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METHOD FOR THE DIAGNOSTICS OF SYNCHRONIZATION DISTURBANCES IN THE TELECOMMUNICATIONS NETWORK OF A CRITICAL USED COMPUTER SYSTEM

Relevance of the study. To improve the quality of service (QoS), the work of all network technologies, protocols, and individual traffic management mechanisms is constantly optimized. It is known that the quality of information transmission in modern telecommunication equipment is affected by the quality of synchronization devices. Synchronization is a means of maintaining the operation of all digital equipment in a data transmission network at one average speed, which must exist at three levels: bit synchronization, synchronization at the level of channel intervals (time slot) and frame synchronization. Therefore, the lack of synchronization of the computer system at the required level can lead to a significant decrease in QoS. At the same time, the requirements for ensuring these indicators are significantly tightened in the face of an increase in the load of network resources. **Subject** of study: computer system synchronization. The **aim** of the article is to develop a method for diagnosing synchronization disturbances in the telecommunications network of a computer system of critical application by increasing the resolution of an acousto-optical spectrum analyzer. Research **results**. The influence of non-stationary data transmission in the telecommunications subsystem of the computer system under study is analyzed. The analysis and classification of the causes of computer network synchronization failure of a critical application computer system is carried out. The article describes the consequences of a violation of computer network stabilization for ensuring the quality of service provided by various frequently used services. Proposed the use of acousto-optic spectrum analyzer with spatial integration for diagnostics of violations of the synchronization network. In work the analysis of the use of acousto-optic spectrum analyzers. The conducted research allowed us to obtain an analytical expression for the output signal of the spectroanalyzer when two rectangular pulses with different carrier frequencies, durations and delay times are received at its input. This result, as well as the numerical calculations provided, allowed us to develop General recommendations for increasing the resolution of the acousto-optical spectrum analyzer, and thus create theoretical prerequisites for improving the synchronization of the computer system. The given analytical relations and numerical estimates were experimentally verified by means of system simulation. **Conclusions**. As a result of the research, a method of diagnostics of synchronization violations in the telecommunications network of a computer system of critical application was proposed. The method is based on increasing the resolution of the measuring system based on an acoustooptic spectrum analyzer.

Keywords: computer system; telecommunication network; synchronization; acousto-optic spectrum analyzer.

The relevance of research

Expanding the range of information transmission services and improving the quality of service are key trends in the development of the telecommunication network. To improve the quality of service (QoS), the work of all network technologies, protocols, and individual traffic management mechanisms is constantly optimized. It is known that the quality of information transmission in modern telecommunication equipment is affected by the quality of synchronization devices. Therefore, the lack of synchronization of the computer system at the required level can lead to a significant decrease in QoS. At the same time, the requirements for ensuring these indicators are significantly tightened in the face of increased load of network resources. Consequently, the quality of functioning of existing and promising computer systems and networks cannot be improved without taking into account the effects of synchronization and ensuring appropriate synchronization indicators.

Formulation of the problem

In the process of transmitting information in a computer system, including a computer data network, there is always a problem of insufficient synchronization, which is caused by various software and hardware factors. Synchronization is a means of maintaining the operation of all digital equipment in a data transmission network at one average speed, which must exist at three levels: bit synchronization, synchronization at the level of channel intervals (time slot) and frame synchronization. The network clock located in the source node controls the transmission frequency of bits, frames, and channel slots through this node. The secondary network generator located in the receiving node is designed to control the speed of reading information. The purpose of network clock synchronization is the coordinated operation of the primary generator and receiver so that the receiving node can correctly interpret the digital signal. The difference in the synchronization of nodes located on the same network can lead to a skipping or re-reading by the receiving node of information sent to it. Thus, improving the quality of functioning of existing and planned computer systems by increasing the system synchronization indicators is an urgent research task.

