Power Line Communication (PLC) has been used for many decades, but a variety of new services and applications require more reliability and a higher data rate. Remote metering, “Smart Grid”, industrial and home automation are applications that can benefit by advanced communications techniques applied over the powerline.

The power line channel is very hostile. Channel characteristics and parameters vary with frequency, location, time and the type of equipment connected to it. The lower frequency regions from 10 to 500 Khz are especially susceptible to interference. Furthermore, the power line is a very frequency selective channel. Besides background noise, it is subject to impulsive noise often occurring at 50/60 Hz, and narrowband interference and group delays up to several hundred microseconds.

Traditional narrowband frequency-shift modulation schemes such as FSK cannot withstand group delay and narrowband interference, and therefore cannot provide a reliable transmission. A higher data rate may not be also possible using such methods. In this paper we will show how Orthogonal Frequency Division Multiplex (OFDM) can provide a robust signal and increased data rate. Further, the solution is practical and cost effective.

OFDM is a modulation technique that can utilize the allowed bandwidth of Cenelec A,B,C, and FCC very efficiently, allowing the use of advanced channel coding techniques. This combination enables a very robust communication in the presence of narrowband interference, impulsive noise, and frequency selective attenuation.

![OFDM transmit path](image)

Figure 1: OFDM transmit path

The approach as shown in figure 1 divides a user-defined bandwidth (such as Cenelec A,B,C, FCC or ARIB) into a number of sub-channels, which can be viewed as many independent BPSK modulated carriers with different non-interfering carrier frequencies.
Convolutional and Reed-Solomon coding provide redundancy bits. This allows the receiver to recover bits lost caused by background and impulsive noise. A time-frequency interleaving scheme is used to decrease the correlation of received noise at the input of the decoder.

Multi-carrier signals are generated by performing IFFT on the complex-valued signal points produced by differentially encoded phase/amplitude modulation allocated into the individual sub-carrier. As a result, carrier phase recovery is therefore not necessary, because only the relative phase difference between adjacent sub-carriers bears the information.

An OFDM symbol is built by appending a cyclic prefix to the beginning of each block generated by IFFT. The length of cyclic prefix is chosen so that a channel group delay will not cause successive OFDM-Symbols or adjacent sub-carriers to interfere. The head of the frame carries multiple preambles, which contain the synchronization sequence. A synchronizer at the receiving end detects the sequences that indicate the beginning of the data frame.

Blind channel estimator technique is used to monitor the channel variation for each data frame. If a severe change in the power line channel condition occurs, the channel estimator switches the OFDM system into a "robust" mode. In the robust mode, data is repeated four times, in addition to the convolution coding and Reed-Solomon encoder. The robust mode provides an additional 5 dB reliability in PLC data communication.

As described above, an OFDM based PLC modem offers several advantages over traditional narrow band carriers approach:

1- Higher bandwidth efficiency - enabling a data rate of 32 Kbps in the Cenelec A band compared with about 2 Kbps achievable with an FSK modem.
2- It is considerably more robust against inter-symbol interference and group delay.
3- It is more robust against impulsive noise. The described system in normal mode can communicate up to 32 Kbps at 3 dB SNR with bit error rate of 10^-4, compared with FSK which can only transmit 2 Kbps at 12 dB SNR with a bit error rate of 10^-4.
4- Robust mode of operation - allows this system an additional 5 dB better performance than it is in normal mode.