Performance Evaluation of Power Line Communication Channels with OFDM System

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Abstract— The main aim of this paper is to design an OFDM modem for powerline-based communication in order to propose and examine a novel approach in comparing the different modulation order, different modulation type, and application of Forward Error Correction (FEC) scheme. This is an attempt to understand and recognise the most suitable technique for the transmission of message or image within a communication system.

Key words: Power Line Communication Channels, OFDM System

I. INTRODUCTION

Power line communication technology capitalises on the existing power networks for communication purposes which offer fewer expenses in new connection set ups. This technology has evolved through the years, shifting focus from narrowband to broadband and different techniques being employed so as to achieve higher bit-rates and more reliable communication over the power lines. Considerable research on this important area is therefore ongoing. The power line's inherent problems are largely due to its novel design which is primarily devised for the transmission of electric power and not communication signals, moreover, in the broadband range. This possibly explains why a universally accepted model for the power line communication channel has not yet been established [1-4].

The work presented here seeks to contribute to the ongoing research of developing a better understanding of the presently unpredictable and harsh communication medium. Transmission line theory and different modulation techniques were studied and then performance evaluation was performed for power line communication using OFDM.

II. POWERLINE COMMUNICATION (PLC)

The concept of using power lines (PL) for communication services is notone that has just emerged. The first applications of PLC date back abouthundred years ago, when analog communications were employed for remote metering and home automation. It was also important for power supply utilities to have a proper communication link to maintain the operation of high-voltage PLs. However, the attention in the past decade or so has been focussed on using PLC for fast Internet access as well as other broadband multimedia services.

Due to the presence of impulsive noise and other undesirable characteristics of PL grids, it is crucial for high-speed PLC to select a modulation technique that can stand against such peculiarities. A number of modulation techniques, including single-carrier, multi-carrier and spread spectrum are of interest for PLC engineers and researchers [5], [6]. Among those, orthogonal frequency division multiplexing (OFDM) stands as an excellent candidate for PLC. The basic principle of OFDM is to split high-speed data symbols into slow data streams which then modulate multiple narrowband orthogonal subcarriers simultaneously. This reduces the effect of multipath by enlarging the symbol duration so that, depending on the channel delay spread, only a small portion of the symbol is affected. With the addition of a cyclic time guard, the problem of multipath can be completely eliminated in OFDM. Besides, the effect of impulsive noise is minimized because the received OFDM signal in addition to the added noise is divided by the number of subchannels through the discrete Fourier transform (DFT) operation in the receiver. OFDM offers robustness as well as simple implementation which make this technique a favoured candidate for PLC.

III. TRANSMISSION LINE MODEL

Various methods used to simulate and study the transmission line behaviour are described [7-8]. Most of them are obtained from the time dependent telegrapher's equations which are for the elementary line transmission cell.

$$\frac{\partial v(x,t)}{\partial x} + R' i(x,t) + L' \frac{\partial i(x,t)}{\partial t} = 0 \quad (1)$$

$$\frac{\partial i(x,t)}{\partial x} + G' v(x,t) + C' \frac{\partial v(x,t)}{\partial t} = 0 \quad (2)$$

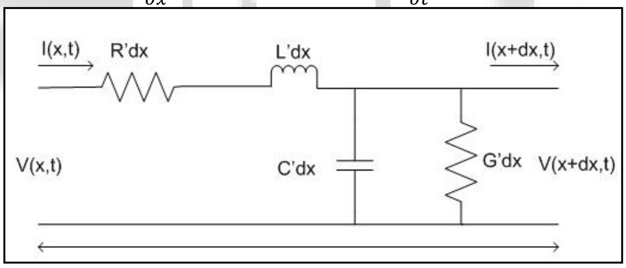

Fig. 1: Elementary cell of a transmission line

The Elementary cell of a transmission line is depicted in Fig.1. In the above equations *x* denotes the longitudinal direction of the line and R', L', G' and C' are per unit length resistance (Ω/m), inductance (H/m), conductance (S/m) and capacitance (F/m), respectively. The electric quantities are dependent on the geometric and constitutive parameters. Transmission lines are described using the characteristic impedance Zc and the propagation constant γ:

$$Z_c = \sqrt{\frac{R' + j\omega L'}{G' + j\omega C'}} \quad (3)$$

$$\gamma = \sqrt{(R' + j\omega L')(G' + j\omega C')} \quad (4)$$

The characteristic impedance Zc and the propagation constant γ are related to the per-unit length parameters of the transmission line. It is supposed that the per-unit parameters depend on frequency as [9].

