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Power Line Communication System Using Multi-Carrier Chaos Shift Keying For Secure Data Transfer

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Abstract:

The past few years have witnessed a tremendous development in power-line communications (PLC) for the realization of smart grids. The aim of the paper is to propose a Multi-Carrier Differential Chaos Shift Keying (MC-DCSK) modulation scheme as a potential candidate for the PLC applications. The system endeavors to provide a good trade-off between robustness, energy efficiency and high data rate. Differential Chaos Shift Keying (DCSK) is a robust modulation scheme for secure power line communication. MC- DCSK system can be seen as a parallel extension of the DCSK modulation where one chaotic reference sequence is transmitted over a predefined subcarrier frequency. The bit error rate performance of the MC-DCSK system is computed and compared to the conventional DCSK system over multipath PLC channel in which phase, background and impulsive noise are present. The proposed MC-DCSK system is introduce a potential low cost, robust modulation scheme for secure power line communication applications.

Keywords: Power line communication, DCSK ,Chaoscommunication,MC-DCSK

1. INTRODUCTION

Despite the fact that power-line communications (PLC) have been around for more than a century, it has only recently received particular attention due to the emergence of interesting novel applications.Power Line Communications (PLC) is the use of existing electrical cables to transport data, and it has been around for a very long time. For instance, the electrical power utility in London used PLC to remotely control some of its equipment on the grid (such as high voltages witches) in the 1920s. This technique is still employed by several utilities that use analog or digital devices to transfer 9.6 Kbits/s over many miles of electrical cable. "Power Line Communications" basically means any technology that enables data transfer at narrow or broad band speeds through power lines by using advanced modulation technology. Our system will mostly be implemented in areas such as institutions, offices, etc. Power line communications can be used in office or home to Interconnect home/office computers and peripherals,and home entertainment devices that have an Ethernet Port. Power line adapter sets plug into power outlets and establish an Ethernet connection using the existing electrical wiring in the home/office. (Power strips with filtering may absorb the power line signal.) This allows devices to share data without the inconvenience of running dedicated network cables. With just a simple set up of a transmitterandreceiver,andensuringequalphasesupply,onecancontrolaThepowerline modem is a dedicated device,which is used for transferring data over low voltage power line, where electrical power is transmitted over high voltage transmission line distributed over medium voltage & used inside the building at lower voltages.Most PLC's technologies limits themselves to one set of wires (for ex. Premises wiring),but some can cross between two levels. In other words, PLC is a cheap alternative to both the digital subscriber line (DSL) and the optical networking and wireless regional area networks (WRANs). Not with standing its advantages, PLC faces several disadvantages if utilized in its current unaltered form. For the most part, power transmission medium is not ideal to carry signals with frequencies much higher than 50−60Hz. In fact, experimental results unveiled attenuation as high as 10−30dB for data transmission over low voltage lines and 100dB for transmission over medium and high voltage lines. Additionally, transformers can easily filter out the carrier signal, altogether. Beyond all these, interference induced from outside sources into PLs, multipath corruptions and the back-propagation of noise into the wires from loads such as switching devices and home appliances can superimpose and render the received signal completely undecodable. It isimportant to note that the coherence time of different channel gains in a PLC system is high.To tackle these shortcomings and obstacles, separate standardization working groups, such as IEEE P. 1901 and European telecommunication standard institute (ETSI), are currently working toward developing robust modulation schemes for PLC. Among many proposals, wideband modulation schemes such as orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA) have gained prominence and been considered for possible adoption into futuristic PLC architecture. the other hand, three types of noise can severely hinder communication over PLs: background noise , phase noise and impulsive noise. Many communication systems assume that the background noise in PLC is an additive white Gaussian noise (AWGN). This is usually done to derive the analytical closed-form expression bounds of several performance metrics. Indeed, it has been experimentally verified in that this latter follows the Nakagami-m distribution. The phase and impulsive noise have random but periodic natures and occur in short bursts. Impulse noise has much wider power spectral density (PSD) than the background and phase noise To alleviate the impairments caused by these three noise types, chaotic-based modulation is proposed in this paper. This is in motivation by the fact that chaotic signals can be generated using off-the-shelf electronic devices. Moreover, due to their high sensitivity to initial conditions, chaotic maps can generate infinite number of signals with extremely low cross- correlation levels, at least in theory. Owing to their favorable wideband characteristics, chaotic signals have proved to be one of the native candidates for multi-user spread-spectrum modulation schemes. The system DCSK as a robust and inexpensive modulation scheme for power-line communications. The underpinning reason for such choice is implementation simplicity and its robustness against linear and non-linear channel distortions. To prove this claim, DCSK performance over PL channels with multiple echoes and in the presence of background, impulsive, and phase noise is evaluated through the derivation ofclosed-form analytical expression of the bit error rate (BER) and developing a systemlevel simulator. To the best of our knowledge, this study is the first to analyze the performance of DCSK in PLC systems. In fact, the choice of DCSK system is because of its designation as a prominent benchmark for transmit reference non-coherent modulation class. In this paper, we first introduce a new design of a multicarrier DCSK system (MC-DCSK). The system is a hybrid of multi- carrier and DCSK modulations. On the transmitter side, one of the M subcarriers is assigned to transmitting the reference slot, while the other frequencies will carry the data slots. In this case, justonechaoticreferenceisusedtotransmit$M-1$bits,whichsavesthetransmittedbitenergy