Literature analysis

Much attention is paid to the study of factors that affect the quality of service (QoS) of computer networks. [3–21]. Studies of the influence of data transmission channel throughput were conducted in [1–4]. The analysis [7, 8] of the influence of the architecture of computer systems and computer networks was carried out in [5–8]. Works [9–14] are devoted to the analysis of packet queues and the development of a comprehensive approach to QoS diagnostics of computer systems and networks. In addition, there is a separate question about the relationship

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between QoS indicators and meeting the requirements for computer system transactions [15-20]. In [21], the main parameters of the basic telecommunications network that affect the quality of transaction execution of a computer system are highlighted. In particular, it is shown that when choosing special platforms with centralized management (converged and hyperconverged), synchronization of the computer system plays a significant role. To ensure the required level of synchronization, it is necessary to monitor the stability of the computer system generators [22, 23]. Technical means of such control are presented in [24-27]. In [28], a method for rapid calculation of the jitter value of a telecommunications network is developed based on a method for increasing the resolution of acousto-optical spectroanalysts, which allows for dynamic reconfiguration of network parameters

Aim of the article.

The aim of the article is to develop a method for diagnosing synchronization disturbances in the telecommunications network of a computer system of critical application by increasing the resolution of an acousto-optical spectrum analyzer.

Types of computer system synchronization

Bit synchronization consists in the fact that the transmitting and receiving ends of the transmission line operate at the same clock frequency, so the bits are read correctly. To achieve bit synchronization, the receiver can receive its clock from the incoming line. Bit synchronization includes issues such as transmission line jitter and unit density. These issues are raised when requirements for synchronization and transmission systems are presented.

Time slot synchronization connects the receiver and transmitter so that the channel slots can be identified to retrieve data. This is achieved by using a fixed frame format to separate bytes. The main synchronization problems at the channel interval level are frame change time and frame loss detection.

Frame synchronization is caused by the need for phase matching of the transmitter and receiver in such a way that the beginning of the frame can be identified. A frame in a DS1 or E1 signal is a group of bits consisting of twenty-four or thirty bytes (channel slots), respectively, and one frame synchronization pulse. The frame time is 125 microseconds. Channel intervals correspond to users of specific (telephone) communication channels.

The synchronization characteristics in the hierarchical network of the transmitter-receiver are determined by three components: the error of the control generator, the characteristics of the devices that distribute the reference signal, and the characteristics of the generators of the receiver receiving the reference signal through these devices. It is known that the instability of the synchronization frequency of the control generator usually weakly affects the overall instability in the synchronization networks. The timing characteristics are mainly determined by the combination of the characteristics of the distribution devices and the receiver generator. In real networks, the receiver generator connected to the control generator will operate at a long-term frequency different from the frequency of the control generator. The frequency instability of the receiver oscillator is usually 10–100 times higher than the frequency instability of the control oscillator. Therefore, receiver generators cause most of the synchronization errors and slippage in networks.

For example, if the equipment transmitting information operates at a frequency higher than the frequency of the receiving equipment, then the receiver cannot monitor the flow of information. In this case, the receiver will periodically 6 pass part of the information transmitted to it. Loss of information is called slippage deletion. In the event that the receiver operates at a frequency higher than the frequency of the transmitter, the receiver will duplicate information while continuing to operate at its own frequency and still communicate with the transmitter. This duplication of information is called repetition slippage.

The influence of one or more slippages on the quality of services provided in digital communication networks depends on the type of these services [1-6]. The following describes the effect of single slippage on various types of services. When providing telephone (voice) communication services, slippage can cause random sound clicks. These clicks are not always audible and do not lead to serious speech distortions. Therefore, telephone services are not critical to slippage. The frequency of occurrence of slippages up to several slippages per minute is considered acceptable. Single slippage leads to distortion or missing lines in the received fax message. Slippage can cause up to 8 scanned lines to disappear. This corresponds to a gap of 0.08 inches of vertical space. On a standard printed page, slippage looks like the absence of the top or bottom half of the printed line. A prolonged occurrence of slippage will result in the need to resubmit the pages affected by them. Retransmission cannot be automated and is done manually by the user. The effect of slippage on data transmission using modems is manifested in the form of long error packets in the range from 10 milliseconds to 1.5 seconds. When these errors occur, the terminal receiver connected to the modem receives corrupted data. As a result, the user must retransmit the data. If slippage occurs during a videotelephone session, the image disappears. Subscribers are asked to re-establish a connection to restore the image. The effect of slippage on digital data transmission depends on the protocol used. In protocols that do not provide for retransmission, data may be skipped, repeated, or corrupted. Possible loss of frame synchronization causes the distortion of many frames when resuming the arrival of pulses of frame synchronization. Retransmission protocols have the ability to detect slippage and initiate retransmission. Initializing and performing such a relay usually takes one second. Therefore, slippage will affect throughput, usually resulting in a loss of a second transmission time. When digitally transmitting images (for example, video conferencing), slippage usually causes a part of the image to distort or freeze for up to 6 seconds. The severity and

