Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University

Faculty of Computer Information System and Software Engineering
(full name of faculty)

Department of Computer Science
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QUALIFYING PAPER

For the degree of

Bachelor
(degree name)

topic: The method of organizing data exchange on one communication channel based on TDM technologies

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	(signature)	Nwankwo Francisca Ezinwanne (surname and initials)
Supervisor	(signature)	Dozorskyi V.G. (surname and initials)
Standards verified by	(signature)	Matsiuk O.V. (surname and initials)
Head of Department	(signature)	Bodnarchuk I.O. (surname and initials)
Reviewer	(signature)	(surname and initials)

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Faculty Faculty of Computer Information System and Software Engineering
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Department Department of Computer Science
(full name of department)

APPROVED BY
Head of Department
__________ Bodnarchuk I.O.
(signature) (surname and initials)
« » 20___

ASSIGNMENT
for QUALIFYING PAPER

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Student ____________ Nwankwo Francisca Ezinwanne
(signature) (surname and initials)

Paper supervisor ____________ Dozorskyi V.G.
(signature) (surname and initials)

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In the qualification work, the justification of the method of organizing data exchange on one communication channel based on TDM technologies was carried out. The problem of multi-channel data exchange over a wireline network and methods of increasing the bandwidth of such a network and data transmission speed are analyzed. Time and frequency compression methods are considered. The method of time compression of signals during the organization of data transmission over the power supply network, which is present in every house or office, is considered. In this case, it is not necessary to lay new cable networks. The features and technical parameters of such networks, their advantages and disadvantages are analyzed. A method for multi-data exchange PLC-networks using the method of time division multiplexing (TDM) is grounded. The operation of the TDM method was also modeled on the example of the transmission of eight signals over one network.

Keywords: Time Division Multiplexing, PLC-network, reception/transmission data, multiplexer.

CONTENT

INTRODUCTION

Today, the most common data exchange lines are lines using standard optical fiber. At the same time, systems with time compression of channels are often used. It is possible to increase the bandwidth of such systems by developing and using new ultra-fast electronic systems of modulation, switching and reception of laser radiation, which will naturally lead to the replacement of the final equipment. Such innovations require large financial costs for organizations engaged in the operation and conversion of such communication lines. But in order to increase the bandwidth, only the replacement of the terminal equipment is not enough, it will also be necessary to install unmaintained relay points and insert all kinds of compensators, and even more so, to replace the cable, which in turn is quite uneconomical.

Traditionally, the problem of connecting electronic devices without laying new cable networks has been solved with the help of radio air - that is, various wireless connection technologies. However, a promising way of creating a cable network is the organization of data transmission through the wires of the power supply network using the so-called PLC technologies (Power Line Communications), since, with the coverage that power transmission networks have, the bandwidth in them is used very inefficiently - alternating current to consumers transmitted only at a frequency of 50-60 Hz, while the frequency bands of the higher range remain free, in contrast to the strictly regulated radio air. All that has been said determines the prospects for the development and practical implementation of PLC technologies.

However, a significant drawback of PLC technologies, which slows down their spread, is the inability to withstand the effects of household electrical interference. In addition, the extensiveness of the transmission environment and the influence of interference significantly limit the speed of information exchange, but, given the width of the available spectrum, this problem is practically solved with the help of high-performance signal processors by dividing data stream into several parallel ones and transmitting them through different channels.

In this case, it is promising to use the method of data exchange over one communication channel based on time compression technologies. It is this method that is considered in this thesis.

CHAPTER 1
ANALYSIS OF THE PROBLEM OF DATA EXCHANGE THROUGH ONE COMMUNICATION CHANNEL

1.1 The problem of data exchange over one communication channel and methods of increasing throughput

It is important to ensure the possibility of data exchange through a single communication channel without the laying of leading networks. In particular, this is important when implementing smart home technologies. The laying of new mains networks involves installation work that will affect the appearance of the interior and can often distort it. The use of wireless networks requires expensive equipment and does not always provide reliable coverage quality. At the same time, it is important to ensure the necessary network bandwidth for the possibility of connecting various intelligent devices of a smart house, like an alarm system, climate control, computer equipment, etc. In this case, it is possible to use an already laid network that was not originally intended for data exchange. This is, for example, the electrical network of a house or office. However, due to its difference from computer cable networks, the issue of bandwidth of such a network is also important.

The following main methods of increasing the bandwidth of the data exchange channel are distinguished:

1) Time multiplexing (TDM) method. The essence of TDM: the transmission process is divided into a number of time cycles, each of which in turn is divided into N subcycles, where N is the number of compressed channels. Each subcycle is divided into time positions (time slots), during which part of the information of one of the multiplexed digital streams is transmitted. In addition, several positions are allocated for identification synchronous pulses, inserts and digital flow of service communication. With time multiplexing, each of the information channels of the system, which have a common carrier (one radiation source), is assigned a certain

time interval or time window for information transmission. In the first time interval, the carrier is modulated by the signal of one information channel, in the second by another, etc. The duration of these intervals is determined by various factors, in particular the speed of transmission in the communication line.

As shown in Fig. 1.1, there is a time multiplexer on the transmission part, it sets the sequence and time interval of transmission at the input of the line. On the other side of the line, a demultiplexer is installed that determines the channel number, identifying it.

The TDM method is divided into two types - asynchronous (plesiochronous) and synchronous time multiplexing. Accordingly, the plesiochronous PDH digital hierarchy and the synchronous SDH.

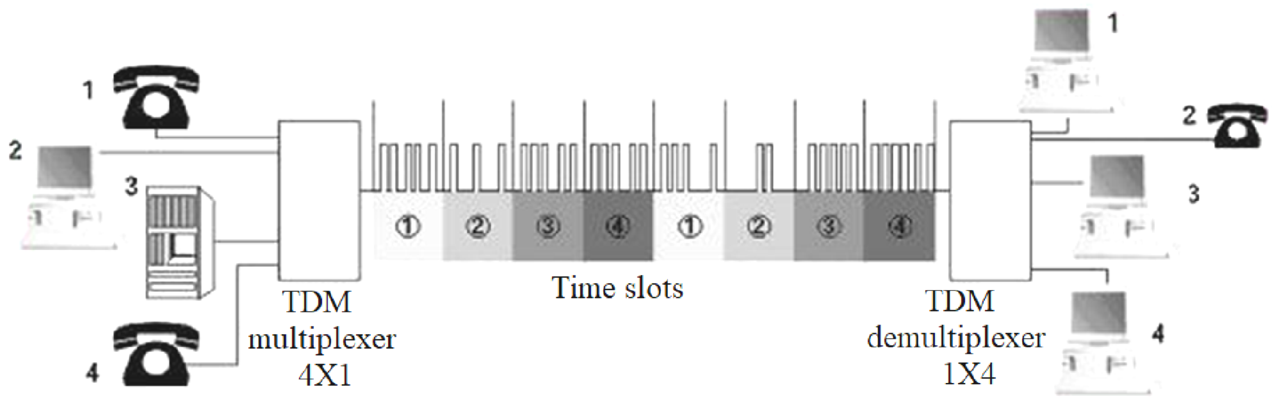

Figure 1.1. Scheme of signal transmission over a network with TDM time multiplexing

The structure of the primary network determines the unification and division of the transmitted information flows, therefore the transmission systems used for this purpose are built according to the hierarchical principle. With regard to the digital transmission system, this principle consists in the fact that the number of channels of such a system corresponding to a given level of the hierarchy is greater than the number of channels of the digital transmission system of the previous level by a whole number of times.

2) The method of spectral compression (WDM). The WDM method allows you to increase the transmission speed in the network due to the simultaneous

transmission of several TDM channels on different wavelengths over the network. In WDM systems, the end electronic equipment has the same requirements as in TDM systems, for other equipment bandwidth is limited only by channels. The full bandwidth of the communication line is not limited by the bandwidth of the electronic components used. If necessary, the required bandwidth is achieved by adding/removing carriers. Each data channel formed by a digital transmission system is processed in a WDM system as a separate channel of a separate wavelength.

The essence of this method is that k information digital streams (their number can be 2, 4, 8, 32..i..k), each carried on its own carrier at a wavelength λm and spread in space, using of special devices – multiplexers, that combines into one stream λi.. λm, after which it is introduced into the network.

1.2 TDM technology

There are usually fewer data transmission channels than those willing to transmit data over these channels. So that several people could simultaneously transmit data over one channel, people came up with "multiplexing".

Multiplexing can be done in different ways. One is "time-division multiplexing".

In this case, all input signals are divided into small parts, after which these parts are transmitted over one common (shared) channel in turn. At the other end of the common channel, the reverse process occurs: the original signals are recreated from the incoming small parts.

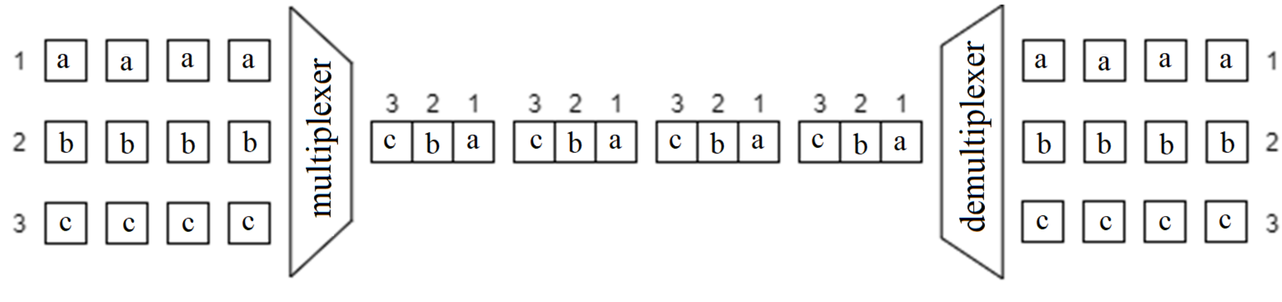

Figure 1.2. Time-division multiplexing

In Fig. 1.2, the data flow is from left to right. The source of the message (signal) contains a device called a multiplexer. This is what does the multiplexing. In the figure, it is schematically depicted by a trapezoid rotated 90° to the right. The recipient of the message (signal) contains a device called a demultiplexer. It divides the received general message (signal) again into separate messages (signals) and sends these messages to the appropriate channels.

In Figure 1, three different signals come to the multiplexer on the left through three channels, which the multiplexer divides into parts, let's call them "frames". The multiplexer allocates to each channel included in it a fixed period of time ("time slot", pronounced with an emphasis on "o", that is, on the last syllable in declension; in English "time slot" or "timeslot") in its work schedule. Since there are three incoming channels in the figure, the schedule of the multiplexer is divided into three time slots, which are allocated to the channels in turn, from the first to the last, and then there is a return to the first (that is, in a circle or "cycle"). During each cycle, the multiplexer receives a piece of data (a frame) from each channel and forms a "superframe" in the shared transmission medium, consisting in our case of three frames, including one frame from each channel. The operation of the multiplexer continues in a circle, superframes move along the shared (common) physical transmission medium to the signal receiver and enter the demultiplexer, which breaks each superframe back into frames and sends each frame to the appropriate receiving channel.

The described operation scheme is called TDM because the operation schedule of the multiplexer and demultiplexer divides on time slots, that are tied to its own data transmission channel.

The numbers 1, 2, 3 to the left of the multiplexer and to the right of the demultiplexer are the numbers of incoming and outgoing channels, respectively. And the numbers 1, 2, 3 between the multiplexer and the demultiplexer, located above the superframes, are the numbers of time slots.

Typically, a common (shared channel) has a capacity (data rate) greater than the data rate of the individual incoming channels. For example, if the data rate in each individual incoming channel is taken equal to one piece of data or frame per second.Data rate in the common (shared) channel is taken equal to three frames per second (one superframe per second), then the user of each individual incoming channel will not even notice that it shares one common physical transmission medium with two more users. After all, the transfer rate of its data will remain equal to one frame per second, that is, there will be no noticeable decrease in the data transfer rate.

TDM operation described above and in Figure 1 is called "synchronous TDM". It is so named because the demultiplexer operates in synchronism with the multiplexer, whereby the demultiplexer knows that (for our example) the data chunk (frame) from timeslot 1 of the incoming superframe should go to outgoing channel 1, and the data chunk (frame) from time slot 1 slot 2 should be routed to outgoing channel 2, and so on. Each piece of data (frame) is not required to carry the number of the outgoing channel in order to get into the desired outgoing channel, because due to the synchronism of the demultiplexer with the multiplexer, everything will go right anyway.

