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Advanced Detection Schemes of Digital Signals in Impulse Noise

by

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in Electrical Engineering

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Abstract

In this thesis, we investigate the optimum approach to mitigate the effects of impulse noise in wireless communication channels. First, we present a measurement campaign to verify the statistical properties of a Middleton Class-A (MCA) model for impulse noise. This campaign measures wireless interference that corrupted a 2.4 GHz industrial, scientific, and medical (ISM) band. We extend this verification to characterize the spatial coupling and correlation of impulse noise for multiple antenna systems.

We then investigate the optimum detector for binary signals corrupted by MCA noise. We approximate the MCA model to a single weighted Gaussian density such that the nonlinearities of the optimum detector can be evaluated in a closed-form expression. The approximate MCA model discriminates the noise probability density function (PDF) of Gaussian and impulsive events using a threshold detection scheme. By means of such approximations, we provide a precise analysis for the behaviors of optimum nonlinearities in reducing the effects of impulse noise. We also introduce a decision boundary analysis to justify and analyze the performance of the optimum detector in different MCA noise environments. We also approximate the nonlinearities to investigate the behaviors of the other suboptimum detectors such as a locally optimum detector (LOD) and a clipping detector. As a suboptimum approach, we further approximate the optimum nonlinearities using linear segments to introduce new suboptimum detectors such as a piecewise linear detector and a clipping-like detector.

Next, we extend the approximate MCA model to derive the optimum combining schemes for time and space diversity in the presence of fading and impulse noise. We assume perfect knowledge of noise states to evaluate the analytical performances of the optimum combining schemes for time, receive, and transmit/receive diversity in Rayleigh fading and MCA noise. Although this assumption is unrealistic, it leads to a tight performance bound for the optimum combining schemes in impulse noise. These evaluations allow us to study the performance loss of spatial diversity with respect to the number of transmit and receive antennas.

Finally, we utilize the spectral dimensions in the mitigation problem of impulse noise for orthogonal frequency division multiplexing (OFDM) systems. We start with the receiver design of OFDM systems applied to fading channels with MCA noise, such as the optimum receiver and a conventional OFDM detector. We then evaluate an upper performance bound for the optimum receiver in flat fading with MCA noise. This analysis indicates a significant performance improvement of the optimum detector over a conventional OFDM detector in impulse noise. We finally develop a sphere decoding along with sparse Bayesian learning (SBL) to realize the optimum OFDM detector in MCA noise.

Acknowledgment

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Statutory Declaration

(on Authorship of a Dissertation)

I, Khodr Ahmad Saaifan hereby declare that I have written this PhD thesis independently, unless where clearly stated otherwise. I have used only the sources, the data and the support that I have clearly mentioned. This PhD thesis has not been submitted for conferral of degree elsewhere.

I confirm that no rights of third parties will be infringed by the publication of this thesis.

Bremen, June 30, 2015

Signature ______________________________

Dedication

To my late father, my mother, and my wife Inas

Contents