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duration of the distortion depends on the coding and compression equipment used 8. The most significant distortion occurs when using low-speed decoding equipment. Slippage is mostly affected by the provision of encrypted data services. Slippage leads to the loss of the encoding key. Loss of the key results in inaccessibility of the transmitted data until the key is retransmitted and communication is repeated. Therefore, all communication stops. More important is the need to relay the key significantly affects security. For many security-related applications, slippage in excess of 1 per day is considered unacceptable.

To control slippage, pointer alignment events, and error beams caused by synchronization, ITU and ANSI have set several requirements for synchronization performance. For international connections, the slip rate threshold for an "acceptable" connection is set by the ITU at the level of one slip for every five hours. To achieve a satisfactory slippage rate during end-to-end transmission, the long-term maximum frequency instability at the output of the digital synchronization system is 1x10-11. This requirement was established by both ANSI [29] and ITU [30, 31]. The requirements for short-term instability allow from 1 to 10 microseconds with errors per day at the output of each network clock [29, 30].

To determine the moment of synchronization disruption in critical use computer systems, it is necessary to use appropriate computing systems, which should determine the current frequency of the generators in the network with high speed and accuracy. Currently, such hardware is acousto-optical spectrum analyzers (AOSA) with spatial integration. The main characteristics and ways to increase the resolution of this device will be investigated in the next part of the proposed work.

Basic relationships and formulations

The structural diagram of the analyzer [22] is shown in fig. 1, where 1 - laser. 2 - capacitor, 3 - collimator, 4 - acousto-optic modulator (AOM), 5 - Fourier lens, 6 - recording device are indicated and the used coordinate systems x_1, y_1, z_1 and x_2, y_2, z_2 are shown.

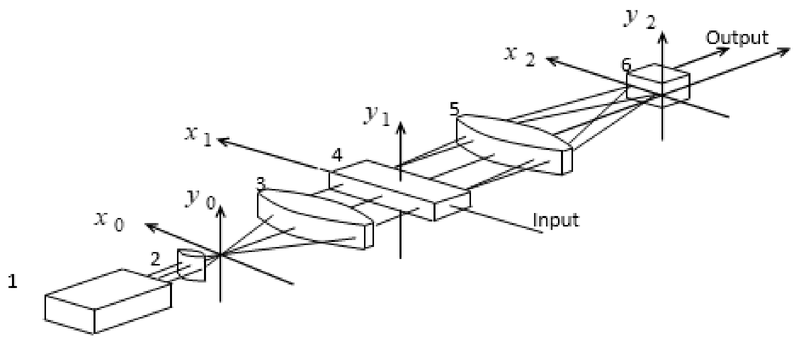

Fig. 1. The structural diagram of an acousto-optical spectrum analyzer

The capacitor and collimator convert the monochromatic wave $\exp[i(\omega_L t - k_L z_1)]$ emitted by the laser into a plane wave incident at an angle θ_i on the AOM $E_0(x_1,t) = r(x_1)\exp[i(\omega_L t - k_L z_1 + k_L x_1 \mathrm{tg}\theta_i)]$ with a given aperture $r(x_1) = \begin{cases} 1, & |x_1| \le D/2; \\ 0, & |x_1| > D/2, \end{cases}$ where $D/2$ is the half-width of the AOAC collimator.

An analyzer receives a radio signal $s(t)$, which is then converted into a traveling acoustic wave $r(x_1)s\left(t - \frac{x_1 + D/2}{v}\right)$ propagating with the speed v. In the linear approximation, the field of the light wave of the first diffraction order is represented as

$$E_1(x_1,t) = Ar(x_1)s\left(t - \frac{x_1 + D/2}{v}\right)\exp[i(\omega_L t - k_L z_1 + k_L x_1 \mathbf{tg}\theta_i)], \quad (1)$$

where A characterizes the modulating effect of an acoustic wave on laser radiation passing through AOM.