$$r = r'; l = l_1 + \frac{l_2}{\sqrt{f}}; g = g_1 f; c = c_1 \quad (5)$$

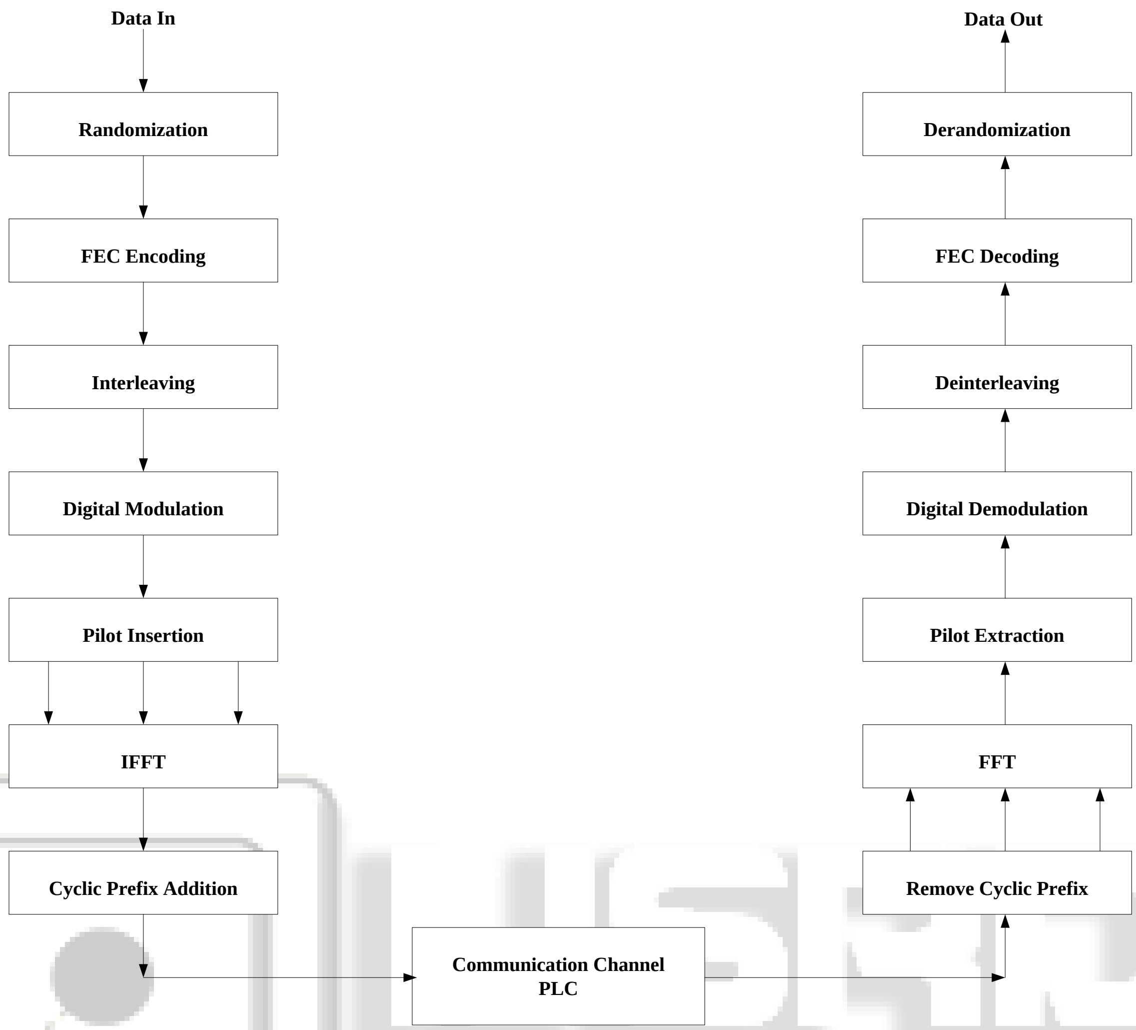

Fig. 2: Block Diagram of Systems

IV. MODULATION SCHEME FOR POWER LINE COMMUNICATION SYSTEM

The selection of a modulation scheme for PLC systems must account for three major factors: The presence of noise and impulse disturbances causing a relatively low signal-to-noise ratio (SNR); the time-varying frequency-selective nature of the channel; and, Regulatory constraints with regard to electromagnetic compatibility that limit the transmitted power.

A. OFDM

Among the techniques that have been used to design a digital communication system, Orthogonal Frequency Division Multiplexing (OFDM) has been referred to as one of the most advantageous technique. OFDM systems have been widely recognised as a bandwidth efficient transmission technique for wireless communications. This multicarrier transmission technique has been gaining more and more interest from communications and signal processing communities [10].

OFDM is sometimes referred to as a frequency-domain approach to communications, and has important advantages when dealing with the frequency-selective nature of high data rate communication channels. In addition, it benefits from a high spectral efficiency, simple implementation, strong multipath tolerance, robust against narrowband co-channel interference and channel fading etc. Moreover, one of the main advantages of using OFDM technique is that the transmission signal is affixed with the cyclic prefix (CP), assisting it in counteracting the effects of delay. However, in addition to its important advantages, OFDM has number of disadvantages, such as the loss of bandwidth due to guard time, large Peak to Average Power Ratio (PAPR) and it's prone to frequency and phase offset errors.

