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S. P. KONONOV, M. V. MENTYNSKYI, R. S. LYKHA
Vinnytsia National Technical University

PANORAMIC CURVE-TRACING OSCILLOSCOPE MARKER BLOCKS AND RELATIONSHIP BETWEEN FREQUENCY SWEEP NONLINEARITY PARAMETERS

The paper presents the generator of frequency markers and a block diagram of the sweep generator frequency determinant.

The principles of operation , the timing diagrams and the peculiarities of harmonic oscillator frequency change are presented and analyzed. The analytical expressions that define the relationship between the coefficient of non-linearity and sweep non-linearity multiplier are presented.

Keywords: frequency marker generator, analog multiplier, reference generator, sweep generator, marker frequency, nonlinearity multiplier, coefficient of nonlinearity

С. П. КОНОНОВ, М. В. МЕНТИНСЬКИЙ, Р. С. ЛИХА
Вінницький національний технічний університет

БЛОКИ МІТОК ПАНОРАМНОГО ХАРАКТЕРОГРАФА І ВЗАЄМОЗВЯЗОК МІЖ ПАРАМЕТРАМИ НЕЛІНІЙНОСТІ РОЗГОРТКИ ЧАСТОТИ

В роботі запропоновано генератор частотних міток та структурну схему визначника частоти свіп-генератора. Розглянуто принцип їх роботи, наведені та проаналізовані часові діаграми роботи, особливості зміни частоти генератора гармонік. Наведені аналітичні вирази, які визначають взаємозв'язок між коефіцієнтом нелінійності і множником нелінійності розгортки.

Ключові слова: генератор частотних міток, аналоговий перемножувач, опорний генератор, свіп-генератор, частота мітки, нелінійність розгортання, множник нелінійності, коефіцієнт нелінійності

Introduction

The generation of known frequency in panoramic radio measuring device is important when determining the frequency characteristics of electrical circuits. In modern devices of sweep generator frequency determination a great disadvantage is the increase of error with nonlinearity increasing of sweep generator frequency dependence on the readjustment unit control voltage.

The aim of the paper is the development of panoramic radio measuring device marker block with reduced sweep generator frequency error and and the determination of non-linearity coefficient and non-linearity factor of sweep generator correlation.

Frequency marker oscillator

The reduction of frequency marker determination error is achieved by using a known frequency marker generator [1] (fig. 1), consisting of the first 1 and second 7 analog multipliers of signals, low-pass filter 4, reference generator 2, the summation block 11, the frequency divider 5 and of the first 8 and second 9 pulse shaper. A second reference generator 3, the third analog signal multiplier 6, the third pulse shaper 10 and the computer unit 12 are additionaly used in such frequency marker generator.

The frequency marker generator operates as follows (fig.1). A test signal with a linear variable frequency $f(t)$ is fed on the first input of analog signal multiplier 1 from the sweep generator. The reference generator 2 creates a sequence of short rectangular pulses with the duration $\tau = \frac{1}{2F_{MAX}}$, where F_{MAX} – the maximum frequency of the test signal. The range of reference generator 2 voltages is discrete and consists of the first and higher harmonics [2] nearly equal by amplitude, that have frequency $f_0, 2f_0, 3f_0, ..., n_{MAX} f_0$, where $n_{MAX} = \frac{F_{MAX}}{f_0}$ – maximum number of the reference oscillator harmonic with a frequency f_0.

A lowpass filter 4 with a bandwidth $\frac{f_0}{2}$ is connected to the first analog multiplier 1 output. The voltage frequency in the voltage low-pass filter 4 output is changed in time according to the triangular law (fig.1, b).

The pulse frequency marker M sequence is formed in the output of the first pulse shaper 8 (fig.2, c). Pulse shaper 8 consists of series-connected narrowband lowpass filter, detector and univibrator. Marker pulses occur when measuring frequency $f(t)$ is multiple to the frequency f_0.

A frequency divider 5 in the output generates the short pulses with duration $\tau_N = \frac{1}{f_0}$ and frequency

$\frac{f_0}{2N}$, where f_0 – the frequency formed by the first reference generator, $2N = 2, 4, 6...$ – coefficient of frequency division. Accordingly, the marker pulses M_N will be formed when the frequency of the voltage at the output of the second analog signal multiplier 7 is multiple to the frequency $\frac{f_0}{2N}$, at the output of the second pulse shaper 9 marker pulses (Fig. 1, c for the case $N = 2$).

