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ANALYSIS OF DATA TRANSMISSION SYSTEM USING TDA5051

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Abstract- The objective of the study was to find a solution for a cheap and reliable data transmission system over the power line of a standard industrial power grid 220V for the implementation of projects of sensor and actuator local networks. The article considers the option of building a PLC path based on a ready-made solution using the TDA5051 modem chip from NXP Semiconductors. This modem uses ASK 1200 baud modulation. To test the operation of the PLC, prototypes of modules based on the STM32F103 microcontroller was assembled. The modem microcircuit adequately generates the carrier frequency signal, while the envelope filter is noticeable, and reduces the level of out-of-band emissions. Under ideal conditions, communication between communication modules was relatively stable, the share of lost packets was 11%. When testing communication in a real power grid, the attempt to transfer data was unsuccessful, the percentage of lost packets was 100%. Revealed very low noise immunity. The interference from the built-in power supply, based on the LNK306, was enough to completely interrupt communication. Another power supply plugged into the network also interrupts the communication.

Keywords: Power Line Communication, TDA5051, Interference, Amplitude Shift Keying.

1. INTRODUCTION

The authors of the article set the goal of the study - to find a cheap and reliable solution for a data transmission system over power lines.

The data transmission system must operate over the existing standard industrial electrical network 220V for the implementation of projects of sensor and actuator local networks.

Currently, data transmission systems are replete with technology and protocols, shown in Table 1.

Each of the technologies is aimed at solving its own narrow problem, with unique advantages. Therefore, there is no uniform standard in the industry.

For the purpose of this study, low-speed narrowband technologies are of greatest interest. Identifying solutions in such a heterogeneous and wide area is difficult, consisting of many uncertainties and variables.

One of the main challenges is the multitude of communication technologies and protocols currently available [2]. Most modern systems are proprietary solutions from individual vendors that only operate within their own ecosystem and cannot communicate with each other. This can lead to a future blockage situation, which is an additional risk to the infrastructure of any facility.

Table 1. Power line communication technologies classification [1]

	Low speed narrowband	High speed narrowband	Broadband
Frequency range	9-148.5 kHz	9-500 kHz	1.5-50 MHz
Transmission speed	< 10 kbps	50 kbps<…<1 Mbps	> 10 Mbps
Technology [13]	FSK, BPSK, QPSK, 8PSK, ROBO, MSK, FFH, SFSK, DCSK, ASK, CPFSK	QAM, OFDM, MCM, differential coding	MCM, COFDM, Bit loading
Forward Error Correction (FEC)	Low	High	Average
Appointment	Automatic measurements and equipment management	Equipment management, Smart Grid	Last mile, Internet, VoIP, HDTV
Distance		Up to 30 km	Up to 3 km

Research in the field of data transmission using the power grid (PLC) has been going on for a long time [3]. Previously, the use of PLCs was hampered by low data transfer rates and insufficient immunity from interference. The development of microelectronics and the creation of modern and, above all, more efficient processors, made it possible to use complex modulation methods for signal processing, which made it possible to significantly advance in the implementation of PLC [4-8].

PLC technology uses electrical networks for high-speed data transmission and is based on the same principles as ADSL, which is used for data transmission over the telephone network. The operating principle is as follows: a high-frequency signal is superimposed on a regular electrical signal using various modulations, and the signal itself is transmitted through electrical wires. The equipment can receive and process such a signal over a considerable distance.

PLC is the only wired technology that is comparable to wireless in terms of deployment time and cost.

The article considers the option of building a PLC path [9] based on a ready-made solution using the TDA5051 modem chip from NXP Semiconductors [10], shown in Figure 1. This modem uses ASK 1200 baud modulation.

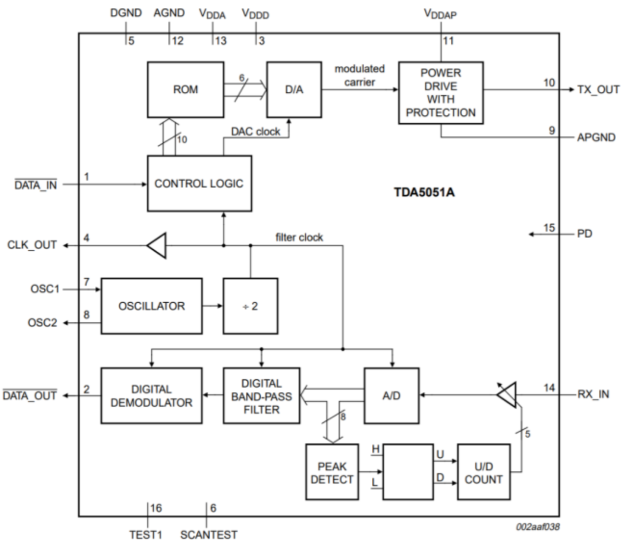

Figure 1. Block diagram microcircuit TDA5051 [9]