In the output plane of the analyzer coinciding with the rear focal plane of the lens 5, the field is written as

$$E_2(x_2,t) = \int_{-\infty}^{\infty} dx_1 E_1(x_1,t)\exp\left(i\frac{2\pi}{\lambda F}x_1 x_2\right), \quad (2)$$

where F is a lens focal length, λ is a laser wavelength.

Using the expansion (1), formula (2) can be transformed to the form

$$E_2(\omega_x,t) = Av\exp(-i\omega_x T/2)\int_0^T d\tau \exp(i\omega_x \tau)s(t-\tau), \quad (3)$$

where the non-essential multiplier $\exp[i(\omega_L t - k_L z_1)]$ is omitted and the notation $\omega_x = v\left(\frac{2\pi}{\lambda F}x_2 + k_L \mathbf{tg}\theta_i\right)$ is entered, and there is a duration of the time sample corresponding to the light aperture D. In formula (3) and everywhere below, the dependence of the field E_2 on the x_2 using $\omega_x = \omega(x_2)$.

Let's consider the incoherent transformation of the output light distribution into an electrical signal proportional to the time integral of its intensity

$$u(\omega_x, T_R) = \int_0^{T_R} dt\,|E_2(\omega_x,t)|^2, \quad (4)$$

where T_R is the registration time, counted from the moment $t = 0$.

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Resolution of pulses with a rectangular envelope

Let two rectangular-shaped pulses of the same unit amplitude simultaneously arrive at the analyzer input, but with different carrier frequencies ω_a, durations τ_a and delay times t_a ($a = 1, 2$): $s(t) = s_1(t) + s_2(t)$, where

$$s_a(t) = \begin{cases} 0, & t < t_a; \\ \sin\left(\omega_a(t - t_a)\right), & t_a \le t \le t_a + \tau_a. \\ 0, & t > t_a + \tau_a. \end{cases} \quad (5)$$

Substituting (5) into (3) gives

$$E_2(\omega_x, t) = E_2^{(1)}(\omega_x, t) + E_2^{(2)}(\omega_x, t), \quad (6)$$

where the summand $E_2^{(a)}(\omega_x, t)$ corresponding to the response to the a-th input pulse ($a = 1, 2$), in the case of a time aperture T that is shorter than the pulse τ_a duration, up to an insignificant factor $Av\exp(-i\omega_x T/2)$ for further consideration, is given by the following expressions:

at $T_R < t_a$:

$$E_2^{(a)}(\omega_x, t) = 0; \quad (7)$$

at $t_a \le T_R < t_a + T$:

$$E_2^{(a)}(\omega_x, t) = e_a(t - t_a, t - t_a, t - t_a); \quad (8)$$

at $t_a + T \le T_R < t_a + \tau_a$:

$$E_2^{(a)}(\omega_x, t) = e_a(T, 2(t - t_a) - T, T); \quad (9)$$

at $t_a + \tau_a \le T_R < t_a + \tau_a + T$:

$$E_2^{(a)}(\omega_x, t) = e_a(t - t_a - \tau_a + T, t - t_a + \tau_a - T, \tau_a + T - t + t_a); \quad (10)$$

at $T_R \ge t_a + \tau_a + T$:

$$E_2^{(a)}(\omega_x, t) = 0. \quad (11)$$

In formulas (8-10), a notation for a function of three variables is introduced to shorten the entry

$$e_a(s_1, s_2, s_3) = e^{i\frac{\omega_x s_1}{2}}\left[e^{i\frac{\omega_a s_2}{2}}\frac{\sin(\omega_a^- s_3/2)}{\omega_a^-} - e^{-i\frac{\omega_a s_2}{2}}\frac{\sin(\omega_a^+ s_3/2)}{\omega_a^+}\right],$$

where $\omega_a^\pm = \omega_x \pm \omega_a$.

