Comparative Analysis of Orthogonal Frequency Division Multiplexing and Single Carrier Cyclic Prefix Modulation Schemes in Powerline Communication Systems

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Abstract- Powerline communication (PLC) requires a robust modulation scheme to combat multipath effects and inherent interferences due to connection and disconnection of electrical equipments in the network and varying nature of the electrical network. The modulation scheme commonly used in contemporary PLC systems is Orthogonal Frequency Division Multiplexing (OFDM). Although OFDM mitigates the negative effects of PLC channel, it has high Peak to Average Power Ratio (PAPR) which translates into high transmit power requirements. However, Single Carrier Cyclic Prefix (SCCP) is closely related modulation scheme to OFDM which inherits its advantages while avoiding PAPR disadvantage. In this paper different types on PLC channels and a number of computer simulations on SCCP and OFDM modulation schemes has been performed. In both cases, it was found that SCCP attained much lower BER than OFDM for the same average signal-to-noise ratio (SNR) while having less PAPR. This concludes that SCCP is better than OFDM in PLC environment.

Keywords- Powerline Communication (PLC), Orthogonal Frequency Division Multiplexing (OFDM), Single Carrier Cyclic Prefix (SCCP), Peak to Average Power Ratio (PAPR).

I. Introduction

Powerline Communication (PLC) technology utilizes the existing indoor and outdoor electric power networks for data communication without installation of data cables. PLC differs from Ethernet and Asynchronous Digital Subscriber Line (ADSL) technologies due to its unpredictable noise caused by connected and disconnected loads on the electric power networks making PLC channel characteristics to vary randomly [1]. OFDM is used in PLC technology to mitigate its random nature as used in wireless communication channel [2]. Single Carrier Cyclic Prefix (SCCP) is a close modulation Scheme to OFDM with all the advantages of OFDM, while avoiding its High Peak to Average Power ration (PAPR) problem [3].

OFDM technology was first used to minimize Inter-Symbol Interference (ISI) by additional of Cyclic Prefix to the transmitted data and later used to solve the multipath effects of wireless channel and bandwidth efficiency problem of the Frequency Division Multiplexing (FDM) and increasing transmission data rate.

Single carrier with cyclic prefix (SCCP) is another modulation scheme, which mitigates the frequency selective fading channel effects. SCCP incorporate a Cyclic Prefix (CP) the same as OFDM into a Single Carrier (SC) signal transmission to enable efficient Frequency Domain Equalization (FDE) for this reason SCCP is also known as Single carrier modulation with frequency domain equalization (SC/FDE) [4]. This research work is organized as in Part II will explain PLC with OFDM and SCCP system model, Part III will express the methodology, which was used for Simulations and data findings and lastly conclusion is given at the end.

II. System Model

An SCCP modulator transmits modulated symbols sequentially. It divides the sequence of modulation symbols into blocks and adds a cyclic prefix (CP) to the beginning of each block. Both SCCP and OFDM systems use the same communication component blocks and the only difference between the two diagrams is the location of the IDFT block. Thus, one can expect the two systems to have similar link level performance and spectral efficiency. So SCCP delivers performance similar to OFDM with essentially the same overall complexity, even for a long channel impulse response.

SCCP transfers the FFT module from transmitter to receiver, thus avoids the high PAPR, but still inherits the low complexity advantage attributed to frequency-domain signal processing.

Being a SC modulation technique SCCP does not suffer from practical implementation difficulties of multicarrier systems, such as high PAPR and sensitivity to frequency and phase offset. Moreover SCCP delivers performance similar and sometimes better than OFDM with essentially the same overall complexity, even for long channel delays while providing low PAPR.