Synchronous TDM has a disadvantage:

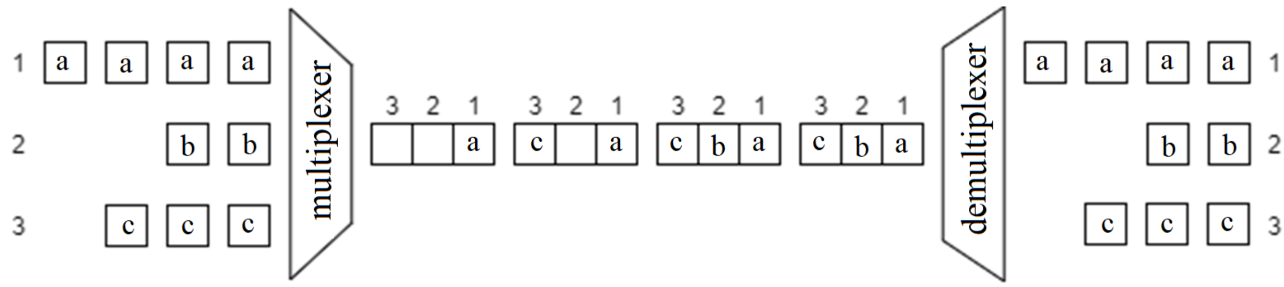

Figure 1.3. Synchronous TDM

Fig. 1.3 shows the same synchronous TDM as in Figure 1. However, the data received from users on the incoming channels is of different sizes. Due to its synchronous nature, the demultiplexer can only place the first channel data in time slot 1 of each superframe, the second channel data only in time slot 2 of each superframe, and so on. As a result, it turns out that due to uneven load from incoming channels, some superframes are partially empty, that is, the shared channel is used inefficiently (this situation is shown in Fig. 1.3 - see the state of the shared channel between the multiplexer and demultiplexer).

To get rid of this shortcoming, they came up with the so-called "asynchronous TDM" (in English "asynchronous TDM"), which is also called "statistical TDM":

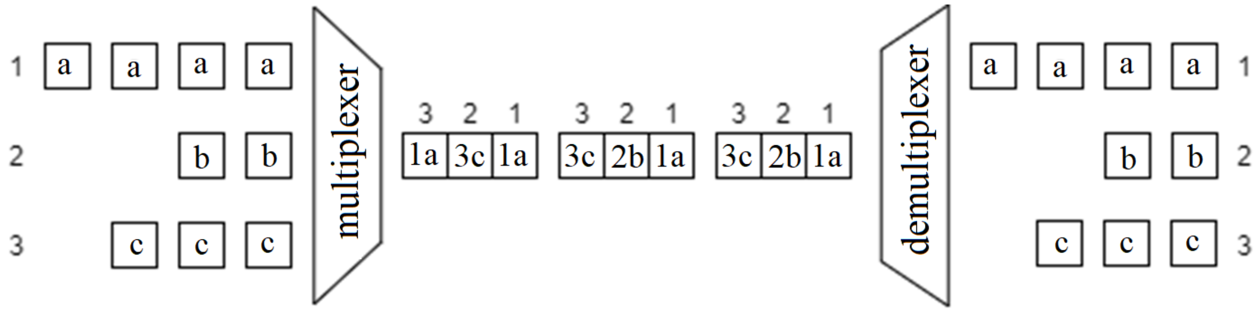

Figure 1.4. Statistical TDM

In Fig. 1.4, TDM occurs asynchronously with demultiplexing, which means that the multiplexer does not bind each incoming channel to its time slot, but can allocate to one incoming channel not one time slot in each superframe, but several, as needed. This can be seen in the figure: the first two superframes on the right in the shared (common) data channel are filled in the same way as in synchronous TDM, because the incoming channels first provide equal data loading. However, on the third sample, the data in the second incoming channel ends and the multiplexer decides to give the second slot of the third superframe from the right for data from the third incoming channel. And so on.

As a result of the operation of asynchronous TDM, incoming channels are not tied to their time slots, so the demultiplexer, without additional information, cannot correctly determine which outgoing channel to send the next received frame to. Figure 3 shows the addition of additional information to each frame: before the data of each frame, the header part of the frame with the number (address) of the desired outgoing channel is placed. Using this number (address), the demultiplexer as a result will be able to correctly distribute the received frames to the desired outgoing channels.

Asynchronous TDM is nown as "statistical TDM" because the multiplexer decides on the allocation of time slots in superframes based on statistics about the incoming load (incoming data) from the incoming channels.

In radio communications, a synchronous TDM application can be called “static TDMA” (the binding of incoming channels to certain time slots remains unchanged, that is, static; in English “static TDMA”), and an asynchronous TDM application can be called “dynamic TDMA” (incoming channels are not tied to certain time slots, the distribution of time slots between channels occurs differently each time, that is, dynamically; in English "dynamic TDMA"). The extra "A" in the acronym stands for "access".

Understanding the operation of TDM, one can understand why there are three types of synchronization of digital signals with data: element-by-bit (by bits), group (by frames) and cyclic (by super-frames).

Let's now consider the features of PLC technology, which consists in the use of an electrical network as a data exchange network within a house.

1.3 PLC technology

With skin fate, information and communication technologies play more and more important role in the lives of people, with the help of which they have contributed to the social and economic development of the country. For the rest of the hour, a wide drink is being shrunk as a part of telecommunications services (access to the Internet, video surveillance, remote control of scorching, lighting, etc.) etc. ("smart house" (Smart Home), "smart place" (Smart City) and "Internet of things" (IoT)).

Necessary intellectual for a large-scale variation of the potential of transferring concepts is the presence of a measure of easy access, buildings to secure a high throughput of buildings. Today, the basis for the provision of wireless access is telephony wires, fiber optic wires, cable wires, mobile and satellite wires, as well as wires of electrical wiring (PLC technology). The skin of them may have its own advantages and nedoliki, as if they were talking about the dotsilnist ïx vikoristannya in the quiet minds of others. Zokrema, electrical wiring fences vicorist as a medium for broadening signals in case of a wake-up infrastructure, designed with the concept of "reasonable location" for organizing services in the remote control of the indications of various sensors installed at the alarm system, as well as with a "robust room".

PLC technology is a promising telecommunication technology, which, working on power electrical circuits, allows organizing high-speed information exchange. In the fall due to the speed of transmission, PLC is subdivided into wide-range (BPL) with more than 1 Mbit/s and high-speed (NPL).

NPL transmission systems operate in the frequency range 9 - 140 kHz. This range divides into three groups: A (9 - 95 kHz) - frequencies recognized for use by public utilities; B (95 - 125 kHz) and C (125 - 140 kHz) are recognized for private whistleblowing. Range A, as a rule, is reserved for the implementation of the so-called energy services for the organization of services in the remote control of the quantity of electricity of home government. Ranges B and C are mainly used for the establishment of a far-flung cherub with a "smart house".

The scope of application of NPL transmission systems is the centralized control of home or office automation devices connected to PL (power lines), such as lighting systems, alarms, heating, air conditioning, elevators, electric locks, as well as monitoring the readings of various sensors located in the building (automatic reading readings of meters connected to PL; receiving information from sensors of lighting, movement, smoke in the room). BPL technology is successfully used in the deployment of the "smart home" concept, as well as the organization of broadband Internet access.

Transmission of data over PL has significant advantages. These include: low initial capital investment, because network construction does not require work related to cable laying; very fast deployment of the network - the network can be deployed in any area where there are power supply lines; the possibility of providing services in almost all places where there is electrical wiring.

In addition to its advantages, like any other high-speed access technology, PLC has a number of disadvantages. The most significant are the division of bandwidth of the data transmission network by wiring between all terminals of this network; the influence of the quality of wiring, the presence of joints made of different materials (for example, copper and aluminum conductors), as well as the number of connections on the stability and speed of data transmission ower PLC line; disruption of radio reception in premises where PLC modems work.

1.4 Conclusions to the chapter 1

The section analyzes methods of data transmission over one channel, including various methods of multiplexing. The method of time and frequency multiplexing is considered. The method of time multiplexing is used for data exchange over power grid lines. Advantages and disadvantages of this method of data exchange are considered.

CHAPTER 2

RESEARCH OF METHODS OF PHYSICAL IMPLEMENTATION OF PLC TECHNOLOGY

2.1 Implementation options for PLC networks

The figures below show options for creating PLC networks on DefiDev equipment:

- an external option for using low-voltage wiring (Fig. 2.1, connection options with repeaters and without repeaters are shown);
- installation inside the building (Fig. 2.2, 2.3);
- complex use of PLC and wireless technologies.