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and increases the data rate. After the subcarriers are removed, a parallel demodulation is achieved to quickly recover the transmittedbits.

2. CHAOSCOMMUNICATION

Chaos communications is an application of chaos theory which is aimed to provide security in the transmission of information performed through telecommunications technologies. By secure communications, one has to understand that the contents of the message transmitted are inaccessible to possible eavesdroppers. In chaos communications security (i.e., privacy) is based on the complex dynamic behaviors provided by chaotic systems. Some properties of chaotic dynamics, such as complex behaviour, noise-like dynamics (pseudorandom noise) and spread spectrum, are used to encode data. On the other hand, chaos being a deterministic phenomenon, it is possible to decode data using this determinism. In practice, implementations of chaos communications devices resort to one of two chaotic phenomena: synchronization of chaos, or control of chaos. The chaos communication systems will offer a cheap alternative of the conventional spread spectrum telecommunication systems in many applications if robust modulation methods will be available. In the real telecommunication channel, the received signal is corrupted by noise and interferences, moreover it suffers from channel imperfections.The conventional coherent receivers use the correlation technique or matched filter approach for demodulation. The exact copy of the signal set used for the transmission of the different symbols has to be known in the correlation receiver. The elements of the signal set are recovered. by synchronization. In the matched filter approach, a set of filters having impulse responses matched to the elements of signal set are used. The two techniques are equivalent and because they minimize the effect of channel noise, they offer the optimum system performance.The phase of the received signal is not known in the noncoherent receivers. A combination of an implementable version of matched filter and envelope detector is applied for demodulation in these receivers. A very simple but robust modulation scheme, called differential phase-shift keying (DPSK),has been developed for the conventional telecommunication systems that combines the advantages of the coherent andnoncoherentreceivers.

3. DCSK COMMUNICATION SYSTEM AND DESCRIPTION FOR PLC CHANNELS

The chaotic circuit used to generate the signal for the DCSK modulator isrunning continuously in the transmitter. Inorder to provide both reference and information signals for the receiver, every incoming information bit is encoded into two bits. The first one serves as reference, while the second one carries the information.As shown in Fig. 1, within the modulator, each bit $bi=\{-1, +1\}$ is represented by two sets of chaotic signal samples,with the first set representing the reference, and the second carrying data. If +1 is transmitted, the data-bearing sequence is equal to the reference sequence, and if −1 is transmitted, an inverted version of the reference sequence is used as the data bearing sequence. Let 2β be the spreading factor in DCSK system, defined as the number of chaotic samples sent for each bit, where β is an integer. In the presentsystem,TDCSK=$2Tb=2Tc$isthelengthofDCSKframeintervalforeachbit,where$Tc$is the chip-time, β is an integer referring to the reference length, and Tb is the bit duration.The

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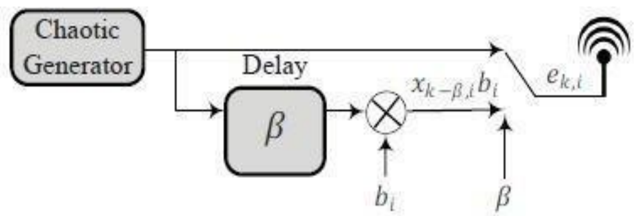
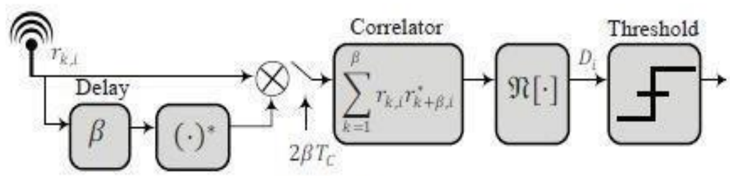
bandwidth spreading factor in DCSK is defined as the ratio of the bit period $Tb$to the chip periodTcwhichisequaltoβ.Duringtheithbitduration,theoutputofthetransmitter$en,i$is

$$e_{n,i} = \{x_{n,i}; 1 < n \leq \beta, b_i x_{n-\beta,i}; \beta < n \leq 2\beta$$



(a) DCSK transmitter.