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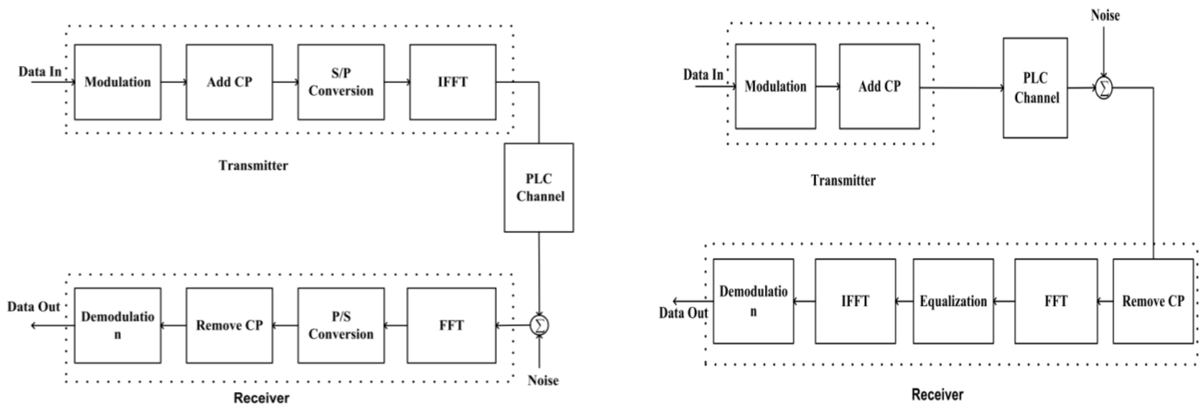

Figure 1: OFDM and SCCP Modulations

III. Simulation Results And Discussion

OFDM and SCCP systems use the same components but the position of the components make the two systems to have difference performance criteria with the same system complexity. Although, In both systems FFT and IFFT are used. However in an OFDM system both Equalization and data detection are performed in frequency domain while in a SCCP system Equalization is performed in frequency domain, whereas data detection is made in time domain making the two systems to have different performances.

Since in OFDM systems data detection is made on different sub-carriers, the carriers with severe amplitude attenuation become unreliable. The information in each SCCP symbol is spread out over the channel spectrum making channel dips to affect only small part of the transmitted symbol making easy to recover the transmitted symbol [5,6]. Therefore an SCCP scheme can exploit the frequency diversity inherent in the channel to outperform the OFDM counterpart.

In Analysis of OFDM and SCCP modulation schemes Zimmermann and Dosert model [7] was used. The frequency response of the PLC Channel as governed by Zimmermann and Dosert model is given by equation 1.

$$H(f)=\sum_{i=1}^{N} g_i e^{(a_0+a_1 f^k) l_i} e^{-j2\pi f \tau_i} \qquad (1)$$

where, a_0, a_1 and k are constants

g_i, is a weighting factor equal to product of the reflection and transmission factors of path i τ_i, is delay of path i.

The BER performance of SCCP and OFDM as given by Equation 2 and Equation 3, shows that the performance of OFDM system depends on the SNR of the individual subchannels and that of SCCP system is determined by the average SNR of the all subchannels.

$$BER_{OFDM}=\frac{1}{N}\sum_{i=0}^{N-1} Q\left(\sqrt{\frac{2E_s}{N_0 |H_i|^2}}\right) \qquad (2)$$

$$BER_{SC}=Q\left(\sqrt{\frac{2E_b/N_0}{\frac{1}{N}\sum_{i=0}^{N-!}|H_i|^{-2}}}\right) \qquad (3)$$

where $Q(x)=\frac{1}{\sqrt{2\pi}}\int_x^{\infty} e^{-y^2/2}\,dy$,

H is Channel response, E_b/N_0 and E_s/N_0 are Signal to noise ratio. Taking into account the channels mentioned in Table.1, the OFDM and SCCP modulation schemes were simulated for each channel and the results are as shown in the Figures 2, Figure 3, figure 4 and figure 5. For each figure the two modulation schemes with the same attribute as mentioned in Table.1 are compared. The figures indicate the simulation of the PLC channels with SCCP and OFDM simulation without equalization and with equalization using Zero Forcing (ZF) equalizer and Minimum Mean Square Error (MMSE) equalizer.