Thus, by virtue of (4) and (6), the total recorded signal can be written as

$$u(\omega_x, T_R) = u_1(\omega_x, T_R) + u_2(\omega_x, T_R) + u_{12}(\omega_x, T_R), \quad (12)$$

where $u_a(\omega_x, T_R) = \int_0^{T_R} dt\,|E_2^{(a)}(\omega_x, t)|^2$ represent the output signal when there is only the a-th pulse at the input, and the third term

$$u_{12}(\omega_x, T_R) = 2\,\mathrm{Re}\left[\int_0^{T_R} dt E_2^{(1)}(\omega_x, t)\overline{E_2^{(2)}(\omega_x, t)}\right] \quad (13)$$

arises as a result of interference of the first two (the bar above means complex conjugation).

The expressions for $u_a(\omega_x, T_R)$ in the case of a temporary aperture T shorter than the duration of each of the pulses τ_i are given in [32]. Explicit expressions for $u_{12}(\omega_x, T_R)$ are obtained after substituting formulas (7–11) in (13) and are not given here only because of their cumbersomeness, since they take into account all possible options for the relative position along the time axis of the steps of entering the aperture, its complete filling, and exit from the aperture of each of pulses. The physical interpretation of these expressions is similar to that given in [32] for the quantities $u_a(\omega_x, T_R)$.

Thus, the set of formulas (7–13) determines the output signal of the spectrum analyzer when two rectangular pulses with different carrier frequencies, durations, and delay times arrive at its input.

Numerical calculations and discussion

The most significant qualitative and quantitative characteristics of the frequency resolution can be seen already on the example of two pulsed signals that differ only in carrier frequencies.

When conducting numerical calculations, it was assumed that the duration of the input pulses $\tau_1 = \tau_2 = \tau = 1000$, and the value of the time aperture $T = 800$ (time was measured in arbitrary units, which were determined by the ratio $\omega_1 = 1$). The delays of both pulses without loss of generality were assumed to be equal $t_1 = t_2 = 0$, and the time evolution of the output signal was considered over the interval $0 \le T_R \le \tau + T$, which made it possible to reveal all the features of the time course, since then the signal went to a stationary value [32].

Fig. 2 illustrates the results of calculations of the time evolution of the dependence of the output signal $u(\omega_x, T_R)$ on a value ω_x proportional to the coordinate x_2 for the relative detuning of the carrier frequencies $\varepsilon = (\omega_2 - \omega_1)/\omega_1 = 0{,}02$.

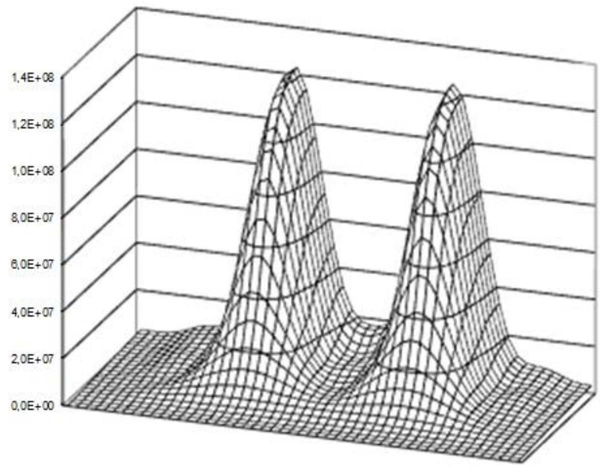

Fig. 2. The output signal of the spectroanalyzer when the carrier frequencies of the input pulses are greatly disrupted

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The axis x corresponds to the value ω_X, and the axis y to the value T_R, with the left peak in this and subsequent figures representing the input pulse with the carrier ω_1, the right – the pulse with the carrier ω_2.

As can be seen from fig. 2, for such a detuning ε, the presence of the interference term in expression (12) is practically insignificant, and the pulses are reliably distinguishable even after the stage of filling the AOM aperture with them.

Fig. 3 shows the results of calculations of the output signal $u(\omega_x, T_R)$ for half as much as in fig. 2, detuning $\varepsilon = 0,01$ with the remaining parameters unchanged. A comparison of these figures shows that for a given mismatch value, a reliable resolution of pulses is possible only at a sufficiently large (close to the stage of reaching the stationary value) observation time.

