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Communication System and Its Use In Signal Processing

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ABSTRACT: In this paper we present the design of a Broadband Power Line Communication receiver optimized complexity. To this end, the Radio-Frequency stage uses a direct conversion architecture while some innovative solutions are used in the base-band signal processing, such as a new frequency offset synchronization scheme based on the frequency domain. Signal processing techniques to combat the adverse communications environment on power lines are addressed, so as to enable reliable high speed data communications over low voltage. In particular, it is argued that the methods can successfully mitigate the influence of the principal impairments in channels, namely time-varying channel attenuation, multipath frequency-selective fading, multiple-access interference, and background noise. Strategies to deal with the most unfavorable noise source, the impulse noise, are also discussed.

Keywords: Power-Line Communication, OFDM, wireless communications.

I. INTRODUCTION

Due to the rapid growth and evolution of the Information Technologies in the last few years has been driven by an increasing demand in the user bandwidth to the development of techniques that provide broadband applications to final users. The increasing demand for home/office networks further necessitates a flexible broadband network access. These techniques overcome the well known limitations of the classical modulation techniques in both, frequency and time selective channels. In this scenario, OFDM (Orthogonal Frequency Division Multiplexing) modulation reduces the channel effects allowing broadband signals to be transmitted in multi-path and time-variant channels. Electric power lines, which can be found in essentially at all places, since it is convenient and cheap communication alternative. Also, in rural areas where services from telephone companies or cable companies do not reach, and where radio coverage is poor or very expensive through one-way satellite access, communication through power lines may be the only feasible solution [1].

Nowadays, OFDM is an attractive choice for broadband communications over power lines due to: (i) the reduction of Inter-Symbol Interference due to multi-path propagation (ii) the immunity to impulsive noise [2,3]. A new technique BPLC (Broadband Power Line Communication) modem can be also proposed. A comprehensive description of the design process of a BPLC receiver is done, showing different solutions and discussing their advantages and drawbacks. Every receiver block is optimized using a new co-simulation tool that allows real-time operation of some critical blocks, while the other blocks are simulated using a description in a high-level simulation language. In this way, co-simulation is shown to be a valid approach to design such a complex receiver. Finally, some experimental results are shown which validate both, the design process and the implemented solutions.

Power Line Communications (PLC) is an attractive alternative for broadband Internet access for in-home/office networking, many difficulties and challenges exist. The characteristics of the power line that need to be contended with are time-varying frequency dependent channel. Originally designed for power delivery rather than for signal transmission, the power line has many less-than-ideal properties as a communications medium [4, 5]. Also to many other communication channels, the noise in a power line environment cannot be described by an additive white Gaussian noise model. In addition, only a low transmitting power density will be possible for future broadband PLC, due to strict emission regulations for electromagnetic (EM) compatibility.

Thus, the signal-to-noise ratio (SNR) at the receiver can be very low if the transmitter is far away while a large noise source can be nearby. This paper is organized as follows. Section (I) describes the Literature Review of OFDM: (Problems Related to PLC) which includes (1) Wireless Communications (2) Multipath Fading Channels (3) Solar Energy and Advanced Signal Processing (4) Communication Model For Power line. In section (II) we describe the experimental results, whereas in Section (III) shows an implementation and illustrates the experimental results.

II. LITERATURE REVIEW: (PROBLEMS RELATED TO PLC)

A. Wireless Communications

The dominant sources of impairment for power line communications are time-varying channel attenuation, multipath frequency-selective fading, multiple-access interference, and impulse noise. These phenomena naturally remind us of the similar impairments and corresponding mitigating techniques used in wireless communications. The receiver is based on the OFDM classical architecture.

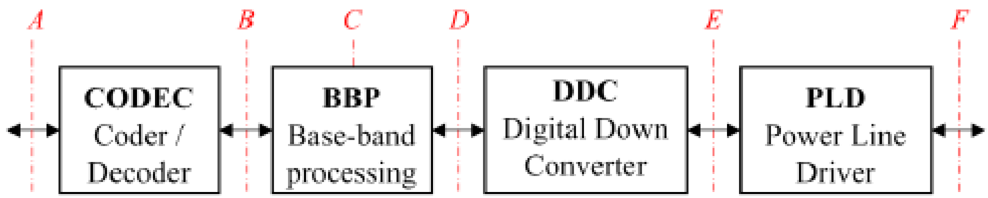

Fig. 1. Modem functional description. Interfaces A, B, C, D, E and F are also defined.