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Table 1: PLC Channels and their Characteristics

Name	Length	Number of branches	Number of path
Channel 1	<100 m	none	5
Channel 2	≤110 m	6	10
Channel 3	≤210 m	8	12
Channel 4	≤300 m	10	20

In the simulation of OFDM and SCCP modulation schemes over PLC channel, Philips and Zimmerman PLC Channel model was used and different PLC channels were used to determine performance of OFDM and SCCP modulation schemes.

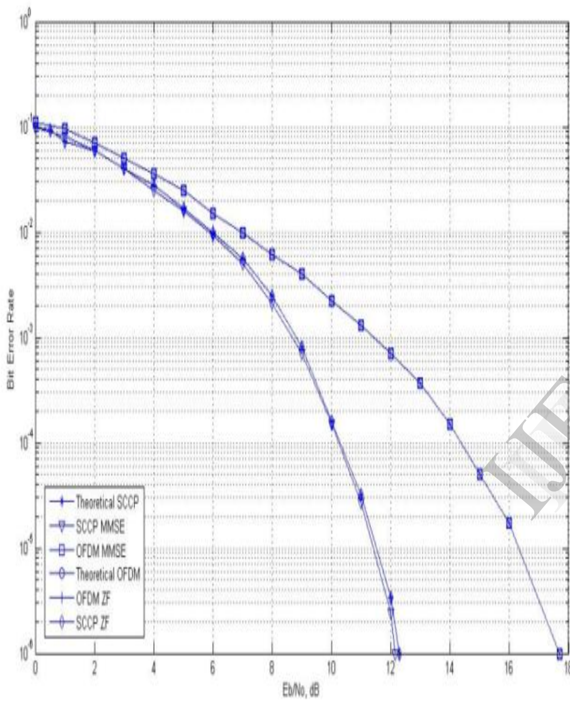

Figure 2: Indoor channel

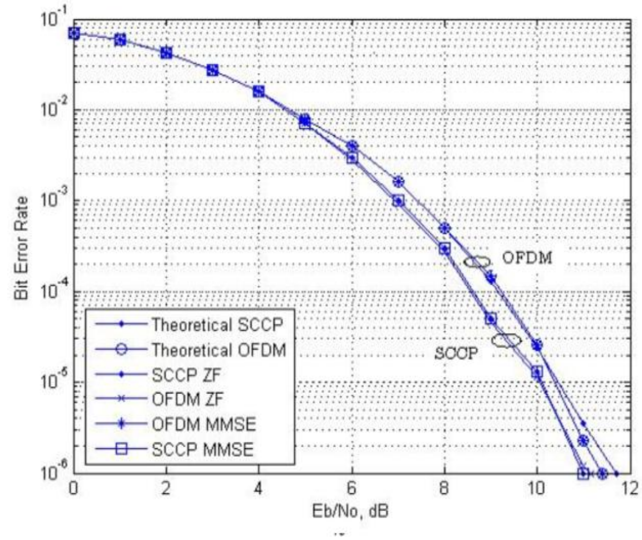

Figure 3: Channel 2

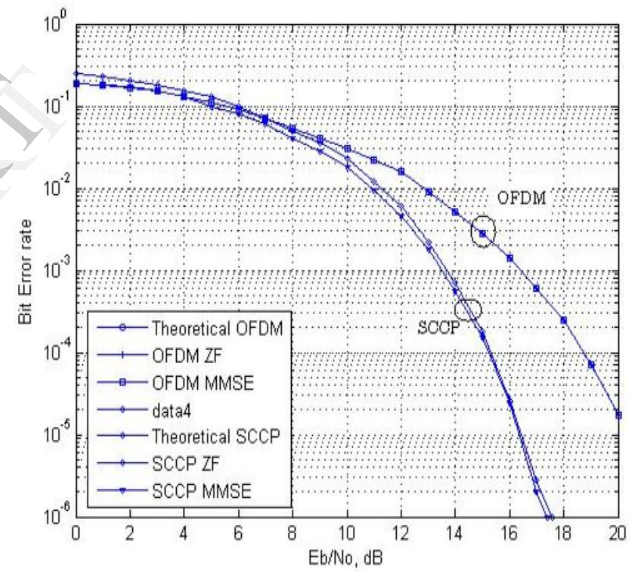

Figure 4: Channel 3

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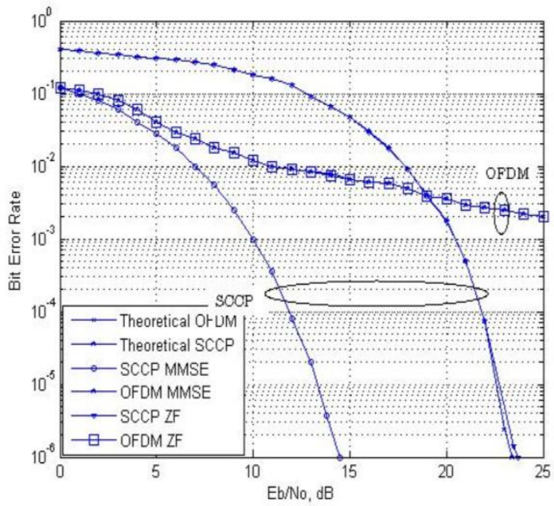

Figure 5: Channel

Conclusion

Despite some similarities between OFDM and SCCP modulation schemes, computer simulations for different PLC channels, shows that there is a great performance difference between the two modulation schemes. Results of four PLC channels shows that with the same transceiver complexity and with the signal having the same strength in the two modulation schemes SCCP outperforms OFDM in all cases, with the performance improvements as PLC channel becomes more hostile.

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References

[1] Anatory. J., Theethayi, N., and Mvungi, N. H "Power Line Channel Models: Comparisons between different Modeling Adopted in BPLC Systems", Third workshop on power line communications, 2009.

[2] Anatory. J. and Theethayi, N., "Broadband Power Line Communication Systems Theory and Application". WIT Press / Computational Mechanics, 1 Edition, 2010

