Interference in data communication over narrow-band PLC

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Summary
Interference in narrow-band PLC (Power Line Communication) is discussed in the paper. In power lines, interference greatly affects the attainable data rate and reliability. Communication rate was measured and evaluated for different media, using various facilities with special narrow-band modems for data communication. The spectrum of signals measured for different interference sources is shown and thus potential problems in communication can be inferred and the possibilities of improving data transfer in the given area of PLC can be focused on.

Key words:
Power Line Communication, communication data channels for PLC, interference on power lines.

1. Introduction

The possibilities of using communication data channels for power engineering requirements are numerous; the application of low-voltage and high-voltage power lines can be seen as an alternative to the other communication technologies currently used such as the PSTN, GSM and GSM GPRS networks. Data communication over power lines is referred to as Power Line Communication (PLC).

Services that can be provided using PLC fall into two categories, depending on the bandwidth used. Narrow-band PLC systems are mostly used in automated remote data acquisition, remote measurement, remote control, transmission from security facilities, etc. They operate at transfer rates of the order of units to hundreds of kbit/s. The respective band is from 9 to 148.5 kHz, defined by the CENELEC standard, and divided into 4 sub-bands.

The main problem can be seen in the time variance of the interference in power distribution networks in the frequency band mentioned above. The attenuation and interference levels depend in part on the loads connected, which vary with time, and in part on the line length.

2. Model of communication channel on power lines

Non-adapted impedance – from the viewpoint of data lines, power distribution networks are non-adapted lines. The input/output impedance varies with time depending on

different loads and distances, etc. The impedance ranges from mΩ to several kΩ. It is considerably lower at the point of supply node [1].

Signal-to-noise ratio – this is an important parameter of the communication system. Noise in power distribution systems is defined as the sum of many different interference types. Loads connected to the mains, TV sets, computers, vacuum cleaners, drilling machines, etc. transmit interference into power lines which then appears in the PLC receiver.

Signal attenuation – is relatively high in power lines (as much as 100 dB) and markedly limits the actual achievable range of PLC.

Fig. 1 gives a simplified block diagram of the model of PLC communication channel, in which all the above properties are comprised. Excepting noise, the interference parameters are illustrated as a time-variant linear filter characterized by impulse response. Noise is illustrated as an additive interfering random process.

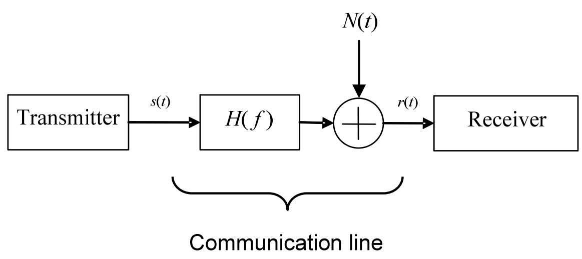

Fig. 1 General model of PLC channel.

Where:
$N(t)$ is the noise (additive interfering random process)
$H(t)$ is the channel transfer function

Although the model in Fig. 1 is much simplified, it captures the whole range of properties describing the

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model of PLC communication system with corresponding characteristics.

The transfer function and noise can thus be estimated from actual measurements or derived from theoretical analyses. The measurements on PLC channel are described in [2] and the theoretical models of power lines are given in [5].

3. Types of interference on power lines

Background colour noise. This type of noise is constantly present in the communication channel; its spectrum is uniform in the band under consideration. The noise is of stochastic nature and has a comparatively low power spectral density (PSD). This type of noise is mostly generated by commutator motors.

Asynchronous impulse interference. This type of interference is characterized by high and short voltage peaks of ca. 10 - 100µs in length, which can reach a voltage level of up to 2kV. This type of noise usually occurs sporadically and is due to various switching operations and contact switching on loads.

Periodic impulse interference synchronous with the mains frequency. This type of interference is usually caused by thyristors in the control circuits of power elements. Thyristors connect when the voltage reaches a certain level and higher harmonics of the fundamental mains frequency are generated, whose amplitude depends on the load. The level of interference mostly does not exceed 70 dBW per every harmonic [4].