(b) DCSK receiver.

Fig 1. A diagrammatic representation of DCSK transmitter & receiver.

wherexn,isthechaoticsequenceusedasthereferencesignaland$xn-\beta,i$isitsdelayedversion. As depicted in Fig. 2, the channel model considered in this paper is the echo model developed for the PL channel. When propagating through the PL, the DCSK signal is corrupted with the impulsive and background noise. Hence, the totaladditive noise can bemodeled as$Yn=Wn+In$, where Yn is the total noise. In is the impulsive complex AWGNnoise.

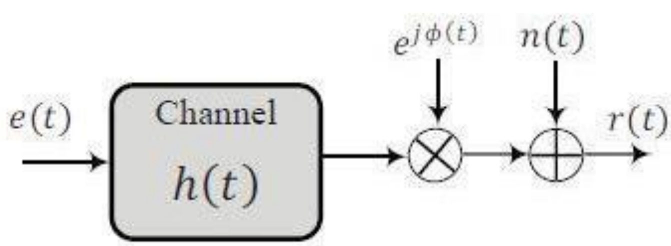


Fig 2. power line channel

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To recover the data at the receiver, the received signal is first correlated with the complex conjugate of its delayed version.Then, the real part of this correlated output is extracted and compared to a threshold.after this we have to calculate the BER .The performance of the different modulation schemes can be compared by plotting the bit error rate (BER) in function of the bit energy to noise spectraldensity

WEAKNESS OF DCSK

As shown in above figures, half the bit duration time is spent sending a non-information- bearing reference. Therefore, the data rate of this architecture is seriously reduced compared to other systems using the same bandwidth, leading to a loss of energy. The reference sequence dissipates half the energy of each bit.

4. MULTI-CARRIER DCSK SYSTEM

The MC-DCSK system benefits from the non-coherent advantages of DCSK and the spectral efficiency of multicarrier modulation. The system endeavors to provide a good trade-off between robustness, energy efficiency and high data rate. Differential Chaos Shift Keying (DCSK) is a robust modulation scheme for secure power line communication. MC-DCSK system can be seen as a parallel extension of the DCSK modulation where one chaotic reference sequence is transmitted over a predefined subcarrierfrequency.

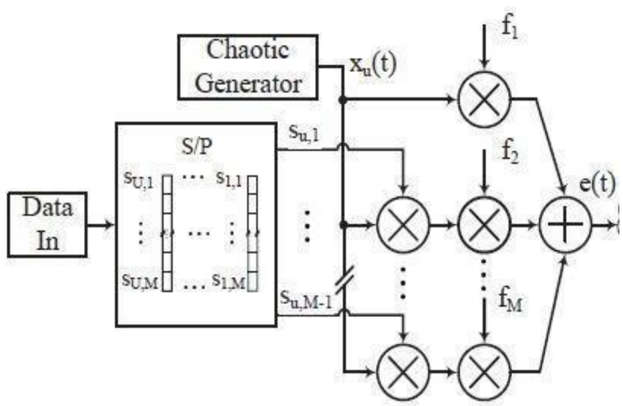

Fig 4(a). MC-DCSK transmitter

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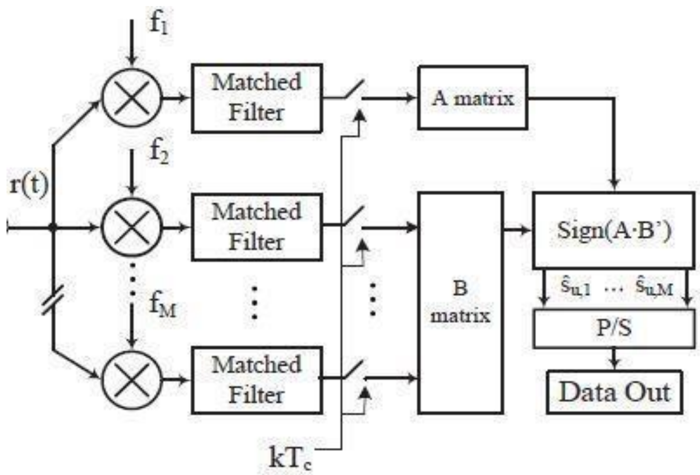

Fig 4(b). MC-DCSK receiver

The MC-DCSK system benefits from the non-coherent advantages of DCSK and the spectral efficiency of multicarrier modulation. In this system, the input information sequence is first converted into U parallel data sequences $Su$for u =1, 2, ...U .

