Data Transmission Via Power Line For Lighting Point Monitoring System

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Abstract: The paper deals with a data transmission via the power line. This data transmission is designed for applications where other wire oriented data transmission and radio data transmission is not possible. It is possible to use an ASK or an FSK digital modulation for data transmission via power line. The paper describes advantages and disadvantages of individual digital modulations. A practical use of the data transmission is shown in conclusion.

Key-Words: power line communication, lighting point monitoring, FSK modulation, very noisy communication environment

1 Introduction

The proposed data transmission is primarily designed for the transmission of short protected data messages between a base station and each lighting point in the frequency band from 60 to 135 kHz. The master communication unit is located in a switch board and the slave unit in each of the street lighting lamp. The MLP (Monitoring of Lighting Point) has been designed for the maximum disturbance resistance. The communication medium is the power line for power supply of the street lighting lamp. This solution less expensive then the other communication methods, e.g. radio communication.

2 Power line communication system

This method is well known and is used for data transmission for a some years. But street lighting is very special system with many sources of disturbance which makes the classic methods of power line communication practically unusable.

The communication used in MLP system is based on half duplex with one master unit and many slaves units. The principle scheme of transmitting and receiving part is shown in Fig. 1.

The transmitting part is composed by a modulator, amplifier and coupling circuits. The coupling circuits separate the low voltage modem and the high voltage parts of the power line. The amplifier has electronically controlled gain because the output power must be limited according to proper standards (e.g. 50mW / 50Ohm for the Central Europe).

The receiving part consists of coupling circuits, amplifier and coupling circuits. Coupling circuits include tuned filter for suppression of disturbance. The amplifier guarantees the level of high frequency signal needed for errorless demodulation.

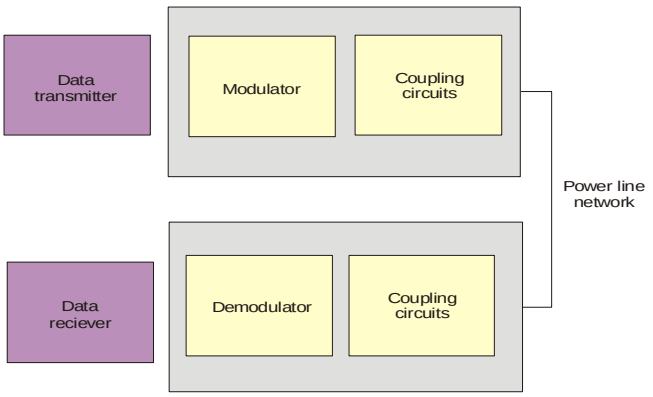

Fig. 1 Power line communication system

The modulator and demodulator use the same integrated circuit. A specific type depends on used digital modulation and will be discussed in subsequent sections, which deal with the ASK and FSK digital modulation.

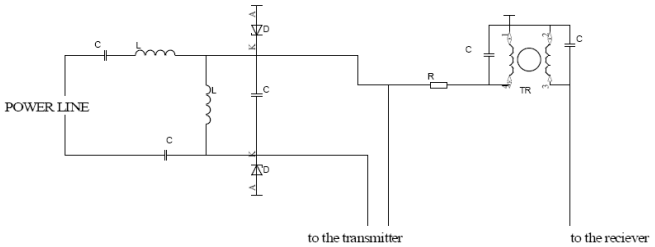

Fig. 2 Coupling circuits

In the present is FSK modulation used exclusively. The reasons will be discussed in subsequent section.

3 General description of properties of the communication medium

According to practical specifications the power line which supplies the street lighting lamps is used as a communication medium.

In view of data transmission is power line a telecommunication line with its primary and secondary properties. In view of the carrier frequency is typical power line with length up to 700m is approximate a quarter wave line. But all scientific knowledge about lossless homogenous line is in this case unusable because the power line is non homogenous and the parameters are changing in time.

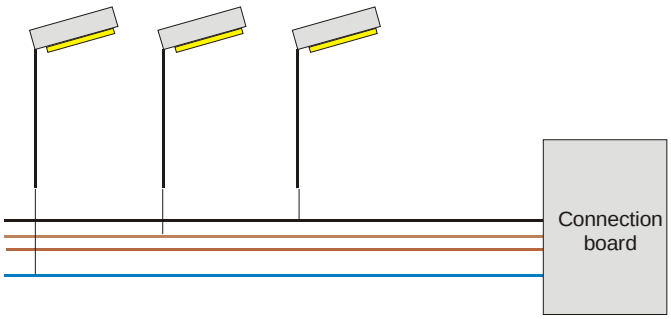

Fig. 3 Connection of the street lighting lamps

In Fig. 3 is shown typical power line with street lighting lamps. The power line is generally designed as a three-phase line. The lamps are connected alternately to all of the phases through the distribution of the power on the line. The lamps are located approximately equidistantly on the power line cable. So the location of the lamps is the main reason for the non - homogeinity of the power line because each of the lamps locally corrupts the properties of the line.