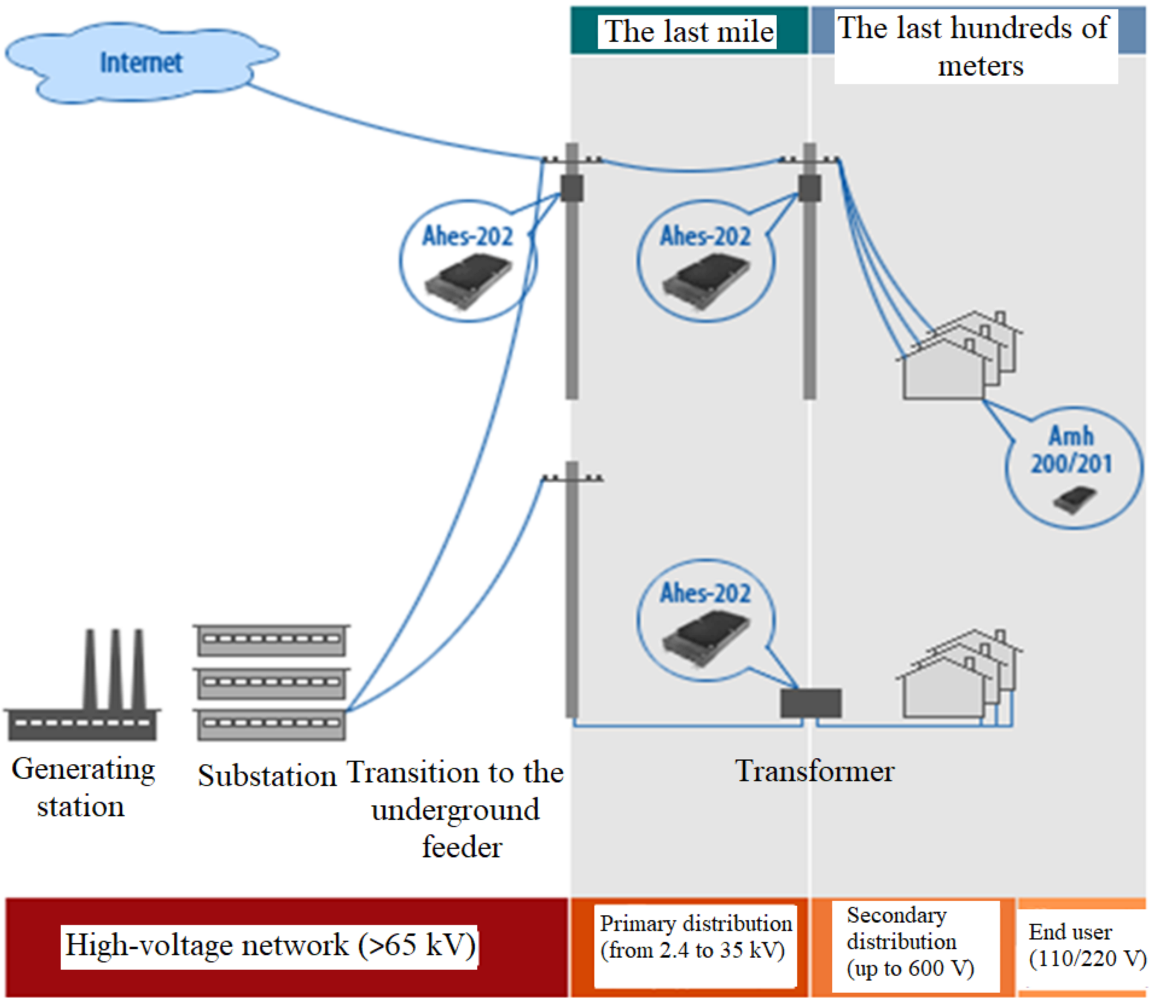

Figure 2.1. An external version of the implementation of the PLC network

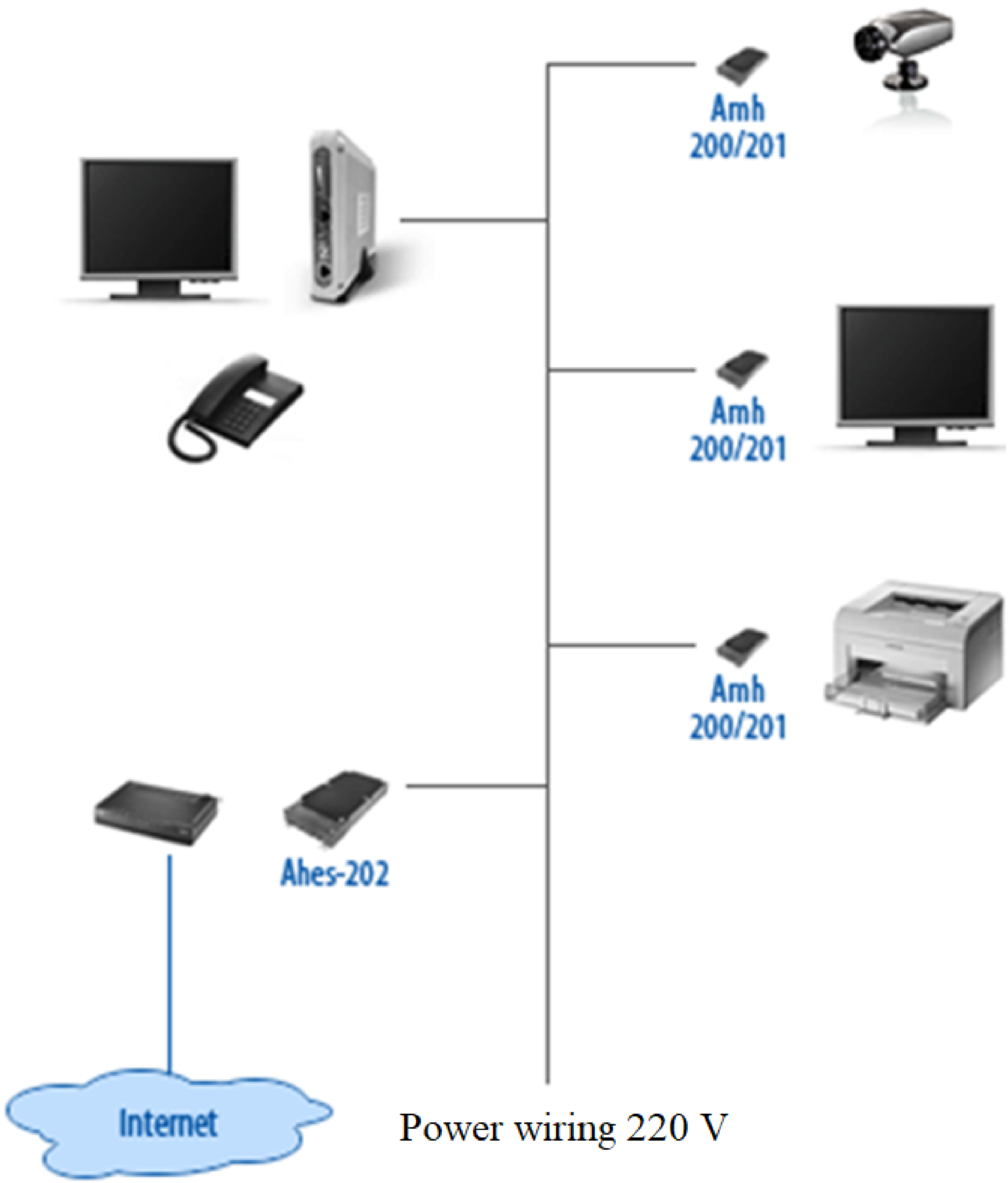

Figure 2.2. A variant of the implementation of the PLC network inside the building: the organization of the segment of the PLC network

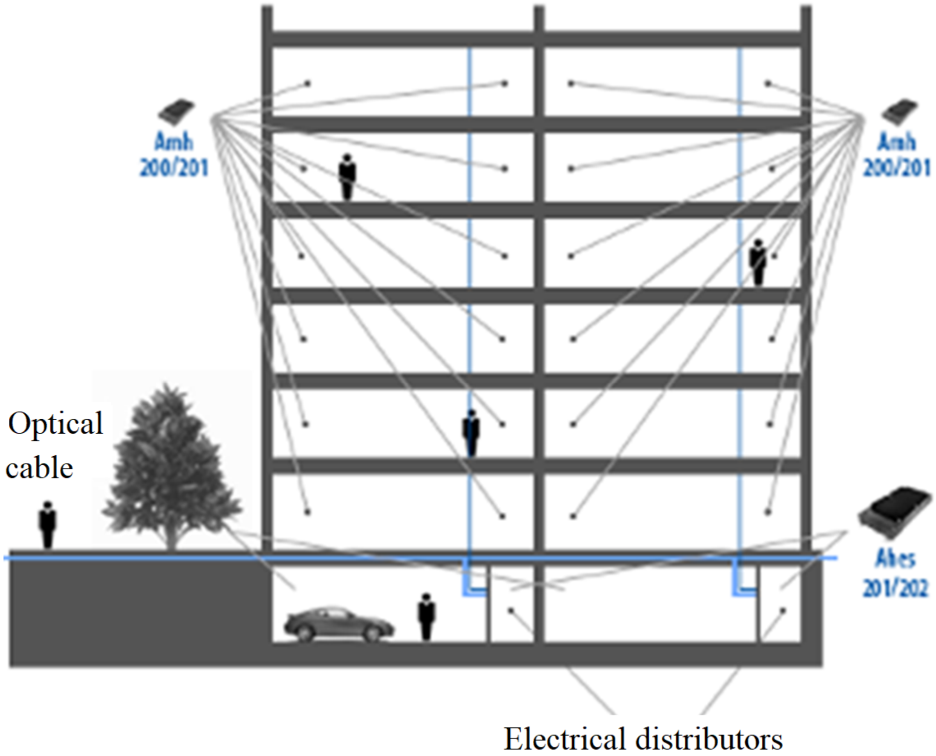

Figure 2.3. A variant of the implementation of the PLC network inside the building: multi-segment PLC network

Control of the PLC network can be carried out both with the help of its own control system and with the help of control systems of third-party manufacturers, for example, HP OpenView.

Composition of the PLC network:

- automated user workstations (AUM) - PCs, laptops, PDAs. In addition, various equipment can be connected, for example, network multifunctional devices, telephones/IP telephony;

- subscriber PLC devices (adapters) with Ethernet (1), USB (2) or Wi-Fi (3) interfaces;

- border PLC modem with built-in functions of routing, authentication and ADSL access to the trunk telecommunications network;

- Electrical wiring: phase connection devices, power distribution boards (secondary distribution panels), circuit breakers (automatic circuit breakers), electrical sockets.

Currently, networks are deployed on all continents using PLC:

2.2 The principle of operation, the main capabilities of the equipment

Narrowband access equipment - modems, capacitive and inductive devices for connection to power lines - is offered for data collection and transmission on 0, 4-110kV power lines.

PLC modems have RS-232/485 and Ethernet input interfaces and are compatible with all standard protocols for these interfaces. With the help of hardware and software, modems can be configured for different modes of operation:

- Master - main trunk modem;
- Repeater;
- Slave edge modem.

Modems set to Master / Repeater mode have a 16-bit address space, i.e. 65536 addresses. The experimentally confirmed data speed for the RS-232/485 interface - up to 100 kbit/s, and for the Ethernet interface - up to 60 kbit/s. The modems operate in the frequency range of 50-525 kHz, the spectral output power of the signal is 38 dBm, thus, the operation of the modems does not create any interference for consumers in the power grid.

Existing modem software based on RS-232 and Ethernet interfaces provides the possibility of building PLC networks of various architectures:

- "Point-to-point" - for systems requiring a single "hard" communication channel.
- "Point-to-multipoint" - for systems using Master / Slave architecture and transparency of slave devices.
- "Multiple point-multipoint" - for global open information systems.

The speed, stability, error-free and reliable transmission of data, as well as the wide bandwidth of the PLC modem signal in real time, allows it to be used in electrical networks of different voltages, with numerous nodes supporting various industrial protocols.

Taking into account the fact that the maximum speed of 100 kbit/s is available to the user at the application level, this solution is most suitable for systems with high requirements for channel bandwidth, automation systems, monitoring and other services that use HF transmission lines.

The capacitive connection device is designed for data transmission over high-voltage lines with a voltage of up to 10 kV, both aerial and cable. The connection device is an integral part in the construction of PLC networks. The UE transmits high-frequency PLC modem signals into the communication channel with a nominal voltage of up to 10 kV and back, providing, in turn, galvanic separation of potentials and impedance matching between the primary and secondary terminals, respectively, does not require additional power supply and does not require any what settings

The inductive connection device has the same purpose as the capacitive connection device, and is distinguished by the speed and ease of installation without direct contact with the current-carrying parts of the power line.

Operating experience shows that a set of equipment (PLC modem + UP) provides data transmission at a distance of up to 10 km.

1. PDSL

PDSL is a technology of the xDSL family that provides symmetrical data transmission up to 2 Mbit/s over power cables (4-20 kV), in parallel with electricity. The connection of PDSL equipment to high-voltage lines is carried out with the help of coupling devices, which are installed in transformer cabinets.

2. Small office (SOHO)

PowerLine technology can be used when creating a local network in small offices (up to 10 computers), where the main requirements for the network are simplicity of implementation, mobility of devices and easy expansion. At the same time, both the entire office network and its individual segments can be built using PowerLine adapters.

3. Home communications

PowerLine technology gives new possibilities in the implementation of the idea of a "Smart House", where all household electronics would be connected in a single information network with the possibility of centralized management. The electrical network is a ready-made medium for the transmission of control signals between household appliances operating in the 110/220 V network.

2.3 Practical analysis of PLC technology

Such technology has made a difficult path from project development to operator class solutions. On this path, at different times, different people had different impressions, which turned into persistent myths. Let's consider some of them.

It is believed that PLC technology is slow and unreliable: - early versions of the standards did not work reliably enough. The UPA and HomePlug AV versions are third generation, and the algorithms and protocols are continuously improved in software updates.

It is believed that you can include several adapters in the sockets and get the maximum speed of operation, but in fact the result is unpredictable - the PLC works on electrical wires that can be connected to three different phases. In some cases, it may turn out that different groups of sockets are connected to different phases and simply do not have an electrical connection with each other. In this situation, the surprising thing is not that the PLC does not work, but that it often works even in such a difficult situation due to the mutual influence of the phases. If you have a power grid plan and experience working with a PLC, you can build a network under any conditions, but of course it will not be possible to do it on the "plug and play" principle.

There are devices that when turned on "block" the entire network and nothing can be done about it - devices that affect the PLC are well known. These are powerful electric motors used in air conditioners, refrigerators, washing machines with an inductive nature of the load, as well as the cheapest small-sized Chinese-made power supply units without filtering circuits. The methods of struggle are also known - the use of specialized inexpensive filters and the correct design of the PLC network.

After deployment of the PLC network, obstacles are created - this is not true, because:

- when transmitting over a coaxial cable, the power and spectrum of the signal used in the PLC is similar in parameters to DOCSIS cable modems;

- when transmitting even through a very good power cable, the signal quickly fades, when transmitted over the air, the signal does not have a noticeable effect on the working equipment, since the power lines and equipment are quite far from each other;

- the small power of the PLC signal (100 mW) is distributed in small portions over a wide spectrum, while the greater power of HF radio stations (1 ... 50 W) is concentrated in a narrow spectrum;

- and most importantly, there is a flexible possibility of configuring the Power mask, which allows you to weaken the radiation of an arbitrary frequency to a given power level. Models with pre-installed masks are supplied to the market, which fully satisfy, for example, the rules of the American FCC regulator.

However, there are certain facts caused by the physical characteristics of signal propagation that significantly narrow the scope of PLC-based solutions.

Fact 1. Some electric meters block the PLC signal. There are three possible options for the effect of counters on PLC operation depending on their design:

- the counter does not affect the signal. Attenuation is about 5 dB;

- the counter weakens the PLC signal. Attenuation 5-40 dB. In this case, you can connect a signal after the counter and ensure the normal quality of the PLC network;

- the counter bypasses the PLC signal. In this case, a large part of the signal is weakened due to the built-in RF shunt, the PLC connection does not work either before the meter or after the meter. The only option to establish a connection is to retreat from the meter via a cable directed towards consumers from 10 meters and above.

Fact 2. In aluminum wiring, signal attenuation is stronger than in copper, which reduces the communication range by approximately 2 times.

Fact 3. In underground cables, due to the properties of the earth, signal attenuation is 2-3 times greater. However, signal transmission in electrical networks is mainly affected not by attenuation, but by the noise level, which is significantly lower in underground communications.

Fact 4. The more branches (machines) in the switchboard, the stronger the signal power drops right at the signal connection point.