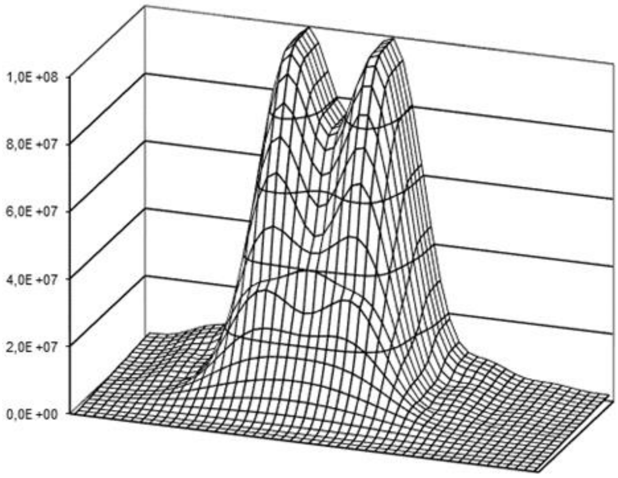

Fig. 3. Output signal with moderate mismatch of carrier frequencies

In addition, if two (even weakly distinguishable) pulses are recorded for the detuning $\varepsilon = 0,02$ at the very beginning, and at the grow of T_R their difference increases, then for the $\varepsilon = 0,01$, both pulses are absolutely indistinguishable (look like a single whole) and only during registration, if its time large enough, their resolution is getting more and more complete.

The calculation data in fig. 3 also illustrates the weak efficiency of the signal discrimination algorithm at the average (according to the Rayleigh criterion) resolution of the output pulses based on filtering the interference term in (12) by passing through a low-pass filter (compared to the beat frequency proportional to the difference $\omega_2 - \omega_1$). Since at such detuning values, the interference term is comparable in magnitude with the responses from individual pulses and makes a comparable contribution to the total output signal, its filtering will lead to a decrease in the level of the useful signal and, accordingly, a decrease in the efficiency of such an algorithm.

The calculation results presented in fig. 4, differ from the previous two by an even greater magnitude of detuning: $\varepsilon = 0,005$. The nature of the change in the output signal is the same as in fig. 3: first, both impulses look as a single indistinguishable, and only in the process of registration the dependence curve $u(\omega_x, T_R)$ of ω_x becomes a two-hump. However, even when the signal reaches a stationary value, this bumpiness is small, and the presence of a second pulse against the background of the first one can only indirectly judge the increased total amplitude of the output signal compared to the previous figure.

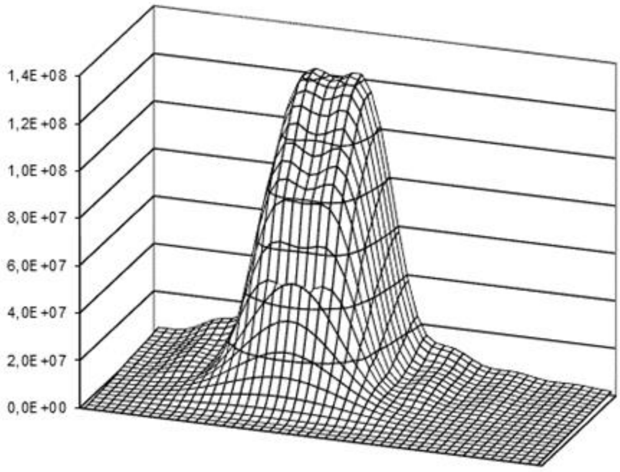

Fig. 4. The output signal with a small detuning carrier frequencies

However, it is easy to see that the total signal from two completely identical pulses is only four times the signal from a single pulse, which may not be enough for devices whose parameters are similar to those used in the calculations in this article.

Thus, to distinguish between the carrier frequencies of the input pulses at medium and small values of the detuning, the general necessary condition is a sufficiently large (compared with the total duration of the input pulse and time aperture of the spectrum analyzer) recording time. Such an increase in the resolution of an acousto-optical spectrum analyzer will improve the quality of synchronization diagnostics of critical use computer systems.