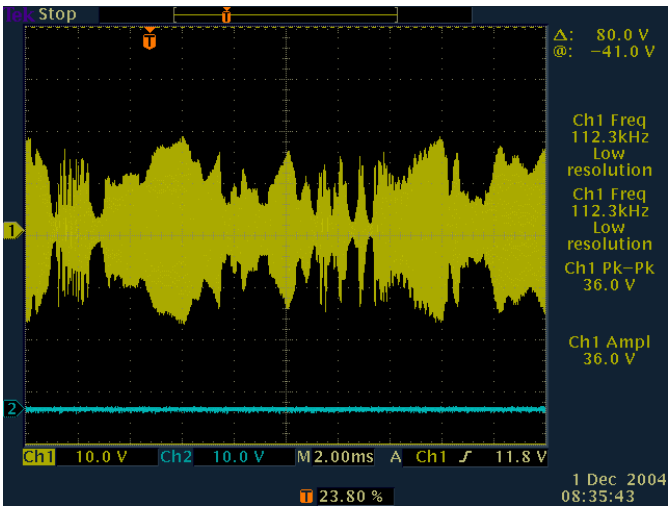

Fig. 4 Carrier frequency in distance 750m from the connection board

The waveform of the current is considerably non - harmonic. The dynamic process causes considerable changes of the characteristic impedance of the line. In Fig. 4 is shown the waveform of the carrier frequency in the slave communication unit at the output of the coupling circuits. The changes of impedances in conjunction with the frequency properties of the input circuits of the slave communication units cause oscillating of the carrier frequency on the line.

4 Experience with ASK modulation

The modulator/demodulator is represented by the Philips TDA5051A – Home Automation ASK modem, whose parameters define properties of whole transmission system. The modem use ASK (Amplitude Shift Keying) digital modulation. As the communicated bit rate of the modem is not given by the manufacturer, the bit rate and the bit synchronization have to be guarantee by an additional microprocessor.

After many experimental measurements, we determined usable communication bit rate of approximately 1200 bps for power line communication.

From the previous section is obvious that the impedance changing modulate the signal so the ASK method cannot be used without changes in the street lighting system.

The power line for using of ASK must be suitably adjusted. This is the main disadvantage of this method. Because the changes of the impedance depend especially on the waveform of the current consumed by the lamp it is necessary to eliminate pulses and make the waveform more harmonic. In Fig. 5 is shown scheme of the lamp. The capacitor is used for compensation of the voltage character which has due to inductor inductive form. The main source of the disturbance and impedance changes is the capacitor. For possibility of using the ASK method must be all the capacitors removed from the lamp and the compensation must be achieved centrally, on the connection board.

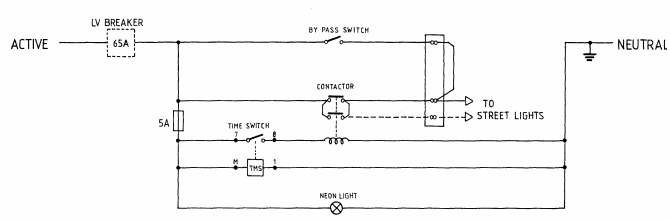

Fig. 5 Scheme of the street lighting lamp

By accomplishment of this condition ASK method is usable and the maximum communication distance is up to 700m (system with 30 lamps per cable).

But not in all the cases this solution can be used, e.g. only a few of the lamps has to be monitored and it is

not possible to remove the capacitors from the other lamps (this case is in praxis very frequent).

5 Experience with FSK modulation

With the FSK has our team very nice results. On the testing ground with 26 lamps we reached on the end of the cable (approximately 1000 m).
The main disadvantage of the ASK method, dependence on the parasitic amplitude modulation due to impedance changes, is eliminated by using of the frequency shift keying digital modulation (FSK).
General is possible to say that FSK is more robust to disturbance and parasitic modulation than ASK.
The basic device of the modem using FSK is the intelligent modem ST7538 from SGS Thomson Corporation. This device is preliminary designed for home power line modem applications. The most properties of the modem are controlled by the internal registers. It can operate at 8 frequencies in frequency band of 60 to 132.5 kHz. The bit rate can be chosen in 4 steps: 600 bit/s, 1200 bit/s, 2400 bit/s and 4800 bit/s. The maximum output amplitude of the carrier frequency is 6 Volts, but due to standards we use smaller amplitude. The receiving sensitivity is better than 1 mV RMS.
We communicate at 4 different frequencies (60, 86, 110 and 132.5 kHz), most on 110 kHz. The used bit rate is 4800 bit/s, but the real bit rate is smaller due to security of the message.

6 The form of the communication

As described above the FSK is more robust but the disturbance in street lighting networks is huge so the transferred messages must be secured and transmitted in parts.
The system is able to locate the best moment for communication when the disturbance is smallest. This moment is different day to day and location to location. It is not possible to easy define the best moment for transmitting and receiving. We have analyzed the course of the disturbance from up to 20 networks of street lighting systems and designed an algorithm which works very well.