The interface A deals with the user information coming from the medium-access layer; interface B defines the base-band coded binary stream; interface C couples frequency and time domains; interface D deals with the I-Q base-band components; interface E is the pass-band analogue-to-digital interface; and F is the power line interface.

B. Multipath Fading Channels

The data processed by the processor are transferred to the authorized remote station using wireless data transmission technology. The data consist of detected license plate region or sometimes the image of whole speeding vehicle when the color of the vehicle is the same with the color of the license plate. The wireless data transmission is achieved via RF transceiver modules that are installed on both the speed camera system and the authorized remote station. The principal problem is the frequency-selective fading, which places deep notches in the frequency response, whose locations vary from cable to cable, time to time, and location to location. Another problem arises when trying to use the rest of the spectrum: usually the channel attenuation increases with frequency and many bands are not flat enough to accommodate high rate communications with narrowband modulation. Also, the signal is easy to localize in frequency and to disturb deliberately [6]. All frequencies and use advanced signal processing to improve the performance at the frequencies which are found to be attenuated at the receiver.

C. Solar Energy and Advanced Signal Processing

Solar Energy the energy consumption of the speed camera system depends on the energy requirements of the hardware. To smoothly operate the speed camera system, the energy requirements of the hardware has to be considered carefully. Three photovoltaic (PV) panels are used to provide energy requirement from the renewable energy source. Each PV panel contains nine cells for directly converting sunlight into electricity. The magnitudes of the voltage and current that are generated by solar panels change according to the surface of the solar panels that is exposed to sunlight.

Multiuser detection (MUD) is well known to be an effective technique for dealing with the multiple-access interference [7]. It exploits the well-defined structure of the multiuser interference, distinct from that of ambient noise, in order to improve the system performance. Multiuser detection can be applied naturally in CDMA systems that use non orthogonal spreading codes. It also can be employed in wireless time-division multiple-access (TDMA) or frequency division multiple-access (FDMA) systems to ameliorate the effects of non-ideal channelization or multipath, or to combat co-channel interference from adjacent cells. Multiuser detection techniques include optimum maximum-likelihood (ML) joint detection and various suboptimum linear and non-linear methods.

Error control coding is a common way of approaching the capacity of communication channels and is a fundamental element in the design of modern digital communication systems. Turbo decoding, is of significant interest for communications applications that require moderate error rates and can tolerate a certain amount of decoding delay. As a specific application of the turbo principle, by introducing an inter leaver between coding and modulation to form a serially concatenated coding system at the transmitter, and the associated turbo decoding between the multiuser detector and channel decoder at the receiver, one has *turbo multiuser detection* which has drawn much attention recently [8].

D. Communication Model For Power line

The complexity of an OFDM system for communication model, mainly due to the large number of cell parameters, the complexity of the involved signal processing techniques, require efficient design tools. Every digital cell involved in the OFDM receiver has a multi-layer description. The co-simulation strategy is carried out in two planes: a cell simulation plane, and a system simulation plane.

In the cell simulation plane the design decisions are evaluated in terms of the existing error between the cell performances when using high-level or low-level models. In this case, the degradation of the algorithm performance when a low-level implementation of the cell is selected is assessed in terms of the error variance. For each cell in the receiver a set of benchmarks has been previously selected.

As power line communication is still a rather new area, few standards have been established, especially for broadband applications, which is clearly not adequate for high speed Internet access. As with its counterpart on twisted-pair phone lines, high speed communications over power lines requires much larger bandwidth than their normal usage, which should be well separated from the lower frequency band where normal services are provided. In the PLC system simulation plane, the receiver performance is evaluated in the presence of a noisy channel. In this simulation plane all the algorithms involved in the reception chain are evaluated in terms of system performance: bit error rate (BER), synchronization error probability, frequency synchronization error, etc.