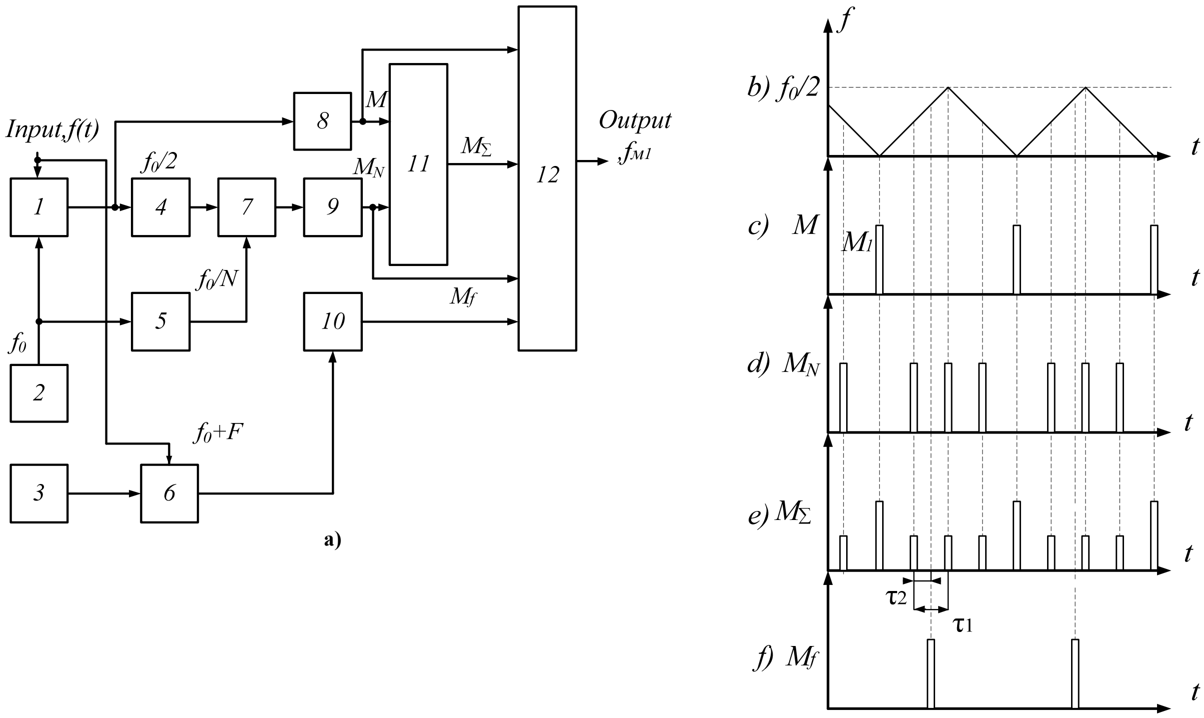

Fig. 1. The frequency marker generator a, The time diagrams of the frequency marker generator b-f

The marker pulses M and M_N (fig.1 e). For example, when $N = 2$ the number of frequency markers increases fourfold. Adding coefficient according to the second input of summing block 11 is higher because the amplitude of the output markers are different.

Frequency step of markers equals $\frac{f_0}{2N}$, and large amplitude markers have step f_0.

The second reference generator 3 generates the frequency $f_0 + F$, where F – shift frequency, which is chosen according to the condition $F = \frac{f_0}{n_{MAX}}$. The marker pulses M_f at the output of the third pulse shaper 10 will be formed when the voltage frequency at the output of the third analog signal multiplier 6 is a multiple with $f_0 + F$ (fig.1,f).

The marker frequency M_1 is determined by formula:

$$f_{M1} = \frac{f_0^2}{2NF}\left(\frac{\tau_2}{\tau_1} + k\right), \qquad (1)$$

where τ_1 – the time interval between the markers on the output of summing block 11;

τ_2 – the time interval between the previous marker at the output of summation block 11 and marker at the output of the third pulse shaper 10;

k – the number of markers at the output of second reference generator 9 before marker appearance at the third pulse shaper output 10.