V. RESULTS

Simulation parameters used in this work are given in the following Table 1

PARAMETER	SELECTED TYPE OR VALUES
Digital Modulation Type	BPSK, QPSK, 16-QAM, 64-QAM
FEC Code	Convolutional Code, RS Code
Considered Channel	Power Line Communication Channel
FFT Size	256
Cyclic Prefix	¼
Channel Bandwidth	20 MHz

Table 1: Simulation parameters used for Power Line Communication

These results have been obtained over PLC channel. In order to decide proper switching levels from this plot, we have to decide what our operating point or desired BER is. Here we choose to use 10-1, 10-2 and 10-3 as our operating points. The case is studied having more number of bits in transmission but at a cost of greater SNR values.

A. BER performance of different modulation techniques over Power Line Communication channel

This section gives the comparison between the different modulation schemes used in the simulator. These results have been obtained over PLC channel. In order to decide proper switching levels from this plot, we have to decide what our operating point or desired BER is. Here we choose to use 10-1, 10-2 and 10-3 as our operating points. The case is studied having more number of bits in transmission but at a cost of greater SNR values.

1) BER variation with SNR of BPSK

In this section RS code is used as FEC encoding with 1/2 Convolution code over PLC channel. It evaluated by plotting the BER Vs SNR characteristics.

In Fig. 3 the curve from represent the BER vs SNR of BPSK with 10-3 BER at 3dB SNR.

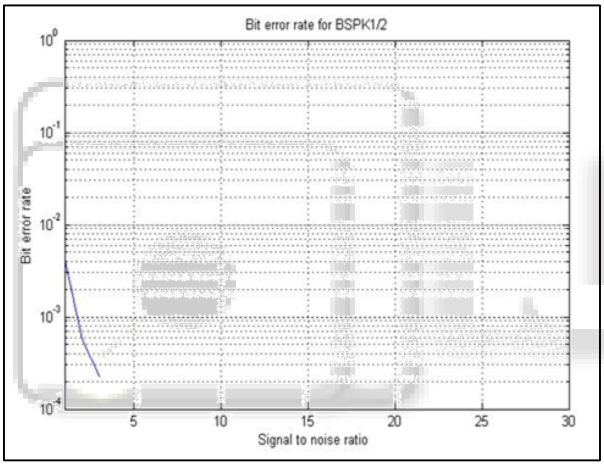

Fig. 3: SNR vs BER performance of BPSK 1/2

2) BER variation with SNR of QPSK

In this section RS code is used as FEC encoding with 1/2 & 3/4 Convolution code over PLC channel. It evaluated by plotting the BER Vs SNR characteristics.

