Chapter 3.9
A Complex Support Vector Machine Approach to OFDM Coherent Demodulation

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ABSTRACT

Most of the approaches to digital communication applications using support vector machines (SVMs) rely on the conventional classification and regression SVM algorithms. However, the introduction of complex algebra in the SVM formulation can provide us with a more flexible and natural framework when dealing with complex constellations and symbols. In this chapter, an SVM algorithm for coherent robust demodulation in orthogonal frequency division multiplexing (OFDM) systems is studied. We present a complex regression SVM formulation specifically adapted to a pilot-based OFDM signal, which provides us with a simpler scheme than an SVM multiclassification method. The feasibility of this approach is substantiated by computer simulation results obtained for Institute of Electrical and Electronic Engineers (IEEE) 802.16 broadband fixed wireless

channel models. These experiments allow us to scrutinize the performance of the OFDM-SVM system and the suitability of the ε-Huber cost function in the presence of non-Gaussian impulse noise interfering with OFDM pilot symbols.

INTRODUCTION

Orthogonal frequency division multiplexing (*OFDM*) is a very attractive technique for high bit rate transmission in wireless environments (Sampath, Talwar, Tellado, Erceg, & Paulraj, 2002). Data symbols are frequency multiplexed with orthogonal subcarriers to minimize the effects of multipath delay spread. Thus, a frequency-selective channel is transformed into a set of parallel flat-fading Gaussian subchannels, which makes equalization a simpler task. Moreover, this transmission technique can be efficiently implemented via (inverse) Discrete Fourier Transform (IDFT/DFT) operations. *Channel estimation* is usually carried out based on *pilot symbols* with an estimation algorithm such as the least squares (LS) criterion (Edfors, Sandell, van de Beek, Wilson, & Börjesson, 1996). However, in a practical environment where **impulse noise** can be present, this channel-estimation method may not be effective for this non-Gaussian noise.

The use of *support vector machines* (SVMs) has already been proposed to solve a variety of digital communications problems. The decision feedback equalizer (Chen, Gunn, & Harris, 2000; Sebald & Buclew, 2000) and the adaptive multiuser detector for direct-sequence code division multiple access (CDMA) signals in multipath channels (Chen, Samingan, & Hanzo, 2001) have been addressed by means of binary SVM nonlinear classifiers. In Rahman, Saito, Okada, and Yamamoto (2004), signal equalization and detection for a multicarrier (MC) CDMA system is based on an SVM linear classification algorithm. Nonlinear channel estimation based on SVM multiregression for multiple-input, multiple-output (MIMO) systems has also been scrutinized (Sánchez-Fernández, de Prado-Cumplido, Arenas-García, & Pérez-Cruz, 2004). In all these applications, SVM techniques outperform classical methods.

This chapter, which is an extended version of the proposal presented in Fernández-Getino García, Rojo-Álvarez, Alonso-Atienza, and Martínez-Ramón (2006), analyzes an SVM-based robust algorithm for channel estimation that is specifically adapted to a typical OFDM data structure. There are two main features in this approach. First, a *complex* regression SVM formulation is developed, which provides us with a simpler scheme than describing OFDM signals with either multilevel or nested binary SVM classification algorithms. Second, the adequacy of free parameters in the ε-Huber *robust cost function* (Mattera & Haykin, 1999; Rojo-Álvarez, Camps-Valls, Martínez-Ramón, Soria-Olivas, Navia Vázquez, & Figueiras-Vidal, 2005) is investigated since the properties of this cost function are suitable for impulse noise scenarios. A detailed description of the ε-Huber robust cost function can be found in Chapter VI. Although the robustness of some digital communication receivers against impulse noise had been examined by using *M*-estimates (Bai, He, Jiang, & Li, 2003; Ghosh, 1996), there were no previous works about the performance of SVM algorithms in digital communications under this condition. For the sake of simplicity, a linear dispersive channel with non-Gaussian noise is analyzed here. The extension of the proposed linear OFDM-SVM scheme to nonlinear scenarios can be easily introduced by using Mercer's kernels in a similar way as proposed for other communication schemes (Sebald & Buclew, 2000). It should also be noted that two of the most common robust cost functions (regularized LS and Huber cost) are particular cases of this SVM approach.

This chapter is organized as follows. In the next section, the algorithm for SVM complex regression is derived in detail. Then, the OFDM system and impulse noise model are described. The coherent demodulation of OFDM signals with SVM is