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RESEARCH ARTICLE

Capacity analysis of power line communication point-to-point and relay channels

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ABSTRACT

In this paper, we present a capacity analysis for broadband power line communication (PLC) channels, impaired by the Bernoulli–Gaussian impulsive noise, exploiting both orthogonal frequency division multiplexing (OFDM) and single-carrier frequency-domain equalisation (SC-FDE) techniques. First, we investigate point-to-point communications and formulate the continuous signal model for OFDM and SC-FDE techniques in PLC environments and find the tight bounds derived for differential entropy of the non-Gaussian noise samples. Capacity bounds and a certain capacity result for point-to-point PLC systems are also computed. Then, we analyse the capacity in the presence of a relay terminal between the transmitter and the receiver. In this part, we assume correlated noises between the relay and the receiver and derive general upper bound and achievable rate using partial decode-and-forward coding strategy for PLC channels. We also show that the obtained bounds coincide in degraded and reversely degraded special cases. Finally, using two statistical divergences, we compare the distances of the Bernoulli–Gaussian and Middleton class A noise models from the normal distribution of their background part and show that the Middleton class A noise is nearer to the Gaussian background noise than the Bernoulli–Gaussian. Therefore, the capacity curve for Middleton class A noise is between the capacity for the Gaussian background noise and the obtained capacity for the Bernoulli–Gaussian model. The obtained capacity theorems are also illustrated numerically. Copyright © 2014 John Wiley & Sons, Ltd.

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1. INTRODUCTION

Using power grid for communication purposes has been the subject of interest for many years. Narrowband power line communication (PLC) has been used for management of power networks from early 1900s. In the last decade, the ability of electrical low-voltage grid in implementing access network and in-home networking has led to the appearance of a new technology known as broadband PLC that can support data rates up to 1 Gbps [1]. Recently, both narrowband and broadband PLC technologies have received increasing attention as promising solutions for smart grid applications such as automatic metre reading, vehicle-to-grid communications and networking of consumer appliances [2, 3].

However, power lines are very harsh channels and suffer from serious challenges such as time and frequency dependent attenuations, multipath effects and impulsive noise [4]. In addition to PLC, the transmitted signal in some environments such as underwater acoustic channels [5], and urban and indoor radio channels [6, 7], is also contaminated by non-Gaussian impulsive noises. Employing the systems already designed for Additive White Gaussian Noise (AWGN) channels in the impulsive noise environments may be caused remarkable performance degradations and hence these channels require new design of the communication structure. Nowadays, considerable knowledge is available on the design process and performance of the different communication techniques in such channels. As some examples, the design and decoding processes for turbo codes, space-time trellis code, spread spectrum technique and memoryless additive impulsive channel are studied in [8–12]. However, because of the non-Gaussian distribution of the noise, capacity analysis of the impulsive noise channels is not straightforward, and a few works have been reported in this area [13–15]. In [13], the bounds of the mutual information have been illustrated numerically. In [14], the capacity of the memoryless additive Middleton class A noise channel has been calculated using perfect knowledge of the noise state information at both the transmitter and the receiver. An interesting analytical analysis for the capacity of mem-