Diagnostics of synchronization failures

A method for diagnosing synchronization disruptions in a telecommunication network consists in determining the moment of desynchronization of the information transmission network of a critical computer system. Most digital communication systems using coherent modulation require all three levels of synchronization: phase, symbol and frame. Incoherent modulation systems usually require only symbolic and frame synchronization; since the modulation is incoherent, accurate phase synchronization is not required. In addition, incoherent systems require frequency synchronization. Frequency synchronization differs from phase synchronization in that the copy of the carrier generated by the receiver may have arbitrary phase shifts from the received carrier.

Network out of sync diagnostics require high-precision phase and frequency measurements of the carrier frequency of the master oscillators of the receiver and transmitter with high resolution of the used hardware.

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Carrier frequency measurements will allow phase synchronization calculations and determination of the moment of frequency synchronization violation. To ensure such measurements, the developed method proposes the use of AOSA with spatial integration. To increase the resolution of AOSA with spatial integration, it is necessary to increase the interval of signal accumulation, which can lead to an increase in the time required for network analysis. Thus, the proposed method will improve the accuracy of determining the fact of a synchronization violation, but this requires an increase in the time and complexity of the analysis. Further improvement of this method requires a significant increase in the resolution of the AOSA for comparing the reference signals with the received ones (by the principle of maximum likelihood).

Conclusions

The paper proposes a method for the diagnosis of disorders of the synchronization of telecommunications networks computer systems for critical applications. The method is based on the higher resolution of the measuring system on the basis of acousto-optic spectrum analyzer. The main findings of the study are:

- the article presents the results of the analysis of factors affecting the violation of the stabilization computer networks computer systems for critical applications. Established qualitative and quantitative indicators of system synchronization;

- this paper analyzes the functionality of the use of acousto-optic spectrum analyzers for quality control of synchronization of computer networks, presents the basic mathematical relations that determine the parameters of the output signal of AOAS;

- as a result of numerical calculations, it was found that to distinguish the carrier frequencies of input pulses at moderate and small values of the detuning the General necessary condition is large enough (compared to the total duration of the input pulse and the time of the aperture spectrum analyser) the time of registration;

- the main outcome of the research opportunities enhance the resolution of OAS is that there is the theoretical background to determine the synchronous operation of generators in the network information computer system of critical usage, which will lead to increased quality of service (QoS);

- further investigation in this direction, it is desirable to devote to obtaining quasi-optimal and optimal methods of resolution enhancement of AOAS to determine the parameters of desynchronization of the computer network.

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МЕТОД ДІАГНОСТИКИ ПОРУШЕНЬ СИНХРОНІЗАЦІЇ ТЕЛЕКОМУНІКАЦІЙНОЇ МЕРЕЖІ КОМП'ЮТЕРНОЇ СИСТЕМИ КРИТИЧНОГО ЗАСТОСУВАННЯ

Актуальність дослідження. Для поліпшення якості обслуговування (QoS) постійно оптимізується робота всіх мережевих технологій, протоколів і окремих механізмів управління трафіком. Відомо, що на якість передачі інформації в сучасному телекомунікаційному обладнанні впливає якість пристроїв синхронізації. Синхронізація – це засіб підтримки роботи всього цифрового устаткування в мережі передачі інформації на одній середній швидкості, яке повинно існувати на трьох рівнях: бітова синхронізація, синхронізація на рівні канальних інтервалів (time slot) і кадрова синхронізація. Тому відсутність синхронізації комп'ютерної системи на необхідному рівні може призвести до значного зниження показників QoS. У той же час істотно посилюються вимоги до забезпечення цих показників в умовах збільшення завантаження мережевих ресурсів. **Предмет** дослідження: синхронізація комп'ютерної системи. **Метою** статті є розробка методу діагностики порушень синхронізації телекомунікаційної мережі комп'ютерної системи критичного застосування за рахунок підвищення роздільної здатності акустооптичного спектроаналізатора. **Результати** дослідження. Проведено аналіз впливу нестаціонарності передачі даних в телекомунікаційній підсистемі досліджуваної комп'ютерної системи. Проведено аналіз та класифікацію причин порушення синхронізації комп'ютерної мережі комп'ютерної системи критичного застосування. Наведено наслідки порушення стабілізації комп'ютерної мережі для забезпечення якості обслуговування, що надається різними сервізами, що часто вживаються. Запропоновано використання акустооптичних спектроаналізаторів з просторовим інтегруванням для діагностики порушення синхронізації мережі. В роботі проведено аналіз використання акустооптичних спектроаналізаторів. Проведені дослідження дозволили отримати аналітичний вираз для вихідного сигналу спектроаналізатора при надходженні на його вхід двох імпульсів прямокутної форми з різними несучими частотами, тривалістю і часом затримки. Цей результат, а також наведені чисельні розрахунки дозволили виробити загальні рекомендації для підвищення роздільної здатності акустооптичного спектроаналізатора, і, таким чином, створити теоретичні передумови для поліпшення синхронізації комп'ютерної системи. Наведені аналітичні співвідношення і чисельні оцінки були експериментально перевірені за допомогою імітаційного моделювання системи. **Висновки**. В результаті досліджень було запропоновано метод діагностики порушень синхронізації телекомунікаційної мережі комп'ютерної системи критичного застосування. Метод заснований на підвищенні роздільної здатності вимірювальної системи на базі акустооптичного спектроаналізатора.