Determinant of the sweep generator frequency

The block diagram of the frequency sweep generator determinant, which solves the problem of determining a reduced error rate in the case of non-linear the sweep generator frequency deployment in time [3], is shown in Fig. 2.

From the control and calculation unit (CCU) to the input of readjustment unit (RU) comes impulse voltage U_{1CCU} (fig. 2, b). In the absence of a pulse the readjustment unit forms linear variable voltage with direct sweep course. At the time of the pulse U_{1CCU} there is reverse movement of sweep readjustment block.

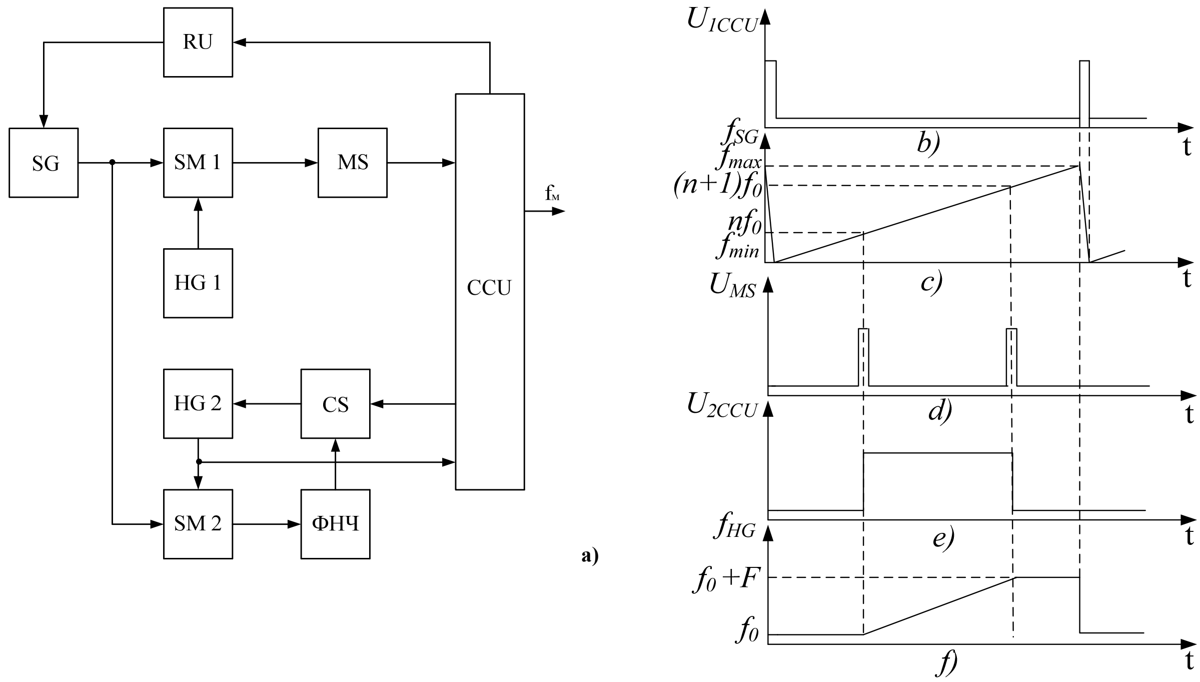

Fig. 2. Sweep generator frequency determinant a, the time dependence of voltages and frequencies b-f

The output voltage frequency f_{RU} of the sweep generator (SG) connected to the inputs of stroboscopic mixers (SM) is changing during the linear variable voltage direct movement of the readjustment unit linearly from the minimum to the maximum value (fig. 2, c).

The harmonics of harmonic generator (HG) output voltage are uniformly distributed in the operating frequency range with the step f_0, $f_0 + F$, respectively. At the output of mixer NW 1 the "zero beating " will be present, then the marker shaper (MS) generates the marker pulses at the input of the control and computation unit (fig. 2, g), corresponding to frequencies nf_0 and $(n+1)f_0$, where n - number of harmonic of harmonic generator. After the first marker appears from marker generator a control and computing unit feed switching voltage (fig. 2 , e) to the control switch (CS), so that takes effect of the first harmonic frequency regulation feedback of the harmonic generator HG 2.

