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Method for Assessing Noise Quality Based on Entropy Quality Factor

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ABSTRACT The work analyzes the existing approaches to solving the problem of a comprehensive study of the qualitative characteristics of side electromagnetic emission generators. In addition, methods and means of information leakage through the channels of side electromagnetic emission are considered, which make it possible to evaluate the effectiveness of noise generators. Electromagnetic emission can propagate in almost all environments. Side electromagnetic emission is one of the effective ways to protect computer equipment from information leakage through the channel of side electromagnetic emissions and interference. The masking noise is generated by the noise generator, and the quality factor of the masking noise is the quality factor of the entropy noise. In addition, measurements of masking noise interference using a spectrum analyzer and an oscilloscope are carried out and a method for estimating the entropy noise quality coefficient (ENQC) is proposed. The calculated value of the entropy noise quality factor is compared with the normalized value set for this type of noise generator. The novelty of the work is the development of a new method for assessing the quality of masking noise interference, based on the calculation of the entropy quality coefficient, as well as the development of software for automating the calculation. The study of the quality characteristics of the noise generator (NG) taking into account the design of a mock-up sample of the device, which is a complex work. In turn, based on the results obtained, it is possible to develop specialized automated tools for assessing the quality of masking noise interference.

KEYWORDS protection of information; masking noise signal; noise generator; spectrum analyzer; entropy factor.

I. INTRODUCTION

PREVENTION of leakage through the channel of side electromagnetic emission (SEME) of confidential information of limited access is solved by both organizational and technical measures, using passive or active means of protection. Computer facilities do not always use passive protection methods, since there are difficulties in their implementation, and also taking into account the need for additional research, etc.

In order to prevent information leakage, in most cases, active protection methods are used to mask the signal and create an increased background of the electromagnetic field. At the same time, there are currently no unified approaches and methods for assessing the quality of generated masking interference, on which the security of protected information will depend.

The theoretical research and practical experiments make it possible to study the visualization interfaces of computer equipment, identify existing vulnerabilities in their use, and develop effective measures to protect against them.

The results of the research were obtained on the basis of the scientific results of the authors and are the basis for calculating the statistical, nonlinear and information-entropy characteristics of the quality of generators of spatial electromagnetic noise.

The articles present describes the results of research on the capabilities of "interception" on video display devices by detecting and decoding electromagnetic interference created by this type of equipment. Researchers in this field argue that it is necessary to obtain a quantitative assessment of the security of the functioning of complex objects in order to make a decision about the degree of information protection from leakage. Existing assessment methods are not optimal due to the required large resource and processing time. There are also standards and regulations that note the need to protect information from leakage and assess the masking signal (noise).

The experimental results obtained on frequency, energy, polarization, and information characteristics helped to determine the optimal types of antenna devices used to work with signals of a wider frequency range. Patents and results on the development of broadband signal generators based on nanostructured elements were used for statistical and nonlinear signal analysis.

The research was carried out on the basis of the information security research laboratory of Kazakh National Research Technical University named after K.I. Satbayev (Satbayev University) using standard laboratory equipment and instrumentation.

Assessing the quality of generated masking interference, which will affect the security of protected information, various approaches and methods are currently used.

In the article, a number of studies were carried out to solve the problems presented below:

- measurements of masking noise interference using measuring instruments;
- determination of the main characteristics of the noise generator (NG);
- research and implementation of a method for estimating the masking noise interference quality.

II. SPATIAL ELECTROMAGNETIC NOISE GENERATORS

One of the ways to protect information from its leakage through the channel of SEME is the use of generators of spatial electromagnetic noise.

The main characteristics of the NG [1-3]:

- frequency range;
- spectral density;
- suppression coefficient;
- noise structure;
- type of emitted interference;
- the amplitude of the generated noise;
- average power;
- noise signal spectrum;
- probability density distribution.

In addition to the above requirements, there are requirements for the quality of interference generated using a spatial electromagnetic noise generator [1]:

- the generated interference should not have a regular structure;
- the noise spectrum should have a normal distribution;
- the entropy quality factor should not be less than the value established by the relevant standards.

The assessment of the masking noise interference quality is carried out according to the statistics of the instantaneous values of the amplitudes of the noise signal, which require measuring equipment [2]. Previously, for such tasks, correlation characteristics meters [4] were used that are not available today.

Currently, digital oscilloscopes are used to measure the instantaneous values of noise signal amplitudes.

In order to protect information, manufacturers present a variety of NG [3, 4]. One of the main parameters of the NG is the spectrum of emitted interference and its power.

To prevent access to confidential information from leaks through side electromagnetic emissions and interference (SEMEI) channels, it is necessary to use masking noise interference with high quality, since otherwise it is possible to filter them with the restoration of protected data [5].

The creation of broadband masking interference can be carried out by dividing the operating frequency range into separate ranges and multiplying the frequencies [1]. In this case, a correlation will be observed between these subranges.

The search for this correlation will lead to the compensation of masking noises and the reception of informative SEMEI with the recovery of confidential information. Of great importance is the repeatability of SEMEI over a relatively long time, which can allow their accumulation [6].

Noise generators "LNG-503K", "LNG-513K", "Zont-1 NG", "Sonata-P3.1", "SEL 111K "Chiffon" and "LNG-504K" were used for research.