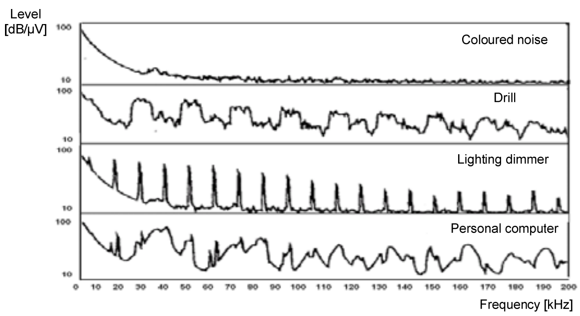

Fig. 2 Example of interference nature and level in el. mains.

Periodic impulse interference asynchronous with the mains frequency. The frequency of this interference is in no way related to the mains frequency or its higher harmonics. It contains impulses that are repeated between ca. 50 and 200 kHz. This type of interference is mostly generated by switched supply sources. Due to the high frequency, this interference affects frequencies that are close to each other and give rise to frequency groups, which are approximated by narrow bands. Also characteristic is interference of a known frequency; it appears in TV sets with the European system PAL, with a frequency of 15.625 kHz.

4. Narrow-band modems in measuring system

For the requirements of narrow-band PLC communication in various control and telemetric systems, PLC modems are manufactured in small series. Their properties are usually rather similar. The Czech company ModemTec Ltd. manufactures modems of the MT23R series. The modems are designed for data transfer over the low-voltage 230 V grid in industrial environment. The maximum data block length that can be transferred by these modems at a time is 520 bytes (320 for the MT23R1 model). MT23R modems can transfer any semi-duplex protocol; the protocol is not crucial to the response time and the maximum datagram length is 520 bytes.

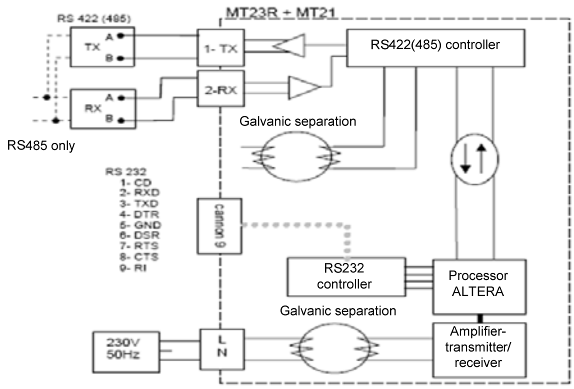

Fig. 3 Block diagram of PLC modem.

PLC modules of the MT23 series work on the one hand as data concentrators and, on the other hand, as data replicators or data communicators with a wide choice of interfaces (serial lines RS 232, 485 and 422, M-Bus lines ...) [3]. Module MT21 is a supply source for the other PLC modules and at the same time it fulfils the function of analog transmitter and receiver of data signals for the PLC network.

The block diagram of PLC modem with available interfaces is given in Fig. 3.

5. Measurement of communication between PLC modems

Using two MT23R modems, the measurement was performed on the one hand in a household with standard electrical appliances and, on the other hand, in the industrial environment of a small factory. The subject of long-term measurement was the rate of communication and interference on the low-voltage 230V/50Hz grid. Measuring the interference on power lines via evaluating the spectral lines present can indicate problems with data transfer. Another measurement carried out was therefore the measurement of spectrum on the power line where data communication was running.

5.1 Measurement of communication rate

To measure communication rate by means of PLC modems the connection according to the block diagram in Fig. 4 was used. The first PC is connected to the PLC modem by the RS232 serial line, the other PC is connected via Ethernet to the Gnome 232 converter and then via the RS232 serial line to the PLC modem. The Ethernet/RS232 converter was used to enable long-term monitoring of the transfer rate at regular intervals, using the “Interface traffic indicator” program. This software monitored the communication and every fifteen minutes it recorded the current transfer rate. In the household environment, the modems were connected over a distance of 150m.