In real facilities, the combination of several unfavorable factors can make the deployment of PLC unprofitable or fundamentally impossible, therefore, before deploying the network, it is always necessary to collect the maximum amount of information, including the plan of the electrical network, the type of cable wiring, circuit boards and automata.

2.4 Spectra of the PLC signal

A wonderful property of the technology is the ability to adjust the degree of modulation for each carrier frequency under attenuation, i.e. adapt to the amplitude-frequency characteristic of the line. In this way, the "congested" frequencies continue to be used to transmit a useful signal, albeit with a smaller number of symbols per carrier.

In Home class solutions, there is no ability to control the spectrum of the transmitted signal, so the quality of work on existing networks may be suboptimal. In operator solutions, there is a possibility to choose the mode of operation (Mode), there are 13 of these modes in total, and they differ seriously in the nature of the application. The spectrum of the live signal received from the coaxial output of the Corinex access gateway PLC is shown in Fig. 2.4.

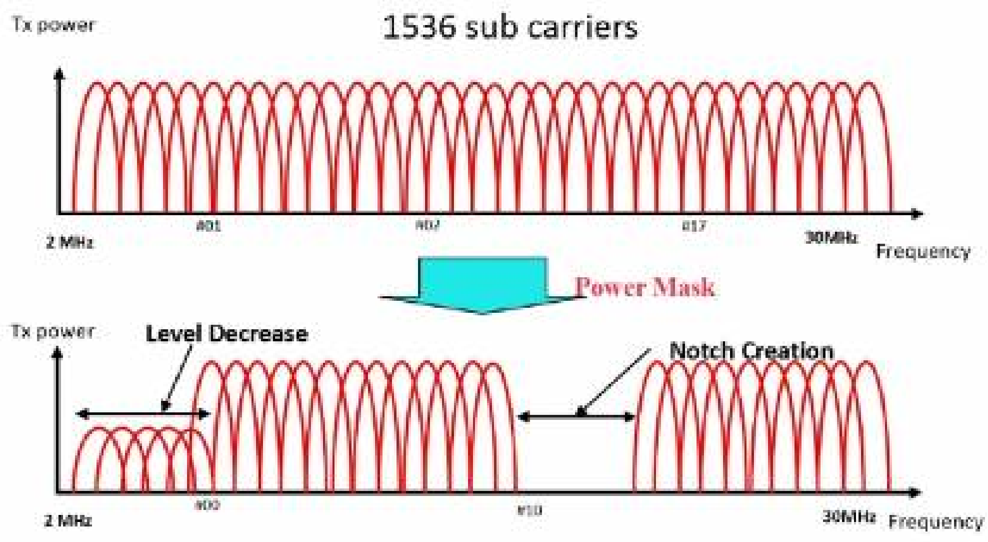

Figure 2.4. PLS signal spectrum

2.5 Characteristics of PLC networks

Two important questions when choosing PLC equipment are: "What is the maximum speed?" and "What is the maximum distance?" The instant physical speed of the line can reach 220 Mbit. The speed given by the "estimator" is slightly lower. When establishing a connection, it may take several minutes before the modem determines the optimal data transfer speed. The relationship between the physical rate of attenuation and the band can be seen on the graph (Fig. 2.7).

Figure 2.5. Graph of the relationship between the physical decay rate and the band

In turn, there is a certain dependence between the physical speed and the real speed of data transfer. Do not forget that in the physical environment of the PLC, the protocol works in half-duplex mode, so the specified value is divided into two directions, as a rule, with a small asymmetry (Fig. 2.8).

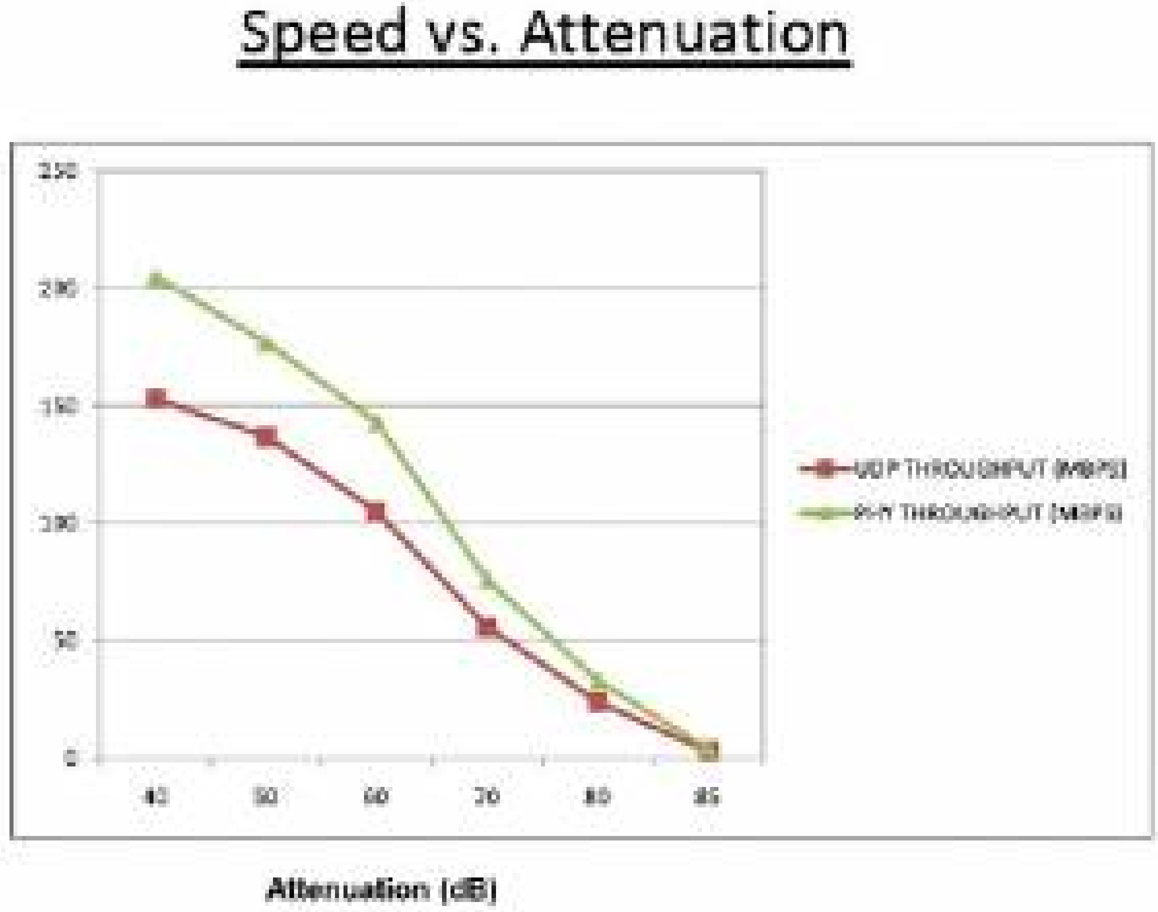

Figure 2.6. PLC protocol graph in half-duplex mode

Manufacturers declare a typical operating range of PLC networks of 300 meters, but due to the large number of factors affecting signal propagation, it is impossible to guarantee this or that speed or distance. In reality, it is not the attenuation that determines the speed and distance, but the signal/noise ratio. It is worth noting that the noise level is quite significant in extensive and low-quality power networks.

2.6 Conclusions to chapter 2

In the chapter, a study of the methods of physical implementation of PLC technologies was carried out, in particular, the methods of implementing a PLC network inside the building were analyzed: the organization of a segment of a PLC network and a multi-segment PLC network.

The principle of operation, the main capabilities of the equipment used for the organization of PLC technology are considered, and an analysis of the capabilities of PLC technology is made.

CHAPTER 3
TECHNICAL MEANS OF IMPLEMENTATION OF PLC NETWORKS

3.1 Technical requirements for building PLC systems

Mains transmission in general, and PLC systems in particular, are extremely complex systems, the development and maintenance of which requires consideration of many aspects. They include:

- determination of the frequency band and corresponding frequencies;
- transmission characteristics and signal attenuation in lines;
- limited noise level of external sources;
- exclusion of the possibility of damage to network devices by transmitted signals;
- elimination of the possibility of damage due to radiated fields;
- exclusion of mutual influence between systems;
- response level from receiver devices;
- admissibility / limitation of the signal level;
- signal modulation and coding.

Next, basic information on these aspects will be given. However, it is worth remembering that they cannot be considered independently of each other, since one aspect can affect the others: for example, the signal level must be higher than the noise level, but not so high that the radiated fields disturb the radio broadcast. Signal modulation and coding are the main indicators that determine the reliability of the system. We must not forget about the economic aspect.

3.1.1 Frequency range of PLC systems.

PLC systems require a fairly wide bandwidth to perform high-speed functions. This band is located in the range of 1-30 MHz.

There are three problems:

- this frequency range is occupied by short-wave radio services: broadcasting, security service, amateur radio. Therefore, these frequencies should be excluded;

- it is necessary to avoid interference between address and internal systems; the solution is to allocate a separate frequency band for each application;

- emitted electromagnetic fields can disrupt the reception of broadcast radio broadcasts or other services in the same frequency range.

3.1.2 Signal transmission.

The wide variety of networks and load conditions makes it very difficult to calculate the RF signal voltage level in 50/60 Hz systems.

Practical statistical measurements give the results of the attenuation with which the signals are transmitted. In Fig. 3.1 (upper curve) is shown as an example of voltage attenuation in a 300-meter cable as a function of frequency: voltage drops of 20 dB at 1 MHz, 80 dB at 20 MHz.

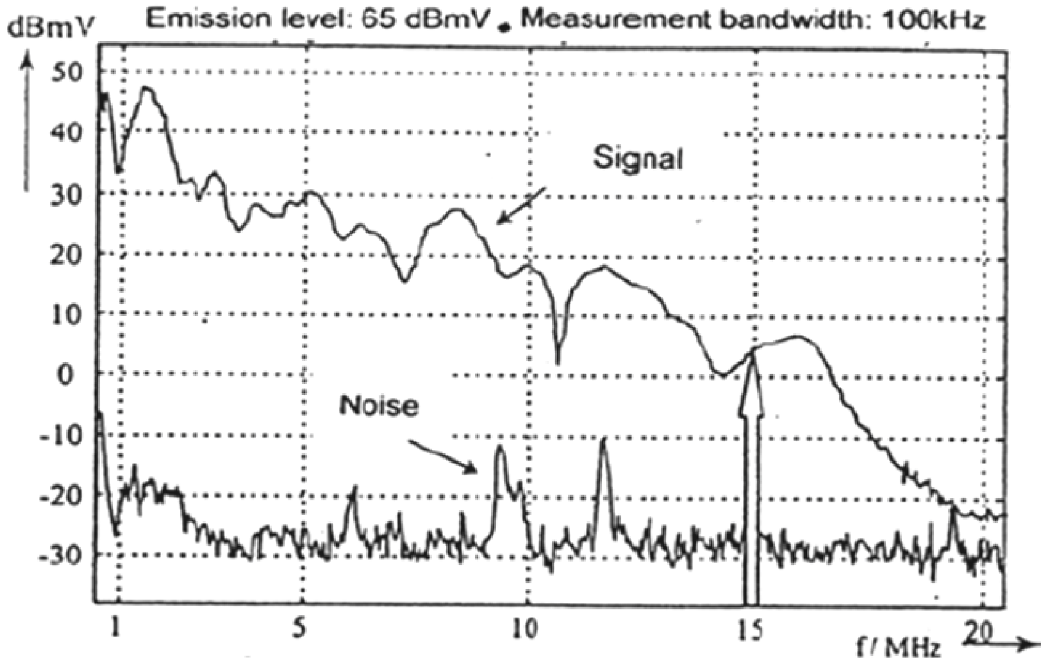

Figure 3.1. Attenuation of signal voltage and noise level in a 300-meter cable

When it is not possible to achieve the required level of response, it is necessary to install repeaters. Gateways between supply lines and internal lines may also be required.

3.1.3 Noise level and conduction interference in low-voltage networks.

The noise level in the lines is determined for modems. There are three types of obstacles:

- constant broadband noise (white noise);
- narrow-band "peaks" (separate frequencies);
- pulsations.

Noise measurements are based on several factors: bandwidth and time constant of the measuring instrument, peak, quasi-peak, or average value, etc. This makes comparative measurements difficult. There must be a suitable method to standardize the measurement, for example according to CISPR 16 (9 kHz bandwidth, peak value). In general, it is worth considering the ranges:

- broadband noise (bandwidth 100 kHz, peak value): 30-40 dB, μV;
- narrow-band noise (up to 50-60 dB μV).

Measurements in buildings show noise levels within the same limits. Comparative levels were also registered in computer networks.