Its frequency is beginning to change from the initial f_0 $(F = 0)$ to the final $f_0 + F$ (fig. 2, f). The process of adjustment is completed with the introduction of the second marker from marker shaper (fig. 2, b-f). Regulation feedback supports "zero beating" at the output of low-pass filter (LPF). As a result, at the time of second marker appearance (fig. 2, d) performs the condition $(n+1)f_0 = n(f_0 + F)$ або $n = \frac{f_0}{f}$. The frequency of sweep generator, which corresponds to the first marker in time $f_M = nf_0$. That is why $f_M = \frac{f_0^2}{F}$.

The frequency F which is the difference between the frequencies of the first harmonic of harmonic generator is measured in the control and calculation unit. The considered process is repeated with the frequency that is reverse to the period of the sweep.

The relationship between the parameters of nonlinearity

Consider the normalized time dependence of the sweep generator frequency f according to the ordinate axis to $y = \frac{f}{f_m}$, the axis of abscissas – to $x = \frac{t}{T_p}$ where f_m - the maximum frequency, and T_p - the sweep period of sweep generator [4] (fig. 3).

$$y = \frac{n-1}{n_{MAX}} + \frac{2}{n_{MAX}} \cdot \frac{e^{Nx} - 1}{e^N - 1}. \qquad (2)$$

Non-linearity multiplier is marked by a factor of N in (2), it can be either more or less than zero.

There are two definitions of the coefficient of frequency sweep nonlinearity of sweep generator. In the first definition [5] of the nonlinearity coefficient it is determined by the derivative of the function (2):

$$K_{H1} = \frac{y'(0) - y'(1)}{y'(0)}, \tag{3}$$

if the nonlinearity multiplier $N < 0$.

We find the derivative of the sweep function in general:

$$y'(x) = \left(\frac{2}{n_{MAX}} \cdot \frac{e^{Nx}}{e^{N} - 1}\right) - \left(\frac{2}{n_{MAX}} \cdot \frac{1}{e^{N} - 1}\right) + \left(\frac{n-1}{n_{MAX}}\right) = \frac{2}{n_{MAX}} \cdot \frac{Ne^{Nx}}{e^{N} - 1}. \tag{4}$$

Substitute the values of the derivatives in equation (3) and get:

$$K_{H1} = 1 - e^{N}. \tag{5}$$

In case of sweep function non-linearity multiplier $N > 0$, nonlinearity coefficient should be determined by the formula:

$$K_{H1} = \frac{y'(1) - y'(0)}{y'(1)} = \frac{e^{N} - 1}{e^{N}} = 1 - e^{-N}. \tag{6}$$

Analysis of the relationship (5, 6) shows that when $|N| \le 0{,}2$, then $K_{H1} \approx |N|$ (fig. 4). If another nonlinearity multiplier is within $0{,}2 < |N| \le 3$ then correlation of nonlinearity coefficient and the multiplier is as follows $K_{H1} \approx (0{,}32...0{,}86) \cdot |N|$.

The second definition of the coefficient of nonlinearity can be found in [6]. According to it the coefficient of nonlinearity is defined by the expression:

$$K_{H2} = \frac{\Delta f_{MAX}}{\Pi_{MAX}}, \tag{7}$$

where Δf_{MAX} – the maximum frequency deviation from the linear law of sorting;

Π_{MAX} – the maximum swing band of sweep generator.

Fig. 3 shows the maximum deviation of the normalized values of the sweep function from the linear law Δf_{MAX} and the maximum normalized value of the swing band $\frac{2}{n_{MAX}}$. Accordingly:

$$K_{H2} = \frac{\Delta y_{MAX}}{\frac{2}{n_{MAX}}}. \tag{8}$$

We find the the relationship between the coefficient of nonlinearity K_{H2} and non-linearity multiplier N. Fig.3 shows that the current deviation of the sweep function from the linear:

$$\Delta y = y - \left(\frac{2}{n_{MAX}} \cdot x + \frac{n-1}{n_{MAX}}\right). \tag{9}$$