In Fig. 4 the curve from represent the BER vs SNR of QPSK 1/2 with 10-1 BER at 5dB SNR. In Fig. 5 the curve from represent the BER vs SNR of QPSK 3/4 with 10-3 BER at 10dB SNR.

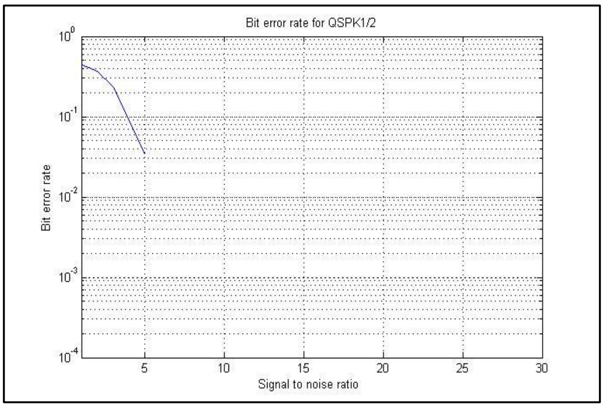

Fig. 4: SNR vs BER performance of QPSK 1/2

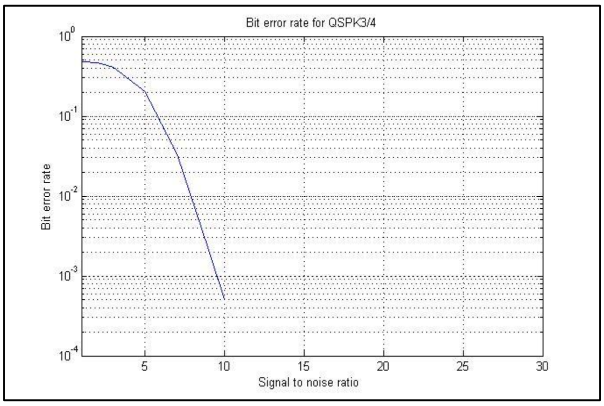

Fig. 5: SNR vs BER performance of QPSK 3/4

B. BER variation with SNR of 16-QAM

In this section RS code is used as FEC encoding with 1/2 & 3/4 Convolution code over PLC channel for 16-QAM. It evaluated by plotting the BER Vs SNR characteristics.

In Fig. 6 the curve from represent the BER vs SNR of 16-QAM 1/2 with 10-2 BER at 12dB SNR. In Fig. 7 the curve from represent the BER vs SNR of 16-QAM 3/4 with 10-2 BER at 15dB SNR.