3.1.4 Limiting the signal level to avoid disturbing the operation of other network devices.

PLC systems must not interfere with other connected devices. Protection of such devices against conducted "noise" in the frequency range from 0.15 to 80 MHz is provided by the general EMC standard. This is much higher than the signal level of the PLC and the danger of such influence is excluded.

3.1.5 Limiting the signal level due to radiated fields.

Voltage in PLC systems and currents circulating in low-voltage networks generate electromagnetic radiation that can interact with radio services operating on the same frequency. In fact, the band 1-30 MHz, which includes the wavelengths 300-10 m, respectively, is occupied by short-wave broadcasting services and other reserved services such as alarm, police, etc. Of course, their functions should not be disturbed.

Some features of power networks:

- each conductor emits electric and magnetic fields. When two conductors carrying opposite currents are very close together, the resulting field is very small;

- if the conductors are at some distance, a certain field is formed due to the asymmetry between the two components. This is the case with 3F + (N + G) power cables in the outer region, especially when the N conductor is grounded. The asymmetry becomes even more significant in the case of overhead lines.

Asymmetry also occurs inside buildings and rooms due to the arbitrary configuration of internal wiring, sockets, household appliances, etc.

Limits for PLC signals are given in two forms: as limits on radiated fields or as limits on network signal level. Fig. 3.2 shows the permissible limits for fields that emit PLC signals for different states. British requirements are stricter, American - softer.

Before installing a new PLC system, it is necessary to determine the field that it can generate. As for power cables, in this case the fields created by the PLC system can be calculated. However, in practice it turns out that, in comparison with the direct measurement of electric fields, the calculations give too large values. This can be explained by the fact that near the cable we cannot determine the field in remote areas. In houses, the wiring configuration is so complex that only statistical measurements are practically applicable. Basically, further statistical studies are necessary.

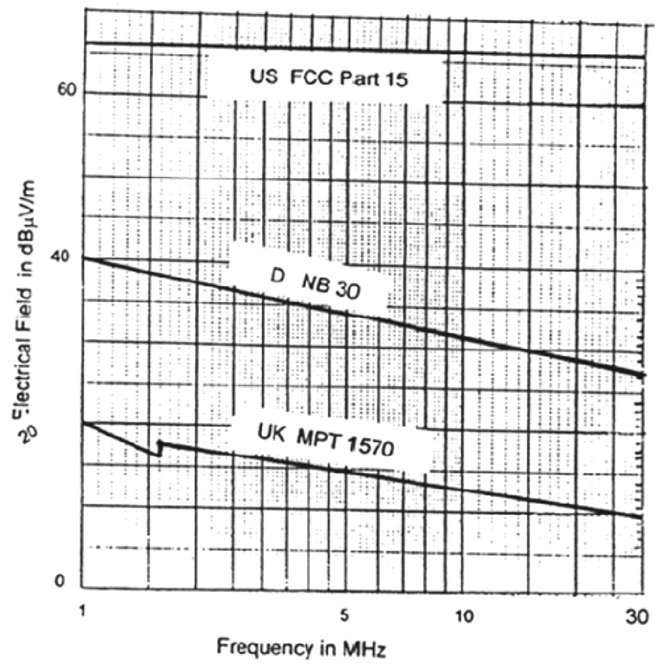

Figure 3.2. Radiated field restrictions in Britain, Germany and the USA

In order to estimate these fields more easily, a simplification has been proposed - to use a replacement function called the "coupling factor".

Practically, in this frequency range, it is easier to measure the magnetic field and convert the result into an electric field by multiplying by the resistance of empty space Zo (377 Ohms).

Note: Another suggestion is to relate the coupling factor to the input power, but this method appears to be less straightforward when measuring at a network node.

Fig. 3.3 illustrates an example of coupling coefficient measurements. In practice, there is a huge spread in the values of this coefficient, possibly due to the resonance effect, which makes the field prediction extremely inaccurate.

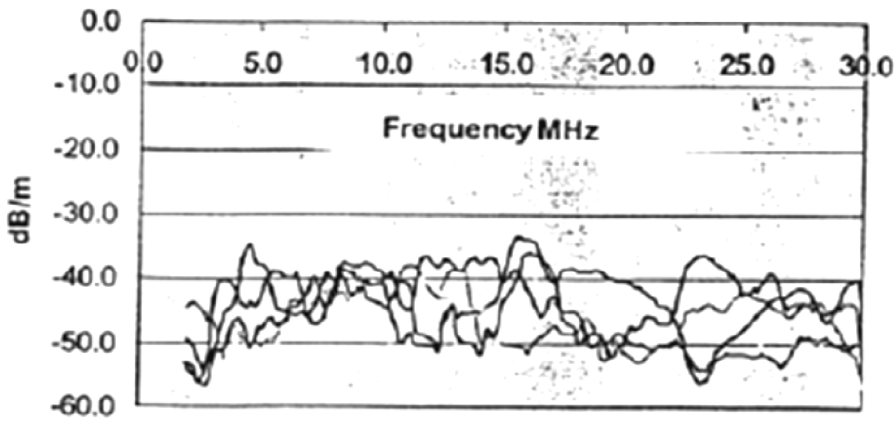

Figure 3.3. Coefficient of connection for voltage near a private house.

At a first approximation, the following values of the connection coefficient can be obtained:

- power cables in external areas: from -35 to -55 dB
- internal areas: from -20 to +40 dB

3.2 Signal modulation and coding

Signal modulation and command coding methods are generally not considered problems, but since they are closely related to network disturbances, we will consider them.

As for the modulation method, only wide-band methods with frequency multiplexing are considered in connection with the transmission of various signals and resistance to impulse interference. OFDM modulation enjoys the greatest advantage. It consists in dividing the available spectrum into a large number of subchannels and transmitting data on N of these channels with frequencies f1, f2, ..., fN. The advantage of this method is that it allows you to avoid channels corresponding to prohibited frequencies and, in this connection, to increase the level of the transmitted signal.

The coding method should be chosen according to the specific functions performed. An important point to consider is the simultaneous launch of various applications, for example, commands and the Internet or telephone. At the same time, each of the applications is allocated a certain number of channels.

3.3 Orthogonal frequency division

We will consider the OFDM modulation technology using the IEEE 802.11a standard as an example.

Basically, OFDM is a special case of data transmission technique using a large number of carriers (MultiCarrier Modulation - MCM). The main principle of MCM is to divide the main stream of bits into a number of parallel sub-streams with a low transmission rate and then use them to modulate several carriers (subcarriers). At the same time, generally speaking, any modulation technique can be applied to each of the subcarriers.

The traditional method of dividing the bandwidth is to use frequency filters. An example is frequency division multiplexing (FDM). To avoid inter-channel interference, sub-channel spectra must be separated by a guard band. Such a requirement leads to inefficient use of the allocated frequency range.

Application of the Fourier transform allows you to divide the frequency range into subcarriers, the spectra of which overlap, but all remain orthogonal. The orthogonality of the subcarriers means that each of them contains an integer number of oscillations per symbol transmission period. As can be seen from fig. 3.4, the spectral curve of any of the subcarriers has a zero value for the "central" frequency of the adjacent one. It is this feature of the spectrum of subcarriers that ensures the absence of interference between them. In the given example, the maxima are separated by a range of 300 Hz.

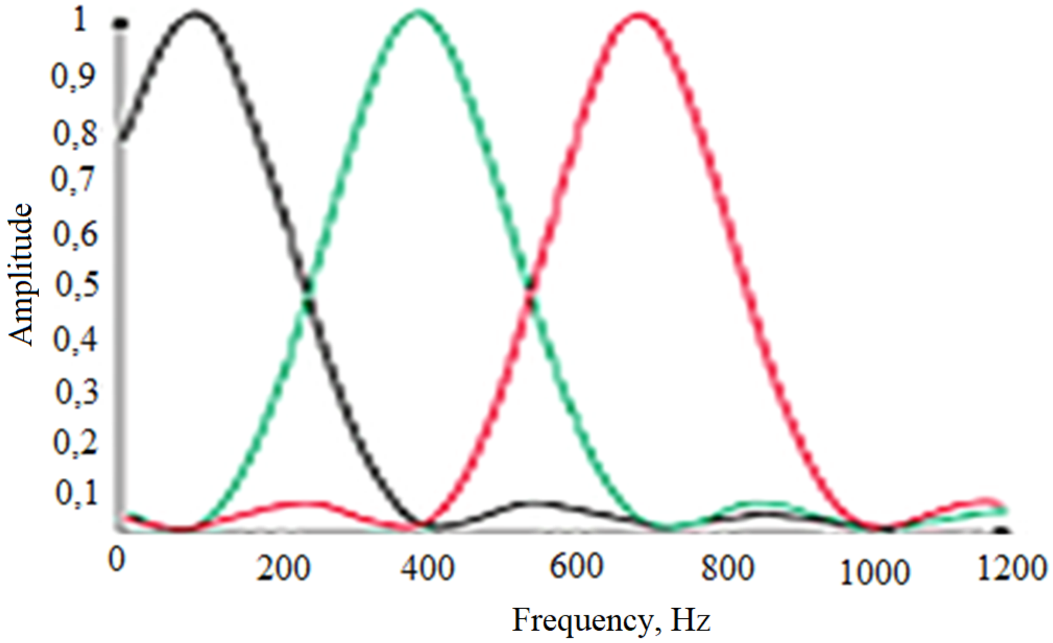

Figure 3.4. Spectral curve of subcarriers

Another advantage of OFDM is its resistance to the so-called multipath delay effect. It is caused by the fact that the radiated signal, reflecting off obstacles, arrives at the receiving antenna in different ways. This can lead to distortions due to intersymbol interference. To weaken the effect of multipath delay, symbols are transmitted with a long period. Robustness can be increased by adding a guard time period between transmitted symbols. Cyclic expansion is usually used - the final part of the wave encoding the symbol is added to the initial part. This increases the character length without breaking orthogonality. In addition, cyclic expansion allows you to select a window for the Fourier transform anywhere in the time interval of the symbol.

Physical level.

The IEEE 802.11a standard provides for the use of a frequency band of 5.15-5.825 GHz, data transfer speed 54 Mbit/s. The band is divided into three working zones, each of which has a width of 100 MHz and a maximum permissible radiated signal power (in the USA). The first 100 MHz in the lower part of the range (5.15-

5.25 GHz) is limited to an output power of 50 mW, the radiated power in the middle band (5.25-5.35 GHz) should not exceed 250 mW, and in the upper band (5.725 - 5.825 GHz) - 1 W. It is assumed that the upper frequency zone will be used for channels connecting buildings or other outdoor applications, while the other two zones are for indoor applications.

3.4 Conclusions to chapter 3

The chapter discusses the technical means of implementing PLC networks, in particular the technical requirements for building PLC systems and the issue of choosing a frequency band and methods of signal transmission. An analysis of the methods of assessing the impact of various levels of noise and conduction disturbances in low-voltage networks and limiting the signal level in order to avoid disruption of other network devices has been carried out.

The issue of limiting the signal level due to radiated fields and methods of their evaluation are considered.

Methods of signal modulation and coding are analyzed, in particular, the method of OFDM.

CHAPTER 4
EXPERIMENTAL RESULTS

4.1 Analysis of solutions for the construction of data reception/transmission devices in PLC systems

The most common data transmission technologies on 220/380 V networks are:

- X-10;
- Intellon CEBus;
- LonWorks of Echelon Corporation;
- Adaptive Networks;
- DPL 1000 manufactured by NOR.WEB;
- PLC Universal Powerline Association.

1X-10 is the oldest technology, developed in 1978. It was focused on managing household appliances.

The main disadvantages of X-10 technology are low speed and small address space. According to this technology, data transmission is carried out by frequency parcels (120kHz) at the moment of transition of alternating voltage 220V through zero. A binary unit is the presence of a frequency parcel, zero is its absence. Repetitions are introduced to increase immunity. The maximum transmission speed is 60 bps (60 baud). A complete command is transmitted in about 0.8s.

CEBus technology (Intellon SSC)

Intellon CEBus (Intellon SSC) is developed by Intellon for the CEBus home network.

The technology of a noise-like signal is used, which involves the transmission of each data bit in the frequency band of 100-400 kHz. The transmission speed is an order of magnitude higher compared to X-10 technology. The Intellon company implements the Power Line Evaluation Kit.

LonWorks and LonTalk technologies

LonWorks was developed by the American corporation Echelon for distributed networks. The basis of LonWorks technology is the LonTalk protocol for information exchange. Each network node contains a microprocessor that implements the functions of this protocol.

LonTalk is a seven-level communication protocol that allows for reliable data transmission over various physical environments. For each type of environment, transceivers have been developed that support network operation with different channel lengths, transmission speeds, and network topologies.