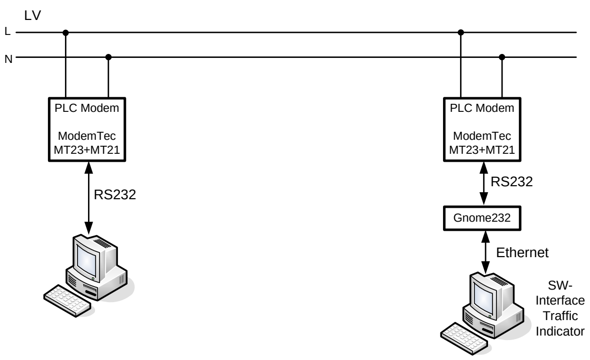

Fig. 4 Block connection for communication rate measurement.

The measurement result is given in Fig. 5, where it can be seen that the transfer rate is ca. 4.5kbit/s. At ca. 10 a.m. and 4 p.m. the transfer rate increased to over 5kbit/s. A possible explanation is that this is due to the change in the load of electrical grid within one supply node, as suggested by the waveform of 24-hour load provided by the power distribution company. But this has not been proved unambiguously and further examination is therefore necessary.

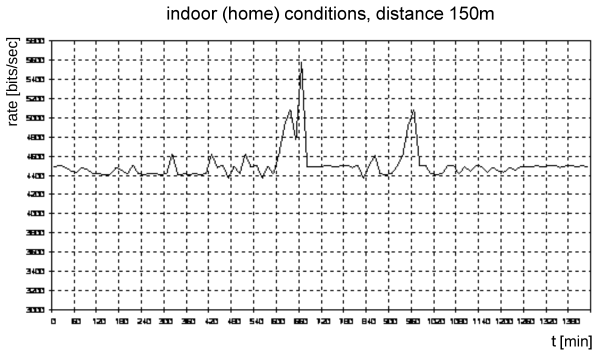

Fig. 5 Transfer rate of PLC communication in household environment, distance about 150m.

The same measurement was conducted in an industrial environment. The modems communicated over a distance of 100m. This environment included machines with programmable logic control, stepping motors with control units, and several frequency converters. The average communication rate obtained is approximately 6.5kbit/s, as can be seen from Fig. 6.

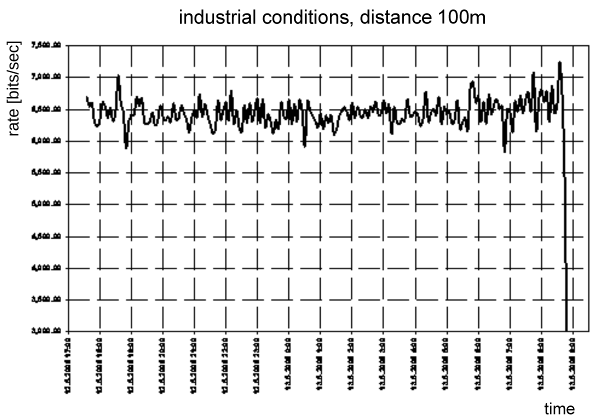

Fig. 6 Transfer rate of PLC communication in industrial environment, distance about 100m.

5.2 Measurement of communication signal spectrum

To measure the spectrum of communication channel, a Tektronix DPO4032 digital oscilloscope was used in combination with the Tektronix P5205 high-voltage differential probe. The connection of the measuring system is shown in Fig. 7.

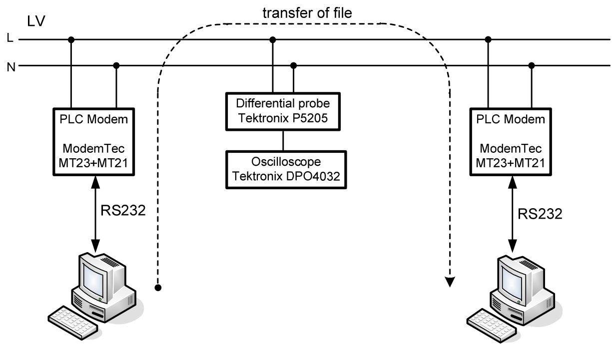

Fig. 7 Block diagram of connection for measuring communication signal spectrum.

For signal conversion from the time domain to the frequency domain on the 230V/50Hz grid the Fast Fourier Transform (FFT) of the DPO4032 oscilloscope was used. The result of measuring the signal spectrum with the communication turned off and with the test data file being transferred over the PLC network is shown in Fig. 8.