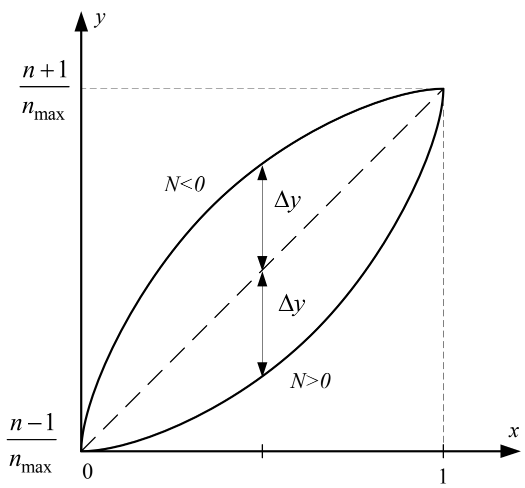

Figure 3. Frequency deviation from the linear law

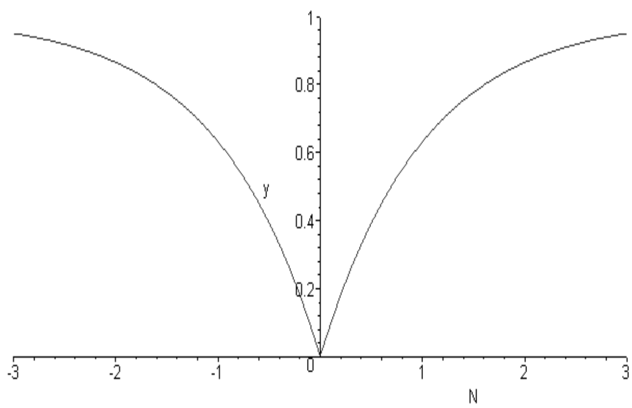

Figure 4. nonlinearity parameter K_{H1}

After transformations we obtain:

$$\Delta y = \frac{2}{n_{MAX}}\left(\frac{e^{Nx}-1}{e^{N}-1}-x\right). \qquad (10)$$

If condition $\Delta y'(x)=0$, then deviation of the sweep function from the linear law will be maximum $\Delta y = \Delta y_{MAX}$. We find the analytical expression of the derivative:

$$\Delta y'(x) = \frac{2}{n_{MAX}}\left(\frac{Ne^{Nx}}{e^{N}-1}-1\right). \qquad (11)$$

The derivative is zero if $\frac{Ne^{N_x}}{e^{N}-1}-1$, or:

$$x_0 = \frac{1}{N}\ln\frac{e^{N}-1}{N}. \qquad (12)$$

Analysis (12) suggests that when multiplier of nonlinearity $|N|\le 1$ maximum deviation of the sweep function from the linear law is observed when $x_0 \approx 0{,}5$. If the nonlinearity multiplier $|N|>1$, then $x_0 \to 0$ or $x_0 \to 1$ at different multiplier signs N.

Find maximum deviation of the sweep function for $x_0 \approx 0{,}5$. We have:

$$\Delta y_{MAX} = \Delta y(x_0) \approx \frac{2}{n_{MAX}}\left(\frac{e^{0{,}5N}-1}{e^{N}-1}-0{,}5\right). \qquad (13)$$

Substitute the resulting expression in (8):

$$K_{H2} = \frac{e^{0{,}5N}-1}{e^{N}-1}-0{,}5. \qquad (14)$$

Fig. 5 shows the dependence K_{H2} of the nonlinearity multiplier N, which varies from -1 to 1. We can see that the coefficient of nonlinearity K_{H2} is associated with the non-linearity multiplier as follows: $K_{H2} \approx 0{,}124|N|$.

We find an expression for the coefficient of nonlinearity K_{H2} in the case of an arbitrary value of nonlinearity multiplier:

$$K_{H2} = \frac{e^{\ln\frac{e^{N}-1}{N}}-1}{e^{N}-1}-\frac{1}{N}\ln\frac{e^{N}-1}{N}. \qquad (15)$$

Fig. 6 shows the corresponding dependence of K_{H2} on N.