[3] António, G., Paulo, T., Rui, D. and Nelson, E. "A Reduced-CP Approach to SC/FDE Block Transmission for Broadband Wireless Communications". Communications IEEE Transaction, Vol 55, No 1, 2007.

[4] Fabrizio, P., Giorgio, M., Reza, K., Naofal, A., Murat, U. and Hakam, M., "Single carrier Frequency domain Equalization", IEEE Signal Processing Magazine, 2008

[5] Neng, W., and Steven, D.B., "Comparison of CP-Based Single Carrier and OFDM with Power Allocation", IEEE Transactions on Communications Vol 53, No 3. 2005.

[6] Hyung, G.M. and David, J.G., "Single Carrier FDMA a new Air Interface for Long term Evolution" A John Wiley and Sons, Ltd, Publication, 2008

[7] Madhukumar, A. S., Francois, C., Ying-C.L. and Kai, Y., "Single Carrier Cyclic Prefix-Assisted CDMA System with Frequency Domain Equalization for High Data Rate Transmission", EURASIP Journal on Wireless Communications and Networking. 2004

[8] Pedro, P., Rui, D., and Fernando, N., "State-Space Estimation for OFDM and SC-FDE Schemes with Strongly Varying Carrier Frequency Offset", ECTI transactions on computer and information technology vol.4, no.1, 2010

[9] Torsten, L., Rainer, S., Markus, Z., Helmut, S. and Rudi, K., "Performance Study of Access Control in Power Line Communication", International Symposium on Powerline communication and its applications, 97-104, 2000

[10] Wladimir, B., Kazunori, H. and Hideaki, S., "Systematic design of single carrier overlap frequency domain equalization", Japan Systems Science, Vol 23, 50-60, 2010.