Adaptive Networks produces a number of devices that support data transmission over any type of electrical wiring. The effective transfer rate is 115 kbit/s. Its features are exceptional reliability and adaptability (probability of error 10-9), noise-like signal, the possibility of using software for twisted pair.

PLC technology and DPL 1000 devices.

DPL 1000, allows data transmission over electrical lines at a speed of up to 1 Mbit/s, developed by the NOR.WEB company. DPL 1000 is a revolution in data transmission over EL. Trial connections using DPL 1000 technology are currently being tested in Europe.

PLC, data transmission technology over 220/380 V, 6/10 kV and coaxial networks. A noise-like signal in the range from 2 to 34 mHz is used. Moreover, you can cut a part of the carrier part of the signal if it interferes with other networks. The system itself adapts to the noise and load of the power grid. Transmission speed up to 200 Mbit/s at a distance between devices of up to 300 m. Experiments on data transmission over the power line have been conducted for a long time, but low transmission speed and poor immunity were the biggest disadvantages of such technology. But progress does not stand still, and the advent of more powerful DSP processors made it possible to use more complex signal modulation methods.

At the moment, a large selection of equipment for creating local networks by PLC technology is offered. For example, produced by PLANET's powerline communication company, which works with a PLC based on the HomePlug1.0 specification standard, which specifies data transfer speed to 14 Mb/s. The product is called PL-401 E and is a bridge with one PLC port and a switch with four LAN ports.

During the development and further operation of various types of automation systems, there is a need for territorial distribution of sources and receivers of information, it can be various measuring sensors on the one hand and a data collection device or executive mechanisms on the other.

The Telecontrolli company offers the Plinius module - a modem for data transmission over the power network (electrical wiring). The main properties of the modem:

- synchronous/asynchronous mode of data transmission over the power network;
- semi-duplex mode of communication with frequency manipulation of the carrier, with a data transmission speed of up to 2400 bps;
- a digital carrier oscillation synthesizer from an internal quartz generator with a frequency of 11.0592 MHz;
- the frequency of the carrier oscillation is 132.45 kHz;
- low power consumption and minimal signal distortion;
- high sensitivity of the receiver;
- scheme for detecting carrier oscillation in the network;
- programmable reset from an external microcontroller;
- formation of a reference voltage of 2.5 V and a frequency of 5.5296 MHz for the external circuit;
- double supply voltage +5 V and +12 / 24 V.

Given that the Plinius module has half-duplex mode, data can be transmitted in only one direction at a time. The direction of transmission is determined by the master microcontroller through the RTS (Request To Send) pin. The CD (Carrier Detect) signal is used as feedback between the module and the control controller, which shows the presence of a carrier oscillation in the power network. Both the RTS and CD signals use active low logic.

The device can work both in a network with a voltage of 220V and in an electrical network of 120V. The Plinius module uses frequency manipulation of bit-carrying information. The default carrier frequency is 132.45 kHz.

Plinius modules are produced in two versions - commercial and industrial. The only difference between them is the voltage of the amplifier: commercial – +12 V, industrial – +24 V. The output power is 116 dBmV (8 mW) and 134 dBmV (31.5 mW), respectively. In addition, both models require an external +5V (25mA) power supply.

For external use, the modem generates a reference constant voltage of 2.5V, which can be used to power an external control microcontroller. The built-in crystal oscillator produces clock signals with frequencies of 11.0592 MHz and 5.5296 MHz, which can be used to clock the external control microcontroller.

You should pay attention to a number of features that developers may encounter when using the modem. First of all, before receiving the data coming from the output of the receiver, it is necessary to monitor the CD signal for the presence of a carrier oscillation in the network. The fact is that extraneous signals caused by interference in the network may be present at the RXD output. Therefore, for data exchange with an external microcontroller, when using the standard UART (universal asynchronous receiver) port of the microcontroller, the CD signal is used as an interrupt signal (source). When an active level occurs at the CD output, an interrupt processing algorithm is launched in the microcontroller, by which the flags of the UART receiver and the data register can be cleared, after which the polling program is launched. The CD signal is triggered if there is a carrier oscillation in the power network in the frequency range of 90 ... 145kHz for at least 4ms. The carrier oscillation level should be equal to or exceed 10mV (VCD parameter).

A similar situation occurs when the modem is connected directly to the COM port of a personal computer. That is, it is necessary to run the processing algorithms of the COM port registers only when a low-level signal occurs on the CD line, otherwise the COM port input data buffer will be constantly overflowing with "parasitic" data caused by interference.

Another feature of the modem when transmitting long data packets, is the duration of which exceeds 3 seconds. After transferring the RTS signal (request for data transfer) to the active low level, after 3s the modem automatically switches to the reception mode. You can return it to transmission mode only after switching the

RTS signal to a high level (with a duration of at least 2 μs), and then back to a low level. Thus, in order to transmit a long data packet (with a duration of more than 3 seconds), it is necessary to programmatically split it into several short packets, with a duration of no more than 3 seconds.

4.2 Implementation and modeling of the process of multi-channel data exchange using TDM technology

The speed of data transfer depends on the method of data representation at the physical level and the signal speed or modulation speed - the speed of change of the signal value. This rate of signal changes per second is measured in units called bots. If the rate of change of the signal value is b bot, then this does not mean that the data is transmitted at a rate of b bits/s. Much depends on the way the signal is encoded: one value change can encode several bits at once. If 8 values (levels) of the signal are used, then each change in its value encodes 3 bits at once.

If there is a line with a speed of b bits/s, then it takes 8/b seconds to transmit 8 bits. Therefore, the frequency of the first harmonic will be b/8 Hz. A telephone line can transmit at a maximum frequency of 3000 Hz (this is its bandwidth). The maximum number of harmonics can be 3000 8/b = 24000/b. For example, if we want to transmit data at a speed of 9600 bps, we can use no more than 2 harmonics.

Another aspect of the coding method is the spectrum of frequencies required for signal transmission. With different coding methods - it is different.

The bit rate is equal to 1/tb, where tb is the bit length. The signal rate shows the rate of change of the signal level. Take the Manchester Code for example. The minimum size of a single signal is equal to half the bit interval. For a sequence of 0 or 1, a sequence of such unit signals will be generated. Therefore, the signal rate of the Manchester code is 2/tb.

In the general case, the ratio between the bit rate and the signal rate is determined by the formula

$$D = \frac{R}{b} ,$$

where D is the signal rate, R is the bit rate in bit/s, b is the number of bits per unit signal.

Consider the transmission of data in digital form using analog signals. A well-known example of such transmission is the use of telephone networks to transmit digital data. Telephone networks were created for the transmission and switching of analog signals in the voice frequency range from 300 to 3400 Hz. This range is not quite suitable for digital data transmission. Therefore, it is impossible to connect the source of such data directly to the telephone network. For this, a special modem device (MOmodulator-DEmodulator) is used. This device will convert a digital signal to analog and vice versa in the appropriate frequency range.

Analog modulation consists in transforming one or more parameters from the three main parameters of the carrier signal: amplitude, frequency and phase. Accordingly, there are three main modulation methods for converting digital data into analog form: amplitude, frequency and phase modulation.

In all these cases, the harmonic spectrum of the received signal is concentrated in the region of the frequency of the carrier signal.

In the case of amplitude modulation, the binary 0 and 1 are represented by an analog signal at the carrier frequency, but of different amplitude. Usually 0 corresponds to a signal with zero amplitude. Thus, with amplitude modulation, the signal S (t) has the form:

$$S(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary} - 1 \\ 0 & \text{binary} - 0 \end{cases} ,$$

where $A\cos(2\pi f_c t)$ carrier signal with amplitude A. The amplitude modulation method is not very efficient compared to other methods, so it is very sensitive to noise. It is most often used in combination with other types of modulation. In its pure form, it is used on a telephone line at speeds up to 1200 bps, as well as for transmitting signals over fiber optic channels.

In frequency modulation, binary 0 and 1 represent signals of different frequencies, shifted, as a rule, in relation to the carrier frequency by the same amount, but in the opposite direction:

$$S(t) = \begin{cases} A\cos(2\pi f_1 t) & for - 1 \\ A\cos(2\pi f_2 t) & for - 0 \end{cases},$$

where $f_c=f_1-\Delta=f_2+\Delta$, where Δ – frequency shift.

Full-duplex communication is called when data can be transmitted over the channel simultaneously in both directions. The power line has a band from 300 Hz to 3400 Hz. To ensure full duplex, this band is divided into two.

Frequency modulation is less sensitive to noise than amplitude modulation. It is most often used in radio modems at frequencies from 3 MHz to 30 MHz, as well as in high-frequency cables of local networks.

Phase modulation consists in the representation of digital data through a phase shift of signal. In the expression below, 0 is represented by a unit signal of the same phase as the previous one; 1 is represented by a single signal shifted in phase by 180º. For differential phase modulation, we get

$$S(t) = \begin{cases} A\cos(2\pi f_c t + \pi) & for - 1 \\ A\cos(2\pi f_c t) & for - 0 \end{cases},$$

Bandwidth efficiency can be significantly increased if a single signal encodes several bits. For example, by shifting the phase of a unit signal by 90º, the following method of encoding digital data, known as quadrature phase modulation, can be proposed:

$$S(t) = \begin{cases} A\cos(2\pi f_c t + \frac{\pi}{4}) & for \quad 11 \\ A\cos(2\pi f_c t + \frac{3\pi}{4}) & for \quad 10 \\ A\cos(2\pi f_c t + \frac{5\pi}{4}) & for \quad 00 \\ A\cos(2\pi f_c t + \frac{7\pi}{4}) & for \quad 01 \end{cases}.$$

This circuit can be improved to transmit three bits at once using 8 phase angles.

Multiplexing itself is the process of combining and transmitting two or more signals (channels) through the same path (physical line) without mutual influence. This is achieved by separating the signals in time or frequency, or by encoding the signal so that only the intended recipient can receive it.

Channel switching based on frequency multiplexing.

The technique of channel frequency multiplexing (FDM) was developed for telephone networks, but it is also used for other types of networks, such as cable television networks.

The technique of modulating a high-frequency carrier sinusoidal signal with a low-frequency speech signal is characteristic for the division of subscriber channels. As a result, the spectrum of the modulated signal is transferred to another range, which is symmetrically located relative to the carrier frequency and has a width that approximately coincides with the width of the modulating signal.

If the signals of each subscriber channel are transferred to their own frequency range, then the signals of several subscriber channels can be simultaneously transmitted in one broadband channel.

Output signals from subscribers of the telephone network are received at the inputs of the FDM switch. The switch transfers the frequency of each channel into its frequency range. Usually, the high-frequency range is divided into bands that are allocated for data transmission of subscriber channels (Fig. 4.1). So that the low-frequency components of the signals of different channels do not mix with each other, the bands are made 4 kHz wide, instead of 3.1 kHz, leaving an insurance gap of 900 Hz between them. In the channel between two FDM switches, the signals of all subscriber channels are simultaneously transmitted, but each of them occupies its own frequency band. Such a channel is called compacted.

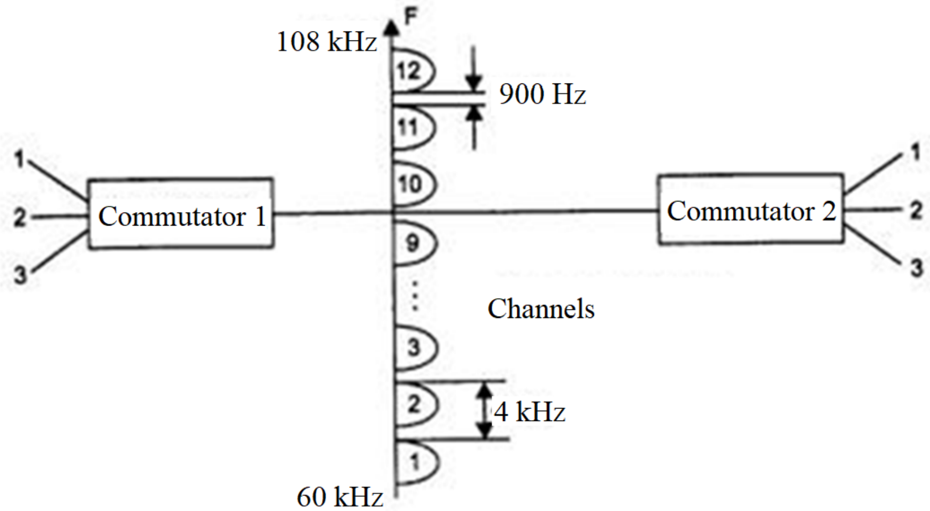

Figure 4.1. Switching based on frequency compression

The output FDM switch separates the modulated signals of each carrier frequency and transmits them to the corresponding output channel to which the subscriber's telephone is directly connected.

