Performance Analysis of a OFDM SISO Powerline Communication System with Non-white Gaussian Channel Noise

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Abstract – Performance analysis is carried out for a power line communication (PLC) system taking into account the effect of background noise and the transfer function of the PLC. The analysis is carried out with orthogonal FDM (OFDM) carrier along with the effect of background channel noise which non-white power spectral density. The expression of the SNR at the output of the OFDM demodulator is developed for k-th subcarrier. The bit error rate for the k-th subcarrier channel and the average BER is then found analytically. The performance results are evaluated numerically for different number of OFDM subcarriers and several bandwidths of the PLC channel upto 30 MHz. The results show that there is deterioration in BER performance with increase in channel bandwidth. However, the performance can be significantly improved by increasing the number of OFDM subcarriers at a given signal to noise ratio.

Key Words – Single carrier; OFDM(orthogonal frequency division multiplexing); SISO(single input single output); Transfer function; Gaussian noise; etc.

I. INTRODUCTION

Power Line Communications have recently emerged as a highly regarded candidate for in-home, local area and rural broadband multimedia transmissions since power line channels present the appealing benefits of low cost access network installation, due to the use of widely deployed power line infrastructure, and theoretical capacities that can surpass 1 Gbps [1].

Presently, a great deal of attention has been devoted to model PL channel properties. Several researches have determined that power line channels always present: (a) attenuation proportional to frequency and distance, (b) time-varying behavior, (c) high impedance varying with time and frequency, (d) strong impulsive noise presence due to switching on/off of electric loads and (e) frequency selectivity [2-3].

The increasing demand for high spectral efficiency modulation has demanded continuous system evolution in order to improve performance. One of the major obstacles that high data rate systems must overcome is the fact that increasing data rates through band limited channels introduces inter-symbol interference (ISI), which drastically degrades the received signal. For band limited power line channels, the occurrence of high power impulsive noise exacerbates the degradation [4].

The use of powerful channel diversity and OFDM techniques to cope with the aforementioned problems in power line channels has been investigated in [5-6]. The receiver performance could be greatly improved if these two tasks were jointly performed. A successful approach to do this is SISO technique to the transmitter and received data.

Now a day, Orthogonal Frequency Division Multiplexing (OFDM) has been adopted in most of the important wireless communication systems such as Digital Audio Broadcasting, Digital Video Broadcasting, Wireless Local Area Network, Wireless Metropolitan Area Network, and Multi Band –OFDM Ultra Wide Band. Moreover, this technique is also employed in important wired applications such as Asymmetric Digital Subscriber Line or Power Line Communication (PLC). And one of the techniques which are proposed for future generation wireless communication system is OFDM because it transmits data over extremely hostile channel at a comparable low complexity with high data rates [7-8].

In OFDM, the radio signal into multiple smaller sub-signals that are transmitted simultaneously on different frequencies, i.e. subcarriers. Inverse Fast Fourier Transform and Fast Fourier Transform are used to divide the frequency at transmitter and receiver respectively. Efficient selection of subcarrier spacing and overall bandwidth, the channel frequency response for each subcarrier can be modeled with a single complex value. This allows a much easier implementation than that required for processing multi-tap time domain channel responses. The combination of OFDM and single-input single output (SISO) is referred to as SISO-OFDM [9-10].

Much attention has been paid to improve the link performance of SISO and MIMO system. This paper investigates the performance of SISO system for OFDM system[11].

II. SYSTEM MODEL

The block diagram of the PLC system with transmitter and receiver of SISO channel is shown in fig 1. In the transmission block, the signal is processed by single transmitters and in the receiving block there is single receiver.

As it is considered that a PLC channel consists of 3-wires which offer additional feeding and receiving options.

In wireless communication system SISO is a technique widely used to enhance system performance. It is possible to set an analogy of the signal feed and receive port is replaced by transmit and receive antenna of the PLC system. Also, the radio channel to be replaced by the electrical wiring.

There are three possibilities of giving input to any 2 of the 3 different feeding ports: P – N (phase to neutral), P – PE (phase to protective earth) and N – PE (neutral to protective earth). We know that the sum of 3 input signal will be zero in this case, so only 2 input ports out of 3 can be used at a time. In the receiver, there is an additional reception path called common mode (CM) path, created in unbalanced network. Due to electromagnetic coupling between adjacent wires, crosstalk arises. So, the transmitted signal from any input port is available on all 4 receiving ports [12]. However, in this paper, the analysis is limited to single input single output system which is shown in fig 1.