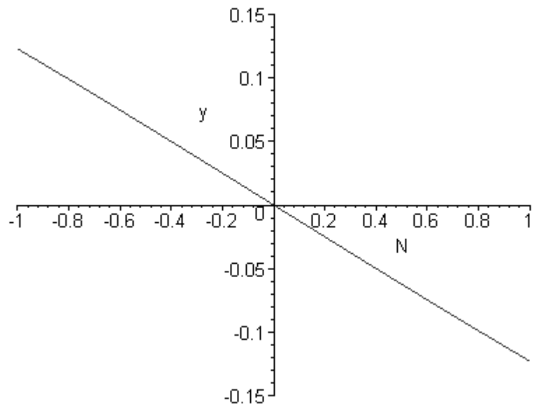

Figure 5. nonlinearity parameter K_{H2}

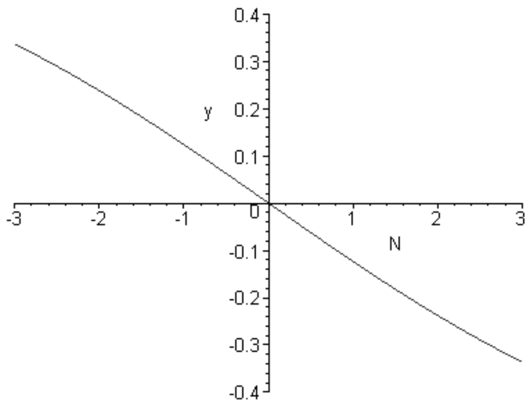

Figure 6. The exact dependence of K_{H2} on N

Fig. 6 shows that if the sweep generator has a coefficient of nonlinearity K_{H2} up to 30 %, then it corresponds to a change of the nonlinearity multiplier $|N|$ ranging from -3 to 3. Also with a good accuracy of calculations you can use relationship $K_{H2} \approx 0{,}124|N|$.

Conclusions

Error reduction of sweep generator frequency determination in the marker generator is achieved by decreasing the marker step and by the transition to the analysis of ratios of short time intervals τ_1, τ_2 at the same time based on the number of pre-generated markers k.

The introduction of feedback into the sweep generator frequency determinant and creation of frequency regulation circuit reduces measurement error in the case of nonlinear sweep generator frequency deployment.

Analytical expressions that connect three parameters of nonlinearity N, K_{H1}, K_{H2} are proposed, which will help to formulate the requirements for the basic characteristics of the frequency marker generator and of sweep generator frequency determinant in their design.

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В.В. ГРАБКО, М.П. РОЗВОДЮК, С.М. ЛЕВИЦЬКИЙ
Вінницький національний технічний університет

ВІРТУАЛЬНИЙ ЛАБОРАТОРНИЙ КОМПЛЕКС ДЛЯ ДОСЛІДЖЕННЯ ПЕРЕТВОРЮВАЧА ЧАСТОТИ ALTIVAR 71 ПО ETHERNET

Розглянуто спосіб розробки віртуального лабораторного комплексу для дослідження частотно-регульованого електроприводу з використанням віддаленого доступу до даних процесу по Ethernet.
Ключові слова: віртуальний лабораторний комплекс, перетворювач частоти, Ethernet.

V.V. GRABKO, M.P. ROZVODIUK, S.M. LEVITSKIY
Vinnitsa National Technical University

VIRTUAL LABORATORY COMPLEX FOR THE FREQUENCY INVERTER ALTIVAR 71 RESEARCH THROUGH ETHERNET

The papre present the method of virtual laboratory complex development for the frequency variable drive research with remote access to the process data through Ethernet.
Keywords: virtual laboratory complex, frequency inverter, Ethernet.

Вступ. Використання віртуальних лабораторних комплексів (ВЛК) для дослідження реальних процесів з використанням сучасного обладнання та програмного забезпечення розширює горизонти енергоефективної експлуатації промислових електромеханічних систем, а також у структурі професійної освіти підготовки фахівців інженерних спеціальностей, виробничого персоналу при проведенні перепідготовки або підвищенні кваліфікації зі значним економічним ефектом.

Аналіз досліджень та публікацій. Найбільш близькими по структурі побудови є ВЛК, які запроваджені в Кременчуцькому національному університеті імені Михайла Остроградського, і які мають суттєву відмінність від відомих – це не просто модель електропривода із зручним інтерфейсом, а модель електромеханічного обладнання або електромеханічного комплексу з технологічним механізмом, що дозволяє зробити принципово якісний стрибок в напряму вирішення задач енерго- та ресурсозбереження, забезпечення ефективного керування процесами перетворення енергії, розвитку наукових досліджень та підвищення якості підготовки фахівців. Деякі приклади реалізації таких ВЛК приведені в роботах [1-7].

Тому перспективним в напрямку розвитку лабораторного обладнання є створення ВЛК.