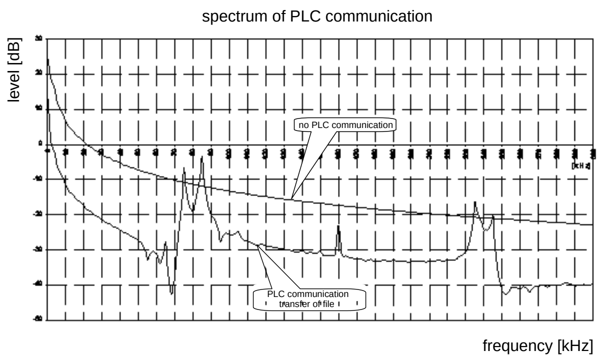

Fig. 8 Communication channel spectrum without and with PLC communication.

In the course of PLC communication, at the beginning of data transfer over power lines, a high level of the signal is apparent (at 50 Hz) and later a higher level at about 80 kHz. In the region of this frequency the communication of PLC modems takes place. Higher signal levels near the 160 kHz and 240 kHz frequencies are evidently the 1st and 2nd harmonic components of PLC signal. At about 80 kHz there are two peaks, at frequencies of 75 and 85 kHz, that is to say 2 channels (signals Rx and Tx). These frequencies correspond to sub-band “A” according to the CENELEC standard. Frequency shift keying (FSK) is used for modulation [2]. FSK is a robust modulation method that can be used even if the signal phase and attenuation are unknown. However, the signal attenuation must be constant throughout the communication bandwidth. A disadvantage of FSK is the little exploitation of the bandwidth. But this is not a major problem in the case of narrow-band PLC with its small volume of transferred data.

5.3 Measurement of interference on electric power grid

For the measurement of interference on the 230V/50Hz grid the same connection as in the measurement of signal spectrum (see Fig. 7) and the calculation function of the FFT oscilloscope were used. In this case, however, averaging could not be used and therefore the waveform envelope was detected.

The result of the measurement, given in Fig. 9, again shows the course of communication in the bands of 80kHz and the higher harmonic 160kHz. It is evident that without artificial interference the noise level is the lowest. When a drilling machine with commutator motor was turned on, the noise level increased by ca. 10dB. When a PC was turned on, an envelope was detected that again indicated an increased level of around 80kHz and 160kHz. This is evidently due to the fact that a voltage came to be applied to the COM port of the computer that was transferred as a logic level over the PLC network.

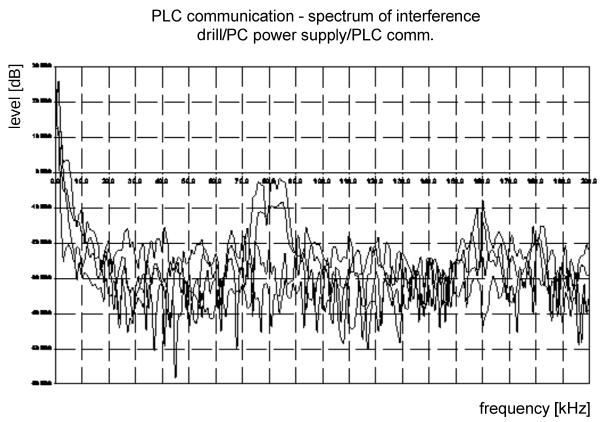

Fig. 9 Example of interference spectrum on power distribution system.

6. Conclusion

Some of the problems encountered in current PLC technologies are discussed in the paper. Measurements were conducted in order to assess the potentials of data communication over power lines. The measurements were carried out in two different environments, namely industrial environment and household environment, where the technology of narrow-band PLC for remote reading and grid control is expected to be deployed. The results have been documented and analyzed. It can be seen that under certain conditions this technology can be used for remote data acquisition and control of power grid elements. The main problem will evidently be the actual range of data communication. It follows from other measurements that this communication is possible over a distance of several hundred metres. In the measurements mentioned above, a distance of some 100-150m was therefore chosen and thus the measurements were not too much affected by attenuation. As can be seen from works by other authors, it will obviously be necessary to focus more on proposing suitable mathematical models of power lines from the viewpoint of data communication. It will then be possible to computer-simulate phenomena on power lines and thus improve the properties of this technology.

Acknowledgments

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