2. REQUIREMENTS FOR THE PLC PATH

It is necessary to evaluate a particular technology to create a data transmission network. To do this, we will formulate the main technical requirements:

1. Network topology is a common bus.
2. The PLC path must ensure uninterrupted data transmission over a distance of one kilometer.
3. Many other devices in the power supply line are allowed, including those incompatible with the projected PLC system.
4. To minimize command transmission delays in an intelligent control system, the data transmission rate should not be lower than 1200 bit / s [10].
5. Since the line can contain devices that create interference in a wide frequency range, the PLC path must ensure data transmission with a poor signal-to-noise ratio.
6. The carrier frequency of the PLC signal must be between 95 and 148.5 kHz.

Requirements for the carrier frequency of the PLC signal are regulated based on the requirements of interstate standards [11]. Such standards are in force on the territory of the Eurasian Union.

This range is allocated to a user reserve and does not require licensing. The frequency ranges allocated for narrowband PLC communications in other regions of the world are shown in Table 2.

Table 2. The frequency ranges allocated for narrowband PLC communication in different regions of the world [12]

Region	Regulatory authority	Frequency band, kHz	Notes
Europe	CENELEC	95-125	user reserve
		125-140	user reserve, reg. CSMA access
		140-148.5	user reserve
Japan	ARIB	10-450	
China	ERPI	3-500 (3-90)	Unregulated
USA	FCC	10-490	

3. MODEM BASED ON TDA5051

To test the operation of the PLC path based on the TDA5051 microcircuit, prototypes of communication modules were assembled, one of which is shown in Figure 2.

Figure 2. Communication module based on TDA5051

The communication module contains a power supply, a voltage regulator, an STM32F103 microcontroller, a TDA5051 microcircuit with filters and an isolation transformer, and a load control circuit. The block diagram of the communication module based on TDA5051 is shown in Figure 3.

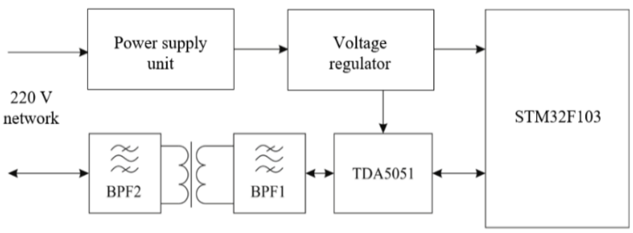

Figure 3. Block diagram of the communication module based on TDA5051

The power supply converts the voltage of the 220V network into a constant voltage of +12V. The voltage stabilizer lowers the +12V voltage to stabilized +5V, which is necessary for the operation of the microcontroller and the modem microcircuit.

The STM32F103 microcontroller executes the control program, generates test data packets for transmission, and controls the correctness of data receipt. The TDA5051 microcircuit generates an ASK signal based on the data received from the microcontroller, and also receives and demodulates the incoming signal from other transmitters.

An isolation transformer is required to isolate the modem circuit from the mains. Filters BPF1 and BPF2 are necessary to prevent the penetration of parasitic harmonics of the generated signal into the mains, as well as to block out-of-band interference from the mains to the receiver input.

The schematic diagram of the connection and strapping of the modem microcircuit is made according to the technical documentation and is shown in Figure 4.

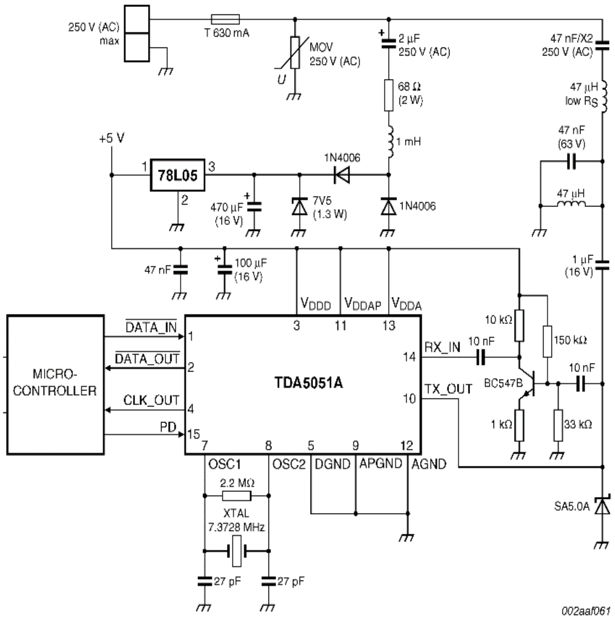

Figure 4. TDA5051 switching circuit [9]

4. TESTING THE OPERATION OF A MODEM BASED ON TDA5051

Testing was carried out under both ideal conditions and real power grid conditions. A test bench was assembled, the diagram of which is shown in Figure 5.