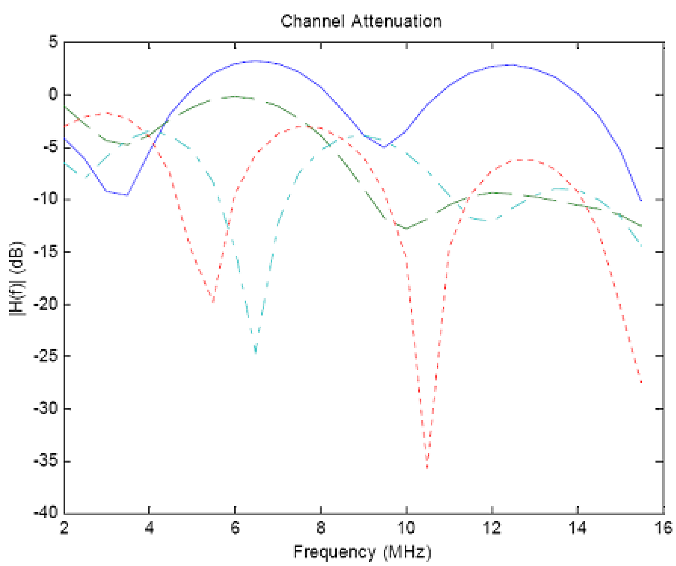

Fig. 2. Simulated channel frequency responces of different users.

Then, the expected performance reduction when a lower-level model of a given block is used (instead of its higher-level model) is measured in terms of the signal to noise ratio (SNR) increase at the receiver input required to maintain the system performance [9]. To support envisioned services such as video on demand, audio or video streaming, multimedia communications with varying quality of service requirements, and high speed Internet access, data transmission rates are needed. A mathematical multipath propagation model for the transfer function of power line channels has been proposed in:

$$H(f)=\sum_{i=1}^{N_p} g_i \cdot e^{-(a_0+a_1 f^k)d_i} \cdot e^{-j2\pi f(d_i/v_p)} \quad \ldots (1)$$

This model is based on physical signal propagation effects in mains networks including numerous branches and impedance mismatching. Besides multipath propagation accompanied by frequency selective fading, signal attenuation of typical power cables increasing with length and frequency is considered.

For such an asynchronous multiuser multipath channel, a received signal **r** containing sufficient numbers of samples should be collected without incurring loss of information, which after some analysis can be expressed in a succinct form

$$\mathbf{r} = \mathbf{F}\,\mathbf{b} + \mathbf{n}, \qquad \ldots(2)$$

where **b** and **n** are the corresponding data and noise vector, respectively, and **F** is a matrix capturing the cross-correlations between different symbols and different users. The effects of a frequency-selective channel can be analyzed in the frequency domain as convolution is replaced by multiplication.

We assume that the subchannel bandwidth is less than the channel coherence bandwidth so that each subchannel experiences frequency-flat fading represented by a corresponding gain. It is straightforward to show that the received signal in the frequency domain is given by a same form as (2), where **r** collects the discrete received spectrum in the *N* subcarriers, **b** and **n** are again the corresponding data and noise vector, respectively, and **F** captures the compound channel characteristics in the frequency domain [9].

