of the estimated DOA in different places. Other methods, presented in Tung-