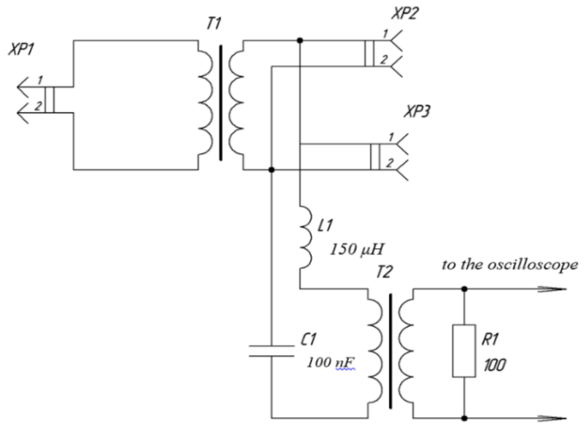

Figure 5. PLC communication test bench

The stand consists of an XP1 mains plug, two XP2 and XP3 sockets, an isolation transformer T1 with a 1:1 transformation ratio, a carrier filter formed by L1 and C1, and a high-frequency transformer T2 for connecting an oscilloscope.

At the first stage, the correctness of the formation of the carrier frequency signal and its quality were checked. The oscillogram and spectrum of the signal are shown in Figure 6.

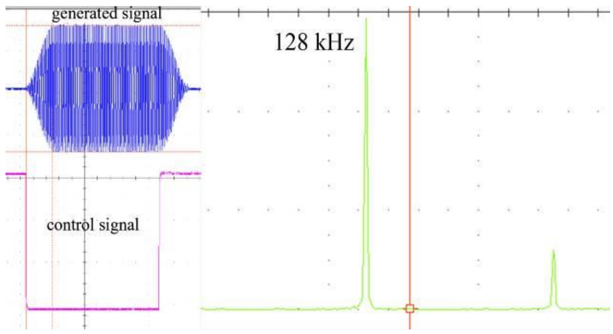

Figure 6. Signal generated by the TDA5051 microcircuit and its spectrum

The oscillogram shows that the modem microcircuit adequately generates the carrier frequency signal, while the operation of the envelope filter, which reduces the level of out-of-band emissions, is visible. Some delay of the generated signal relative to the control one can be noted.

At the second stage, the correctness of transmission of long bit sequences was checked. Figure 7 shows the PLC signal in the mains when transmitting the bit sequence 00000000101111111100101010110101010101 (0x00FF55AA).

The oscillogram clearly shows the deep parasitic amplitude modulation of the PLC carrier signal, caused by a periodic change in the impedance of the mains, which can lead to negative consequences during signal demodulation. In this test, data was transferred between communication modules relatively steadily; the share of lost packets was 11%.

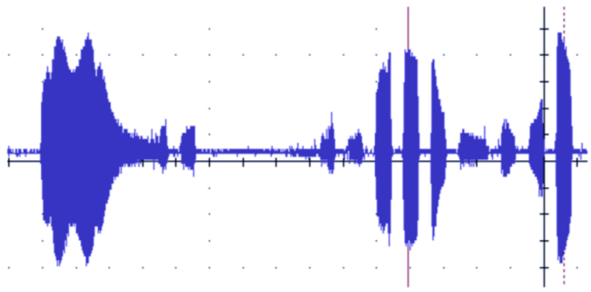

Figure 7. PLC signal in the mains when transmitting a sequence of bits

The next step was testing the modem in real conditions. A network with switched on electrical appliances, including impulse power supplies, was used as a real power grid. An attempt was made to transmit data over a distance of 10 meters.

When testing communication in a real power grid, the attempt to transfer data was unsuccessful, the percentage of lost packets was 100%. The oscillogram of a high-frequency signal in a real power grid is shown in Figure 8.

It is impossible to identify the PLC signal in this oscillogram, which can be explained by the high level of noise. In the demodulated signal at the output of the receiver microcircuit, it was possible to distinguish fragments of transmitted packets, but whole packets did not reach.