FDM switches can perform both dynamic and permanent switching. With dynamic switching, one subscriber initiates a connection with another subscriber by sending the subscriber's number to the network. The switch dynamically allocates one of the free bands of its compressed channel to this subscriber. With permanent switching by subscriber, the 4 kHz band is fixed for a long time by configuring the switch on a separate input, inaccessible to users.

The principle of switching on the basis of frequency division remains unchanged in networks of another type, only the limits of the bands allocated to individual channels change, as well as the number of low-speed channels in a condensed high-speed one.

Channel switching based on time division.

Switching based on the frequency division technique was designed for the transmission of continuous signals representing voice. When moving to a digital form of voice representation, a new multiplexing technique was developed, which focuses on the discrete nature of the transmitted data.

This technique is called TDM. Fig. 4.2 explains the principle of channel switching based on the TDM technique.

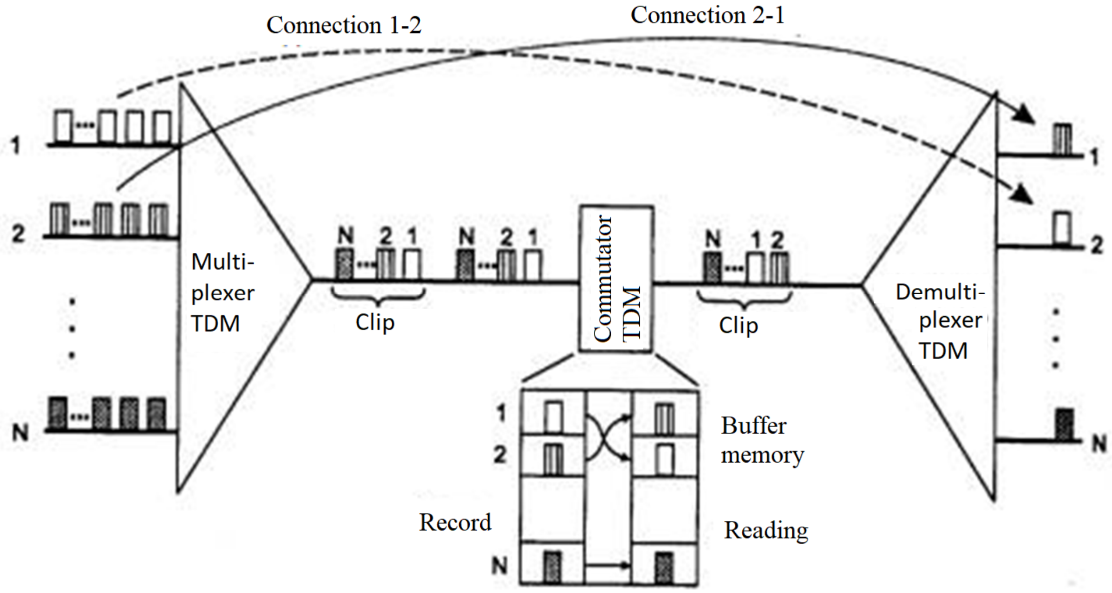

Figure 4.2. Switching based on channel division in time

The equipment of TDM networks - multiplexers, switches, demultiplexers - works in time division mode, serving all subscriber channels in turn during the cycle of its work. Each connection is allocated one time quantum of the equipment operation cycle, which is also called a time slot.

To perform the switching operation, bytes are extracted from the buffer memory not in the order of arrival, but in such an order that corresponds to the subscriber connections supported in the network. So, for example, if the first subscriber of the left part of the network should connect with the second subscriber in the right part of the network, then the byte written in the first cell of the buffer memory will be extracted from its second. By "shuffling" the bytes in the socket in the right way, the switch ensures the connection of end subscribers in the network.

Once allocated, the time slot number remains at the disposal of the "input channel-output slot" connection for the duration of the existence of this connection, even if the transmitted traffic is pulsating and does not always require the captured number of timeslots. This means that a connection in a TDM network always has a known and fixed bandwidth that is a multiple of 64 kbit/s.

The operation of TDM equipment resembles the operation of packet-switched networks, since each byte of data can be considered as some elementary packet. However, unlike a computer network packet, a TDM network "packet" does not have an individual address. Its address is a sequence number in the slot or an allocated timeslot number in the multiplexer or switch. Networks using the TDM technique require synchronous operation of all equipment, which has determined the second name of this technique - synchronous transmission mode (STM). Violation of synchronicity destroys the necessary switching of subscribers, because at the same time address information is lost. Therefore, the redistribution of time slots between different channels in TDM equipment is not possible, even if in some cycle of the multiplexer, the time slot of one of the channels is redundant, since there is no data to transmit at the input of this channel at that moment.

There is a modification of the TDM technique called statistical time division (Statistical TDM, STDM). This technique is designed specifically so that with the help of temporarily free timeslots of one channel, the bandwidth of others can be increased. To solve this problem, each byte of data is supplemented with an address field of a small length, for example, 4 or 5 bits, which allows multiplexing 16 or 32 channels. However, the STDM technique has not found widespread use and is mainly used in non-standard equipment for connecting terminals to mainframes. The development of the ideas of statistical multiplexing became the technology of asynchronous transmission mode - ATM, which incorporated the best features of channel and packet switching techniques.

TDM networks can support either dynamic switching mode or permanent switching mode, or sometimes both.

There is equipment that supports only the permanent switching mode. It includes equipment of type T1/E1, as well as high-speed SDH equipment. Such equipment is used to build primary networks, the main function of which is to create dedicated channels between switches that support dynamic switching.

Today, almost all data - voice, images, computer data - is transmitted in digital form. Therefore, dedicated channels of TDM technology, which provide the lower level for digital data transmission, are universal channels for building networks of any type: telephone, television and computer.

4.3 Experimental modeling of the TDM method

Let's consider the method of implementing the transmission of 8 analog signals on one channel. We will use the multiplexing method with time compression. As a multiplexer and demultiplexer, we will use specialized microcircuits ADG408BR. The multiplexer is a switch of 8 channels to one.

An example of a transmitter circuit of 8 analog signals is shown in Fig. 4.3.

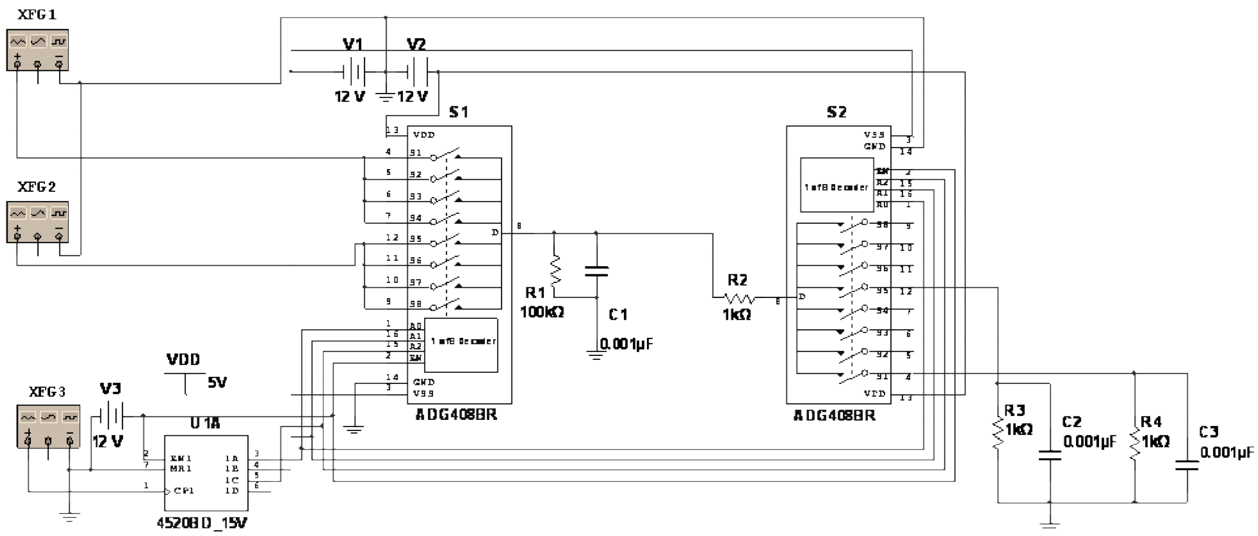

Figure 4.3. Transmitter scheme of 8 analog signals on one line

Microcircuits S1, S2 represent, respectively, a multiplexer and a demultiplexer. They are controlled according to the signals on the control inputs given by the rectangular pulse generator XFG3 and the frequency divider U1A. The frequency at each subsequent control output is half the frequency of the previous output (Fig. 4.4).

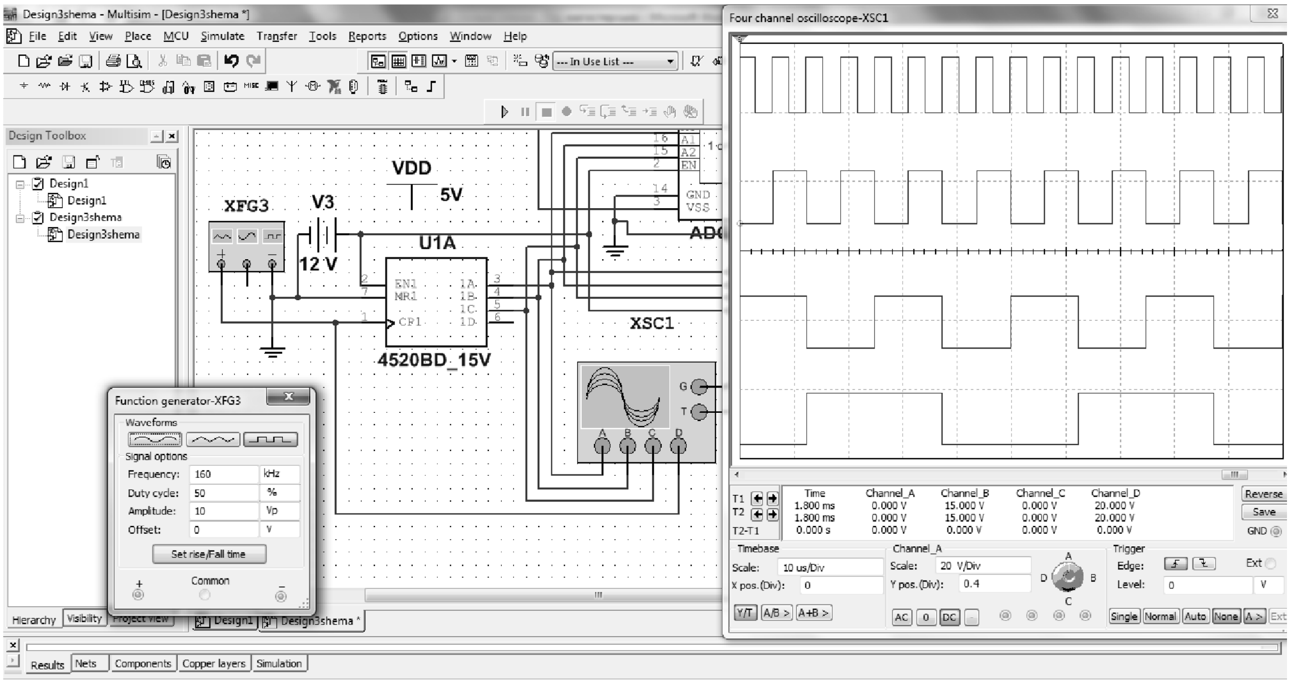

Figure 4.4. View of multiplexer control signals

Thus, in accordance with the truth table, the multiplexer will alternately switch the signal from the first input to the output, when the next control pulse arrives, the signal from the second input, when the next control pulse arrives, the signal from the third input, and so on. Then the process is repeated. Thus, a signal will be formed at the output of the multiplexer, which will contain 8 cells, each of which will correspond to a part of the signal from the corresponding input.

The scheme uses two analog signals for simplification - a harmonic with a frequency of 1 kHz and an amplitude of 1 V, and triangular pulses with a frequency of 500 Hz and an amplitude of 500 mV. The first signal is applied simultaneously to the first four inputs, the other to the next four inputs. An example of the output signal is shown in Fig. 4.5.

