DIGITAL DS-CDMA DETECTION IN IMPULSIVE NOISE: BASE-BAND vs. BAND-PASS NONLINEAR PROCESSING

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***Abstract*— In the context of *DS-CDMA* detection, a digital base-band model for the received signal after chip-matched filtering, is often adopted. Nonlinear treatment of these samples for robust detection in impulsive environments has been already proposed. In this paper we study the advantages of band-pass nonlinear detection schemes for *DS-CDMA* receivers, over those in base-band. We consider for both schemes i) an impulsive noise model with independent α-stable distributed sequences and ii) a hard-limiter as memoryless nonlinearity. Probability of error and asymptotic relative efficiency expressions are given, with simulations that validate them. Results shown that band-pass nonlinear detection is preferable.**

***Keywords*— DS-CDMA, Nonlinear Detection, Impulsive Noise, α-stable Distribution, Hard Limiter.**

I. INTRODUCTION

The most widespread model for the channel noise in *DS-CDMA* systems is additive Gaussian, justified by the central limit theorem. However, the presence of man-made and atmospheric electromagnetic interferences in urban areas called for other noise models with impulsive behavior. One of the simplest models of impulsive channels uses ϵ-mixtures, as in Aazhang and Poor (1988). In the last decade, the family of α-stable distributions received great attention as an appropriate model for impulsive phenomena (Shao and Nikias, 1993). Due to the generalized central limit theorem (Grigoriu, 1995) they can be applied when the noise is thought as a superposition of infinitely many statistically independent sources. The index α parameterizes the level of impulsiveness ($0 < \alpha \leq 2$), including the Gaussian distribution for $\alpha = 2$ and the Cauchy distribution for $\alpha = 1$. These facts and other important mathematical properties, comparable to the gaussian distribution, make the α-stable model attractive. However, there are not closed expressions for their probability densities except for $\alpha = 1$ and $\alpha = 2$, and moments of order greater than α do not exist. Then, except for $\alpha = 2$, the model forces an infinite variance noise.

The performance of linear receivers, which are optimum in the gaussian case, degrades drastically when operating in impulsive environments. In the schemes we found in the literature of robust *DS-CDMA* receivers, the received signal is first chip-matched filtered (i.e. linearly processed). The base-band signal is then passed through a memoryless nonlinearity and finally correlated with the local replica of the spreading code to form the test statistic whose sign decides the estimated bit (Aazhang and Poor, 1988; Aazhang and Poor, 1989; Deliç and Hocanin, 2002; Chuah and Hinton, 2000). This scheme is justified with the concept of locally optimum detection (Spaulding, 1985). That is, for signal to noise ratio (*SNR*) tending to zero the Maximum Likelihood (*ML*) detector becomes a memoryless nonlinearity followed by the conventional correlator, when the signal and noise are at base-band.

However, the impulsive noise appears already in the samples of the received signal, at the front-end or band-pass stage, and propagates into the base-band signal. Moreover, the assumption of low *SNR* is more adequate at the band-pass samples, prior to any averaging. Then, we propose to place the nonlinearity directly at the band-pass stage. In this way, the occasionally large impulses are "suppressed" before they can corrupt other samples. We show results where there are considerable advantages of band-pass nonlinear detection structure over the base-band.

This paper is organized as follows. In section II we describe the model of received signal and the detection systems to consider. In section III the performance of these systems is calculated using an asymptotic analysis. The results of these calculations are compared with simulations in IV, and we conclude in section V.

II. SYSTEM MODEL AND DETECTION SCHEMES

We consider the digital detection of a *BPSK* signal, transmitted using *DS-CDMA* through a channel with additive white impulsive noise. There is a single user with perfect code and carrier synchronization. The samples of the received signal during a bit interval can be expressed as

$$r[n] = bAs[n]\cos(\Omega_c n + \phi) + v[n] \tag{1}$$

where $b \in \{+1, -1\}$ is the transmitted bit, A is the amplitude of the received signal, $s[n]$ are samples of the spreading code (with values +1 or -1) with K chips per bit, and

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