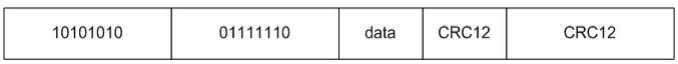

Fig. 6 Example of suitable structure of the data frame

The structure of the transferred data is shown in Fig. 6. We use the synchronous transmission between master and slave station. The designed structure of the transmitted data preserves criterions for to obtain the reliable data transmission in very noisy environment:

- Each frame starts with a synchronizing sequence of "01010101b" that is transmitted in the time when the transmitter waits for the best moment for the transmission.
- An 8 bit start mark "01111110b" follows the synchronizing sequence. The start mark serves as unique identification of the frame start.
- The data transmitter ensures a bit transparency that prevents the presence of the start mark "01111110b" inside the frame.
- The frames are as short as possible, consisting of the necessary number of information bits and protection bits.
- Data protection of information bits is at least 12 bits (CRC12); it has no ability to correct error bits (self-correcting code causes unacceptable redundancy).
- The frames are transmitted in fast succession; there is only very short time delay between the frames.
- The message is divided into smaller parts because the above mentioned "best moment" is no longer then 2 ms.
- The real transfer bit rate is approximately 200 bit/s.

It is sufficient to transfer 12 information bits in our tested experimental application. The structure of the message and sub - messages is shown in following Fig. 7. The point of the wasted sequence is to fill the time the system is waiting for the "best moment".

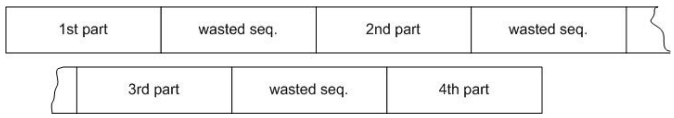

Fig. 7 Example of the structure of the message

7 Practical use of the described data transmission

The power line data transmission offers use for obtain information from up to 256 lamps, for example. In our application is transmitted information about:

- state of the lamp (shining / not shining),
- end of the life of the lamp tube,
- state of the capacitor,
- command for lamp shut down,
- commands for an intelligent regulator.

The described method is in present time tested in a location with 90 lamps. In each of the lamp is installed a small communicator and in connection box is master communication unit. The data collected from each of the lamps are transmitted via radio modem to a control centre - dispatching.

Meanwhile we have found out some problems which are in present time solved:

- Propagation of the carrier frequency into the distribution network and following interference of systems in contiguous street lighting networks. We are testing data transmission in different frequency bands. This method requires consequent planning of using given frequency bands.
- Using in street lighting networks with lamps with power of 250 Watts and above. The disturbance in this system is so intense that the "best moment" is shorter than 1 ms and this time is not sufficient for exact data transmission. We are trying to eliminate disturbance using noise-suppressing filters. This way is possible but needs service intervention.
- Distances over 1000 m. The repeater must be used. Each of the slave communicators can be used as a repeater. It is only the software question.

8 Conclusion

The described mean of data transmission is usable in all noisy environments no matter what communication medium is used. According to concrete conditions must be changed the algorithm for determining the best moment for data transmission. However the adjustment of the determining algorithm can be done not until a complete and exact analysis is finished. In our case measurements and analysis of transmission conditions consumed 2 years of researching in terrain conditions and 6 months of testing and tuning of the designed algorithm.

References:

[1] SGS-THOMSON - Power Line Modem & Applications data book - September 1994;

[2] CENELEC, European Committee for Electrotechnical Standardization - EN 50065-1, Signaling on lowvoltage electrical installations in the frequency range 3 kHz to 148,5Khz. Part 1: General requirements, frequency bands and electromagnetic disturbances - July 2001

[3] CENELEC, European Committee for Electrotechnical Standardization - EN 50065-4-2, Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148,5Khz. Part 4-2: Low voltage decoupling filters- Safety requirements - August 2001

[4] CENELEC, European Committee for Electrotechnical Standardization - EN 50065-7, Signaling on lowvoltage electrical installations in the frequency range 3 kHz to 148,5Khz. Part 7: Equipment impedance - November 2001

[5] CENELEC, European Committee for Electrotechnical Standardization - prEN 50065-2-1, Signaling on low-voltage electrical installations in the frequency range 3kHz to 148,5Khz. Part 2-1: Immunity requirements for mains Communications Equipment and systems operating in the range of frequencies 95 kHz to 148,5 kHz and intended for use in Residential, Commercial and Light Industrial Environments - 1999

[6] IEC, International Electrotechnical Commission, International Special Committee On Radio Interferences - CISPR 16-1, Specification for radio disturbance and immunity measuring apparatus and methods. Part 1: Radio disturbance and immunity measuring apparatus - first edition, August 1993

[7] EHSA, European Home System Association - EHS specifications, version 1.3a - May 2001

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