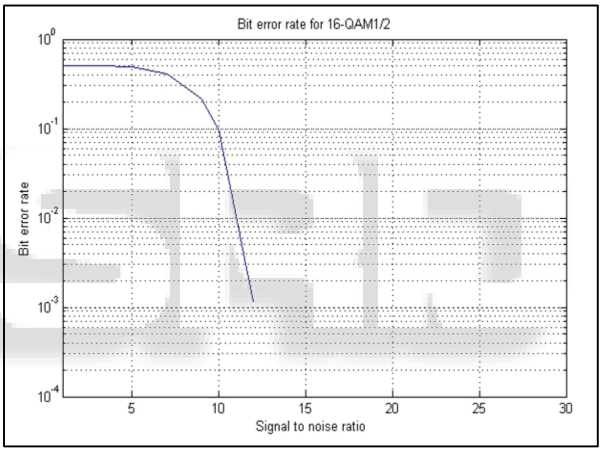

Fig. 6: SNR vs BER performance of 16-QAM 1/2

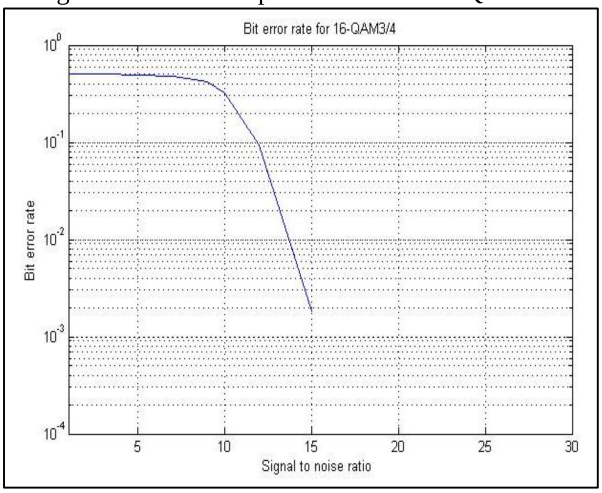

Fig. 7: SNR vs BER performance of 16-QAM 3/4

BER variation with SNR of 64-QAM

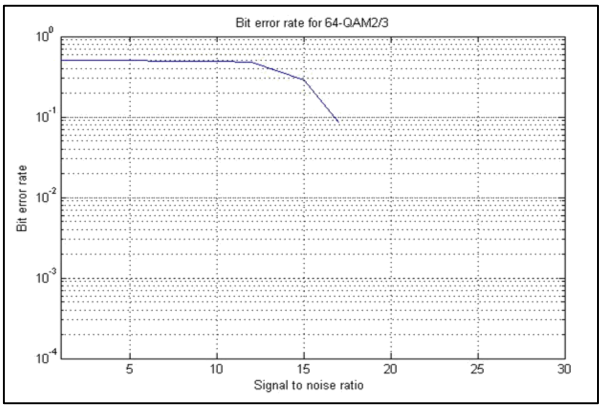

Fig. 8: SNR vs BER performance of 64-QAM 2/3

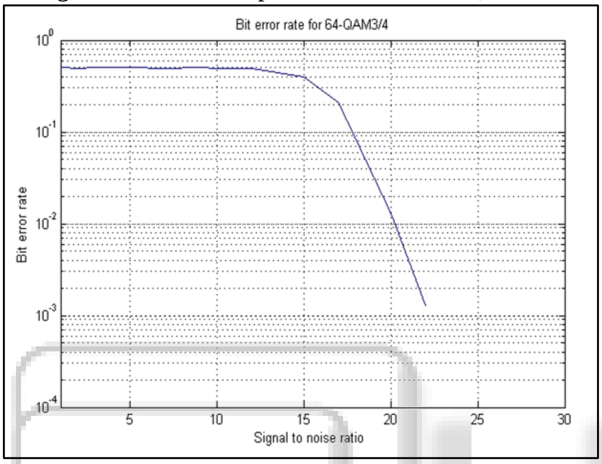

Fig. 9: SNR vs BER performance of 64-QAM 3/4

In this section RS code is used as FEC encoding with 2/3 & 3/4 Convolution code over PLC channel for 64-QAM. It evaluated by plotting the BER Vs SNR characteristics.

In Fig. 8 the curve from represent the BER vs SNR of 64-QAM 2/3 with 10-1 BER at 17dB SNR. In Fig. 9 the curve from represent the BER vs SNR of 64-QAM 3/4 with 10-2 BER at 22dB SNR.

FEC code	Modulation	SNR at AWGN channel
RS code	BPSK1/2	7dB at BER 10^{-3}
	QPSK1/2	12dB at BER 10^{-1}
	QPSK3/4	23dB at BER 10^{-3}
	16-QAM1/2	24dB at BER 10^{-1}
	16-QAM3/4	32dB at BER 10^{-2}
	64-QAM2/3	33dB at BER 10^{-1}
	64-QAM3/4	36dB at BER 10^{-1}

Table 4.2: SNR for different modulation techniques over PLC channel

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