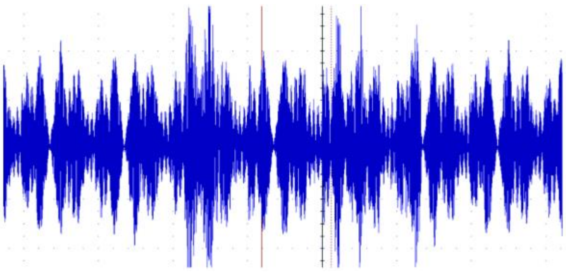

Figure 8. PLC signal in real power grid conditions

Revealed very low noise immunity. The interference from the built-in power supply, based on the LNK306, was enough to completely interrupt communication. Another power supply plugged into the network also interrupts the communication.

Thus, even under ideal conditions, with the boards powered by batteries and switched off electrical appliances, communication did not show 100% of the result at a distance of 10 meters. At the same time, in the worst conditions, there is no communication even when the modules plug into the same outlet.

5. CONCLUSIONS

During the experiments, possible types of interference that affect the PLC signal were analyzed, which led to the conclusion that the main type of interference is multiplicative interference, which uncontrollably rotates the phase of the signal and its amplitude.

In this regard, the use of amplitude modulation technology is ineffective to build a smart grid over power lines. When testing communication in a real power grid, the attempt to transfer data was unsuccessful, the percentage of lost packets was 100%.

For further research, from the available types of modulation, continuous phase frequency shift keying (CPFSK) was chosen as the most insensitive to multiplicative interference.

NOMENCLATURES

1. Acronyms

PLC	Power Line Communication
FSK	Frequency Shift Keying
BPSK	Binary Phase Shift Keying
QPSK	Quad Phase Shift Keying
8PSK	Eight Phase Shift Keying
ROBO	Robust Operation
MSK	Minimal Shift Keying
QAM	Quadrature Amplitude Modulation
FFH	Fast Frequency Hopping
SFSK	Sinusoidal Frequency Shift Keying
DCSK	Differential Code Shift Keying
OFDM	Orthogonal Frequency Division Multiplexing
ASK	Amplitude Shift Keying
MCM	Multi Carrier Modulation
COFDM	Coded Orthogonal Frequency Division Multiplexing
FEC	Forward Error Correction
VoIP	Voice over Internet Protocol
HDTV	High Definition Television
CPFSK	Continuous Phase Frequency Shift Keying
CENELEC	European Committee for Electrotechnical Standardization
ARIB	Association of Radio Industry and Business
EPRI	Electric Power Research Institute
FCC	Federal Communications Commission
CSMA	Carrier Sense Multiple Access
USA	United State of America
BPF	Berkeley Packet Filters

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BIOGRAPHIES

Vasily Yakovlevich Ushakov was born in Kazakh SSR, on March 27, 1939. He graduated from Faculty of Electricity, Tomsk Polytechnic Institute, Tomsk, Russia, in 1962. He received Candidate of Technical Sciences in 1965, and Doctor of Technical Sciences in 1973. From 1974 to 1981 he was a Professor, Head of the Department of High Voltage Engineering. Simultaneously, from 1979 to 1992 he was the Director of the Research Institute of High Voltage at Tomsk Polytechnic Institute. In 1986 to 1991, he was Head of the Department of Electrical Systems and Networks of the same institute. In 1992-2001 he was Vice-Rector for scientific work of Tomsk Polytechnic University. In 2001, he created and headed the Regional Educational, Scientific and Technological Center for Resource Saving at the same university (2006-2010). At the same time, he was the head of the newly created department "Electric power systems and high-voltage technology". He is the founder of the Tomsk Scientific School in the field of insulation of high-voltage electro physical installations. He and his students made a significant contribution to the study of the nature of electrical breakdown of liquid dielectrics and electrical aging of polymer insulation, to the development of the engineering foundations for the design of the most important elements of high-voltage pulse installations.

Seidamet R. Suleimanov was born in Temirtau, Kazakhstan in 1990. He received a master's degree in power engineering at Karaganda State Technical University, Kazakhstan. Currently, he is a postgraduate student at the National Research Tomsk Polytechnic University, Russia. From 2011 to 2019 he worked at the Karaganda State Technical University in the positions of assistant lecturer and lecturer. From 2012 to the present, he participates in six research projects and technology commercialization projects. His area of interests are electronics, power engineering, automation, implementation of innovative developments in production and everyday life.

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