III. ANALYSIS OF BER

The powerline channel transfer function has a bandwidth upto 30MHz which is sub-divided into N_C sub-channels of bandwidth B_{PLC} to make OFDM modulation. So, the OFDM signal transmitted for the k-th symbol period can be expressed as

$$s(t) = \sqrt{\frac{2E_s}{T_s}} \sum_{n=0}^{N-1} a_{0.n} \exp\left(j\frac{2\pi nt}{NT_s} \right) .\exp\left[\frac{-j\pi(N-1)t}{NT_s} \right], \ 0 \le t \le NT_s \quad \text{……………... (1)}$$

where N is the FFT size, Es is the symbol energy and Ts is the symbol period.

The received OFDM signal can be expressed as [2]

$$r_k(t) = s_k(t)\, h(t) + n_r(t) \quad \text{...... (2)}$$

where $n_r(t)$ is the powerline background noise which can be modeled as non-white Gaussian noise. The spectral density of $n_r(t)$ is shown in fig 2 for 0 to 30 MHz. The power spectral density (PSD) of noise can be expressed as [6]

$$N_r(f) = \frac{1}{f^2} + 10^{-15.5}\ mW/Hz \quad \text{……………... (3)}$$

The term h(t) in equation (2) represents the impulse response of the powerline channel which is inverse Fourier transfer of the powerline transfer function H(f) given by [6],

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

$$or,\ H(f) = \sum_{i=1}^{N_p} g_i\ e^{-(a_0 + a_1 f^k)d_i} .e^{-j2\pi f\tau_i} \quad \text{……………... (4)}$$

where g_i is the weighting factor for path i, a_0 and a_1 the attenuation parameters, f the frequency, k the exponent of the attenuation factor (0.5…1), d_i the length of the path and the delay is τ_i.

For SISO (Single input single output) communication channel, the SNR at the output of OFDM receiver for k-th OFDM subcarrier is given by

$$SNR(k) = \frac{P_T(f_k)}{N_R(f_k)} \left| H(f_k) \right|^2 \quad \text{……. (5)}$$

where $N_R(f_k)$ is the powerline noise power at the subcarrier frequency f_k.

Considering BPSK modulation of each carrier with coherent demodulation, the bit error rate (BER) for the k-th OFDM subcarrier channel is then given by

$$BER(k) = \frac{1}{2} erfc\left(\frac{\sqrt{SNR(k)}}{\sqrt{2}} \right) \quad \text{…… (6)}$$

for BPSK modulation with coherent detection.