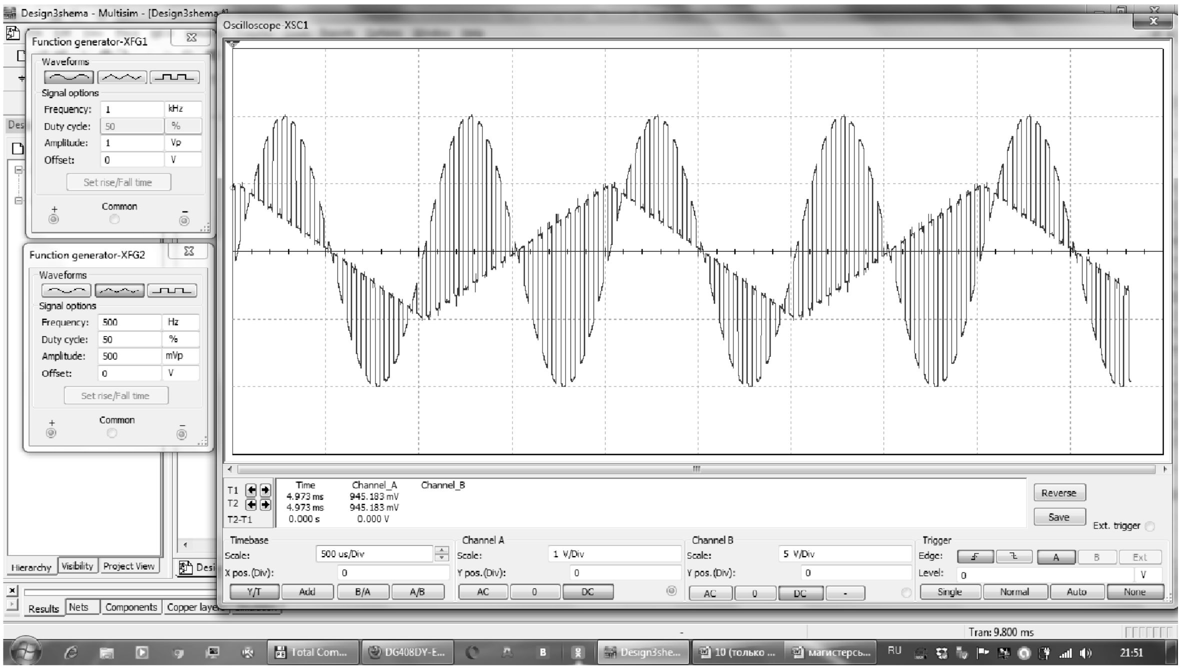

Figure 4.5. The signal at the output of the multiplexer

Demultiplexer S2 will decode the received signal, distributing the cells to the corresponding outputs of the demultiplexer. The duration of the cell will be determined by the period of the control clock pulses. To simplify the control of the multiplexer is synchronized with the control of the demultiplexer. An example of two output signals selected from the first and fifth outputs of the demultiplexer is shown in Fig. 4.6.

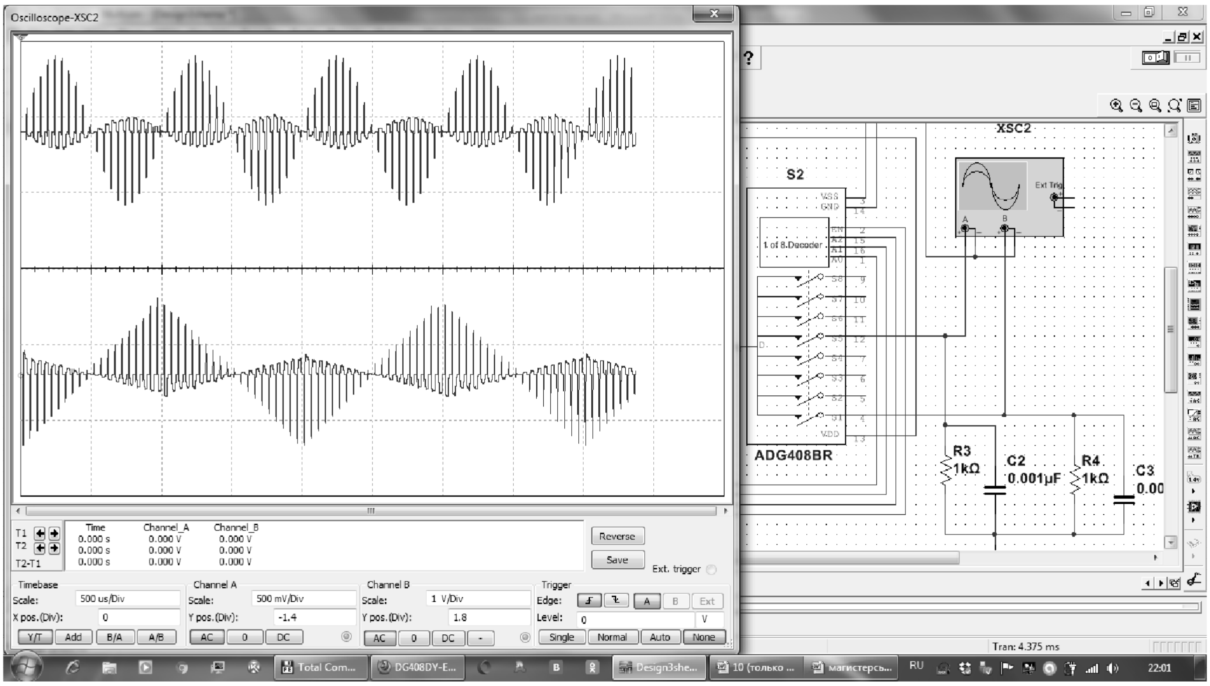

Figure 4.6. View of the output signals of the demultiplexer

Thus, if we eliminate the effect of overmodulation, we managed to transmit two analog signals on one channel and separate them. Using detectors of AM signals, it is possible to completely restore the incoming harmonic signal and triangular pulses.

4.4 Conclusions to chapter 4

The chapter analyzes solutions for building data reception/transmission devices in PLC systems, equipment used to organize this network.

The method of implementing the transmission of 8 analog signals on one channel, which can be used as an electrical network, is considered. The method of multiplexing with time compression is used. Specialized microcircuits ADG408BR were used as a multiplexer and demultiplexer. The electrical principle diagram of the device for receiving/transmitting data over the power grid and a separate system of coding, transmission over one communication line, reception and decoding of 8 analog signals have been developed. The circuit itself and the output and intermediate signals were simulated in the Multisim environment.

CHAPTER 5
LIFE SAFETY, BASICS OF LABOR PROTECTION

4.1 Safety when setting up computer networks

Before starting work, you should make sure that the wiring, switches, sockets, with which the equipment is connected to the network, are in good condition, that the computer is grounded, that it is working,

In order to avoid damage to the insulation of wires and the occurrence of short circuits, it is not allowed to: hang anything on wires, paint over and whitewash cords and wires, lay wires and cords behind gas and water pipes, behind heating system batteries, pull out the plug from the socket by the cord, force must be attached to the plug body.

To avoid electric shock, it is forbidden: to frequently turn on and off the computer without the need, to touch the screen and to the back of the computer blocks, to work on computer equipment and peripheral equipment with wet hands, to work on computer equipment and peripheral equipment that have violations of the integrity of the case, violations of wire insulation, faulty indication of power on, with signs of electrical voltage on the case, put foreign objects on computer equipment and peripheral equipment.

It is forbidden to clean the electrical equipment from dust and dirt while energized.

It is forbidden to check the operability of electrical equipment in premises unsuitable for operation with conductive floors, damp, which do not allow accessible metal parts to be grounded.

It is unacceptable to carry out repairs of computer equipment and peripheral equipment under voltage. Repair of electrical equipment is carried out only by specialist technicians in compliance with the necessary technical requirements.

To avoid electric shock, when using electrical appliances, do not touch any pipelines, radiators, metal structures connected to the ground at the same time.

Take special care when using electricity in damp rooms.

Safety requirements in emergency situations

If a malfunction is detected, immediately turn off the power to the electrical equipment, notify the administration. Continuation of work is possible only after the malfunction has been eliminated.

If a broken wire is found, it is necessary to immediately inform the administration about this, take measures to exclude people from contact with it. Touching the wire is life-threatening.

In all cases of electric shock to a person, a doctor is immediately called. Before the arrival of the doctor, it is necessary, without wasting time, to start providing first aid to the victim.

It is necessary to immediately start artificial respiration, the most effective of which is the mouth-to-mouth or mouth-to-nose method, as well as external heart massage.

Artificial respiration to the person affected by electric current is performed until the arrival of a doctor.

It is forbidden to have flammable substances in the workplace.

In the premises it is prohibited:

a) light a fire

b) turn on electrical equipment if the room smells of gas;

c) smoke;

d) dry something on heaters;

e) close the ventilation openings in electrical equipment

Sources of ignition are:

a) a spark when discharging static electricity

b) sparks from electrical equipment

c) sparks from impact and friction

d) open flame

In the event of a fire hazard or fire, the personnel must immediately take the necessary measures to eliminate it, at the same time notify the administration about the fire.

Safety requirements at the end of work

After finishing work, it is necessary to de-energize all computer equipment and peripheral equipment. In the case of a continuous production process, it is necessary to leave only the necessary equipment switched on.

4.2 Lighting of the computer worker's workplace

Among the factors of the external environment that affect the human body during work, light occupies one of the first places. After all, it is known that almost 90% of all information about the environment a person receives through the organs of vision. During the implementation of any work, eye fatigue mainly depends on the intensity of the processes accompanying visual perception. Such processes include adaptation, accommodation and convergence.

Adaptation – adjustment of the eye to changing lighting conditions (illumination level).

Accommodation is the adaptation of the eye to clear vision of objects that are at different distances from it due to changes in the curvature of the lens.

Convergence is the ability of the eye to take a position when viewing close objects, in which the visual axes of both eyes intersect on the object.

Light affects not only the function of the organs of vision, but also the activity of the body as a whole. With poor lighting, a person gets tired quickly, works less productively, and the potential danger of wrong actions and accidents increases. According to statistics, up to 5% of injuries can be explained by insufficient or irrational lighting, and in 20% it contributed to the occurrence of injuries. After all, poor lighting can lead to occupational diseases.

To create optimal conditions for visual work at the computer, not only the amount and quality of lighting, but also the color environment should be taken into account. Thus, with light painting of the interior, due to the increase in the amount of reflected light, the level of illumination increases by 20-40% (with the same power of light sources), the sharpness of shadows decreases, and the uniformity of lighting improves.

Artificial lighting is provided in all industrial and domestic premises where there is not enough natural light, as well as for lighting premises in the dark period of the day. When organizing artificial lighting, it is necessary to ensure favorable hygienic conditions for visual work and at the same time take into account economic indicators.

In order to create favorable conditions for visual work at the computer, which would exclude rapid eye fatigue, the occurrence of occupational diseases, accidents and contribute to increasing labor productivity, lighting should meet the following requirements:

- should not have a blinding effect both from the light sources themselves and from other objects in the field of vision;
- ensure sufficient uniformity and constancy of the level of illumination in the rooms in order to avoid frequent re-adaptation of the visual organs;
- do not create sharp and deep shadows (especially moving ones) on the work surface;
- the contrast of illuminated surfaces must be sufficient to distinguish details;
- do not create dangerous and harmful production factors (noise, thermal radiation, dangerous electric shock, fire and explosion hazard of lamps).

CONCLUSIONS

Based on the results of the qualification work, the following conclusions can be drawn:

1. A promising way of creating a cable network is the organization of data transmission over the wires of the power supply network using the so-called PLC technologies. However, a significant drawback of PLC technologies, which slows down their spread, is the inability to withstand the effects of household electrical interference. In addition, the extensiveness of the transmission environment and the influence of interference significantly limit the speed of information exchange, but, given the width of the available spectrum, this problem is practically solved with the help of high-performance signal processors by dividing data stream on several parallel ones and transmitting them through different channels. In this case, it is promising to use the method of data exchange over one communication channel based on time compression technologies.

2. The methods of increasing the bandwidth of networks are analyzed, in particular the method of time multiplexing and the possibility of its application to PLC technology.

3. A study of methods of physical implementation of PLC technologies, methods of coding data and analog signals was conducted, and it was established that the application of the multiplexing/demultiplexing process will provide an opportunity to implement multi-channel data transmission over the power grid.

4. The implementation and modeling of the process of multi-channel data exchange in the Multisim environment was carried out. The basis of data reception/transmission is the multiplexing process.

5. The method of implementing the transmission of 8 analog signals on one channel, which can be used as an electrical network, is considered. The method of multiplexing with time compression is used. Specialized microcircuits ADG408BR were used as a multiplexer and demultiplexer. The electrical principle diagram of the device for receiving/transmitting data over the power grid and a separate system of

coding, transmission over one communication line, reception and decoding of 8 analog signals have been developed. The circuit itself and the output and intermediate signals were simulated in the Multisim environment.

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