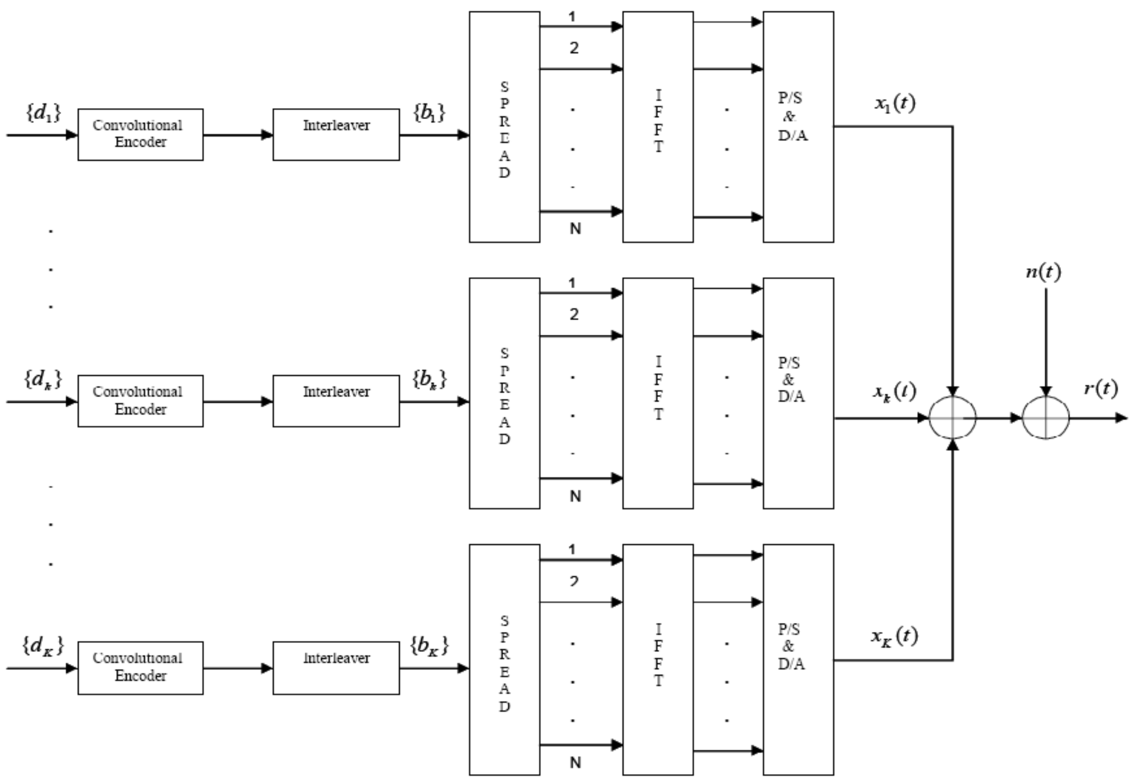

Fig. 3. A coded multiuser Multiplexing system.

Since the received signals can be expressed in the same form, the receiver signal processing described below can be applied to either system.

III. EXPERIMENTAL RESULTS

In this section, we simulate a multiple-access high-speed PLC system with different users, using that which the proposed advanced signal processing techniques are tested and compared with some traditional detection techniques. For each user, the multipath weighting factors are independent normalized complex Gaussian random variables, and the lengths of paths are uniformly distributed within a certain range. The simulated channel frequency responses are shown in figure (2). One may argue that the single carrier system can choose a favorable band for data communication, but this will add complexity to the transmitter and the protocols, and even may not be possible due to the rapid time-varying nature of power line channels. We can see that there is a substantial performance gap between the traditional single user detector and the single user bound [9].

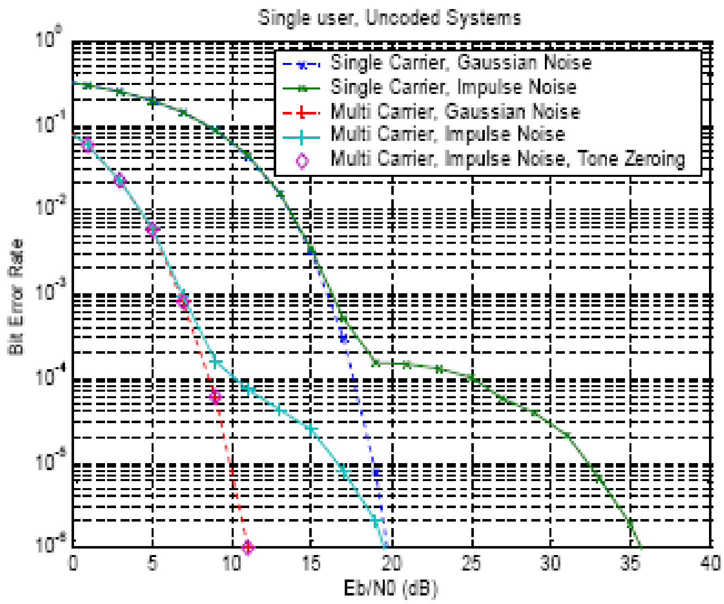

Fig. 4. Performance comparison of single-carrier and MC-CDMA systems with Gaussian and impulse noise.

Optimum ML multiuser detection significantly narrows this gap down, but it suffers from a complexity exponentially increasing with the number of users. The interference cancellation method, posses a good tradeoff between performance and complexity. This excellent performance with reasonable computational complexity, making it very appealing for practical systems.

IV. CONCLUSIONS

OFDM modulation is presently used in many wired and wireless communication standards. This paper addresses the design process of an OFDM receiver for power-line communications. Advanced signal processing techniques previously developed for wireless communications have been applied to high speed power line communications and have been seen to achieved satisfactory results therein. To be specific, PLC systems have been employed for data transmission, and multiuser detection has been used for data detection. The detrimental effects of impulse noise to the proposed scheme are remedied through erasure decoding techniques. For appropriate environment and applications, adapting code rate, power, or constellation size to the different conditions of sub channels is foreseen to substantially improve the system performance. For example, if some power lines exhibit quite good conditions sub-optimum or even traditional receivers may be sufficient, with simpler structure and lower cost.

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