Ключові слова: комп'ютерна система; телекомунікаційна мережа; синхронізація; акустооптичний спектроаналізатор.

МЕТОД ДИАГНОСТИКИ НАРУШЕНИЙ СИНХРОНИЗАЦИИ ТЕЛЕКОММУНИКАЦИОННОЙ СЕТИ КОМПЬЮТЕРНОЙ СИСТЕМЫ КРИТИЧЕСКОГО ПРИМЕНЕНИЯ

Актуальность исследования. Для улучшения качества обслуживания (QoS) постоянно оптимизируется работа всех сетевых технологий, протоколов и отдельных механизмов управления трафиком. Известно, что на качество передачи информации в современном телекоммуникационном оборудовании влияет качество устройств синхронизации. Синхронизация – это средство поддержания работы всего цифрового оборудования в сети передачи информации на одной средней скорости, которое должно существовать на трех уровнях: битовая синхронизация, синхронизация на уровне канальных интервалов (time slot) и кадровая синхронизация. Поэтому отсутствие синхронизации компьютерной системы на требуемом уровне может привести к значительному снижению показателей QoS. В тоже время существенно ужесточаются требования к обеспечению этих показателей в условиях увеличения загрузки сетевых ресурсов. **Предмет** исследования: синхронизации компьютерной системы. **Целью** статьи является разработка метода диагностики нарушений синхронизации телекоммуникационной сети компьютерной системы критического применения за счет повышения разрешающей способности акустооптического спектроанализатора. **Результаты** исследования. Проведен анализ влияния нестационарности передачи данных в телекоммуникационной подсистеме исследуемой компьютерной системы. Проведен анализ и классификация причин нарушения синхронизации компьютерной сети компьютерной системы критического применения. Приведены последствия нарушения стабилизации компьютерной сети для обеспечения качества обслуживания, предоставляемого различными часто употребляющимися сервисами. Предложено использования акустооптических спектроанализаторов с пространственным интегрированием для диагностики нарушения синхронизации сети. В работе проведен анализ использования акустооптических спектроанализаторов. Проведенные исследования позволили получить аналитическое выражение для выходного сигнала спектроанализатора при поступлении на его вход двух импульсов

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прямоугольной формы с различными несущими частотами, длительностями и временами задержки. Этот результат, а также приведенные численные расчеты позволили выработать общие рекомендации для повышения разрешающей способности акустооптического спектроанализатора, и, таким образом, создать теоретические предпосылки для улучшения синхронизации компьютерной системы. Приведенные аналитические соотношения и численные оценки были экспериментально проверены посредством имитационного моделирования системы. **Выводы**. В результате исследований был предложен метод диагностики нарушений синхронизации телекоммуникационной сети компьютерной системы критического применения. Метод основан на повышении разрешающей способности измерительной системы на базе акустооптического спектроанализатора.

Ключевые слова: компьютерная система; телекоммуникационная сеть; синхронизация; акустооптический спектроанализатор.

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