$$Su=[su,1, . . . ,su,i, . . . , su,M-1]$$

where $Su,i$is the $i$thbit of the u thsequence data and M-1 is the number of data per u thsequence.As shown in Fig. 3, a reference chaotic code $xu(t)$ to be used as a reference signal and spreading code. After a serial to parallel conversion, the M-1 bits stream of the u thdata sequence are spread due to multiplication in time with thesame chaotic spreading code$xu(t)$.

$$xu(t) =\Sigma xu,kh(t-kTc)\beta K=1$$

where, β is the spreading factor, $h(t)$ is the square-root raised cosine filter. The block diagram of the MC-DCSK receiver is illustrated in Fig. 3. One of the objectives of this design was to provide a robust receiver providing good performance. We consider a set of matched filters, each demodulating the desired signal of the corresponding carrier frequency fi, and then the signals are sampled every kTctime. The outputs discrete signals are stored in matrix memory. Finally, afterβclockcycles,allthesamplesarestored,andthedecodingstepisactivated.The transmitted $M-1$ bits are recovered in parallel by computing the sign of the resultant vector of the matrix product. where × is the matrix product and ` is the matrix transpose operator. In fact, this matrix product can be seen as a set of a parallel correlator where the reference signal multiplies each data slot, and the result is summed over the duration βTc.

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5. SIMULATION RESULT

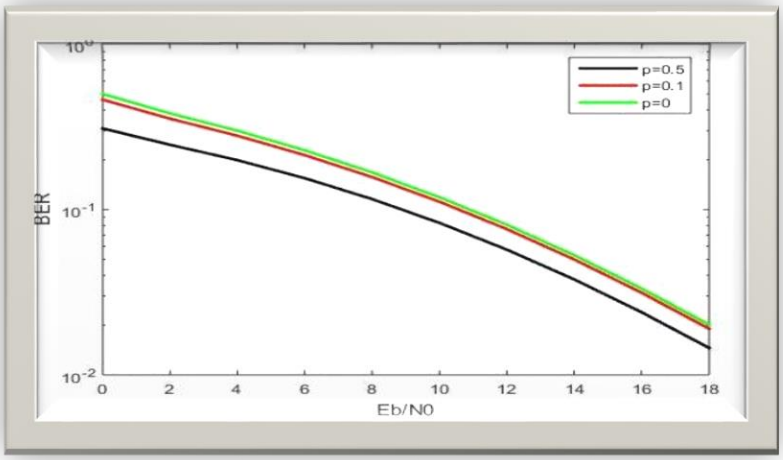

Fig 5(a): BER performance of DCSK system

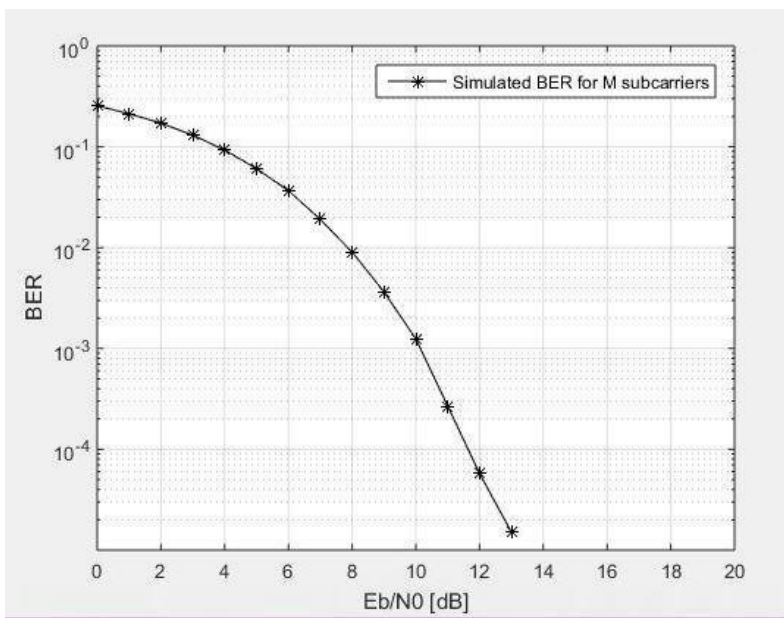

Fig 5(b): BER performance of MC- DCSK system

CONCLUSION

In this paper we propose a DCSK system as potential candidate for power-line communication (PLC) applications.The performance of DCSK system was analysed over power line channel with multiple echoes and in the presence of background,impulsive and phase noise. the DCSK system is introduced as a potential low-cost, robust modulation scheme for secure PLCapplications.

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