The average bit error rate can be obtained as

$$BER = \frac{1}{N}\sum_{k=1}^{N} BER(k) \qquad \text{.........(7)}$$

IV. TABLE AND FIGURES

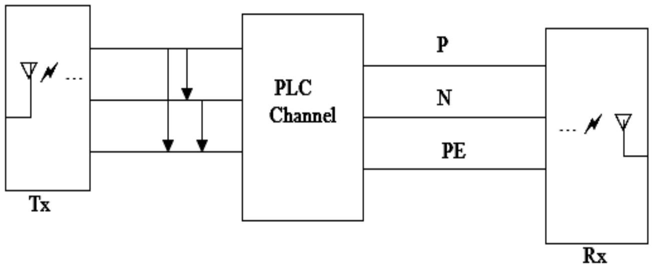

Fig 1: SISO PLC channel block diagram

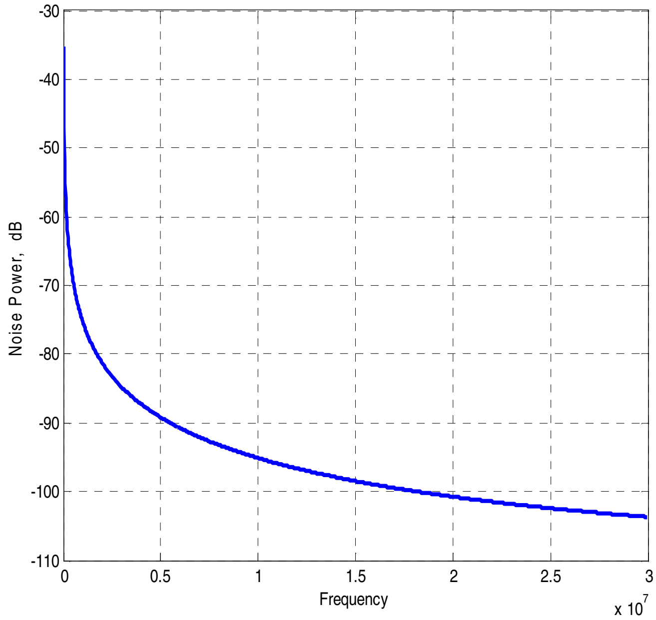

Fig 2: Noise spectral density for 30 MHz bandwidth

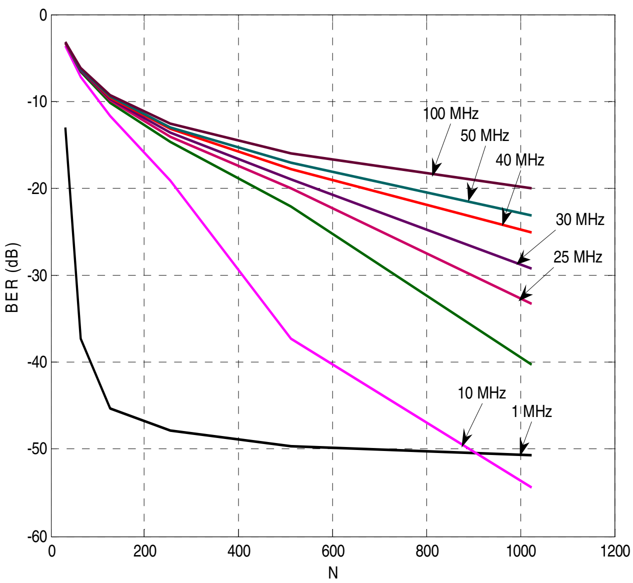

Fig 3: Plot of BER Vs. no of OFDM subcarrier for PLC system bandwidth 1, 10, 20 ,25, 30, 40, 50 and 100 MHz.

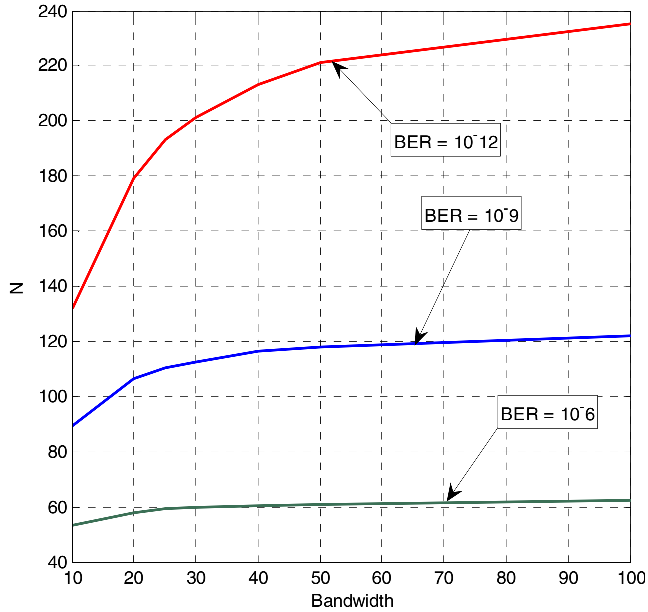

Fig 4: Plot of required number of OFDM subcarrier at a given BER versus the PLC system bandwidth.

V. RESULT AND DISCUSSION

Following the theoretical analysis given in section III, we evaluated the bit error rate performance of a PLC system taking into account the effect of power line non-white Gaussian noise with number of path to be one. The power spectral density of the noise is shown in fig 2 for frequency upto 30 MHz. It is noted that low frequency noise components are more stronger than high frequency noise. As a result, the signal to noise ratio will be higher for higher frequency OFDM subcarriers resulting in low BER for high frequency carriers. The plots of average BER versus number of OFDM subcarriers are shown in fig 3. It is noticed that as the number of subcarrier increases ,there is significant reduction in BER at a given symbol energy. For example, the BER is found to be about 10^-10 when number of OFDM subcarrier is 100 and it significantly reduces to 10^-30 when the number of subcarrier is increased to 400. Thus there is improvement in BER by two order of magnitude due to increase in N from100 to 400. It is also noticed that there is an optimum number of subcarrier after which there is no decrease in BER with increase in N, i.e, BER floor occurs from N higher than or equal to the optimum value. The optimum number of subcarrier from 1 MHz system bandwidth is found to be 256. Further, there is deterioration in BER performance as the system bandwidth is increased. It is noticed that BER floor occurs at a higher value as the system bandwidth is increased.

It is noticed that to achieve a given BER (say 10^-6) there is requirement of minimum number of OFDM subcarriers corresponding to a given symbol energy. The plots of required number of OFDM subcarrier versus the system bandwidth corresponding to a given BER are shown in fig 4. The figure reveals that higher bandwidth require a higher number of OFDM subcarrier to achieve a given BER.

V. CONCLUSION

Performance analysis is carried out for a PLC system with OFDM in the presence of non-white background channel noise. Results are evaluated numerically in terms of BER for given OFDM symbol energy and several system bandwidth and different values of number of OFDM subcarriers. It is found that BER can be improved only by increasing the number of OFDM subcarriers without increasing the symbol energy and there are optimum number of subcarriers corresponding to a given BER.

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