III. METHODS AND MATERIALS

One of the most important requirements for NG is the wide-width spectrum of the noise signal and the high uniformity of the spectral density of the noise power. For this reason, noise generators mainly use three schemes for generating a broadband noise signal:

1) classic method of generating direct noise interference. In this case, it is possible to use several noise sources operating in different frequency ranges. Noise resistors, diodes, transistors, Zener diodes and other elements forming noise similar in their characteristics to “white” can be used as the primary sources of noise in such NG;

2) the method for assessing the quality of frequency-modulated noise interferences involves the following steps: receive a frequency-modulated noise interference, convert it into an electrical signal, and calculate its voltage at discrete moments in time. Based on the obtained values, the entropy quality coefficient of the frequency-modulated noise interference is computed, which is used to assess the quality of this interference.

3) the method for assessing the quality of amplitude-modulated noise interferences is similar to that for frequency-modulated noise interferences. However, in this method, after calculating the entropy quality coefficient of the amplitude-modulated noise interference, the second moment of the distribution law and the expected value of the natural logarithm of the voltage values of the electrical signal are calculated. Next, the entropy of the reference Rayleigh distribution law is computed, and the entropy quality coefficient of the amplitude-modulated noise interference is determined, which is used to assess the quality of the interference.

4) the use of a universal indicator for assessing the effectiveness of masking and imitative radio interferences. In this case, informational-energetic indicators (criteria) have been proposed to assess the quality of noise and imitative radio interferences. The assessment of the quantitative values of these indicators is based on the density distributions of the instantaneous amplitude values of signals and interferences. The instrumental-computational method for evaluating these

indicators includes procedures for measuring the distribution laws of signals and interferences using digital spectrum analyzers and calculating specific indicators of energy and informational-probabilistic effectiveness of radio interferences.

5) use of a digital noise generator, the "digital" noise of which is a temporary random process that is close in its properties to the process of physical noise and is called a "pseudo-random process". Such generators form chaotic (pseudorandom) sequences of binary symbols and convert them into a sequence of rectangular pulses of pseudorandom duration with pseudorandom intervals between them. Noise sources in such NG can be microband elements, various integrated circuits, digital signal processors, programmable logic integrated circuits, and other elements [7-9];

6) use of a stochastic or chaotic method of generating a noise signal. The signal from the harmonic signal generator is fed to a power amplifier operating in a non-linear mode and loaded onto a non-autonomous non-linear dynamic system in the form of a parallel non-linear oscillatory circuit in which the amplified signal is converted into stochastic noise [10].

At the same time, noisy informative TEMPEST can be filtered and in case of poor-quality masking, the enemy can gain access to the protected information [1].

In NG, a scheme for dividing the entire frequency range into subbands using a frequency multiplier can be used to generate a broadband noise signal. In such cases, the generated noise in different subbands will be correlated, i.e. have the same parameters except for the frequency.

This circumstance will allow the subtraction of noise in different ranges in which informative TEMPEST has a large amplitude (power) and the further restoration of the protected information. It should be noted that the presence of additional factors in the form of repeatability of the informative signal, the level of its amplitude (power), etc. is also important.

In addition, in the absence of complete randomness of the generated noise, statistical analysis methods are used, through which it is possible to identify patterns of noise formation, including their frequency.

Determining the parameters of noise interference to assess their quality is possible using statistical methods. In turn, they allow to evaluate the quality of the noise by calculating a certain numerical coefficient. For this, methods of mathematical statistics are used, such as the average value, variance, standard deviation, etc. Their purpose is to search for the degree of uncertainty in the values of masking noise interference, determined by the entropy quality factor [5].

IV. RESULTS OBTAINED

Protection of computer equipment (CQ) from leakage through SEME channels is achieved by using passive and active protection methods. The passive methods of protection include shielding, grounding, isolation and filtration, and the active ones include the use of systems of spatial electromagnetic noise and the setting of imitation (masking) interference.

The use of passive methods of protection of CQ is the most preferable, since when using them there are no problems associated with electromagnetic compatibility and the presence of unmasking signs of the operation of protective equipment.

However, the use of passive methods of protection of CQ is not always possible due to the complexity of their implementation, high cost, the need for additional development work, etc.

In the course of ensuring the protection of information from its leakage through technical channels due to side electromagnetic radiation and interference, it is preferable to use passive methods that use shielding, reducing the power and informativeness of signals, filtering, decoupling and grounding.

However, it is not always possible to use these methods of information protection. In such cases, as a rule, means of generating masking noise interference are used.

However, noisy informative signals can be filtered and restored in case of poor-quality masking. In this connection, an important task arises related to the assessment of the quality of the noise signal generated by active means of protection (generators of spatial electromagnetic noise) [1].

When assessing the noise quality, the instantaneous values of the amplitudes of the noise signal are used, and the measurement of which is carried out using digital oscilloscopes. Instantaneous amplitude values are measured from the connector or from the NG antenna output. However, such measurements do not take into account the influence of the NG antenna [11, 12].

The easiest to use method of protection against the specified leakage channel is the use of active means of protection – generators of spatial NG [13-15].

In this regard, it is proposed to use spectrum analyzers with digital storage oscilloscopes as a means of measuring the instantaneous values of the noise signal amplitudes. Figure 1 shows a measuring bench, which includes:

- measuring antenna with a wide range of operating frequencies;
- measuring cable;
- spectrum analyzer;
- digital oscilloscope.

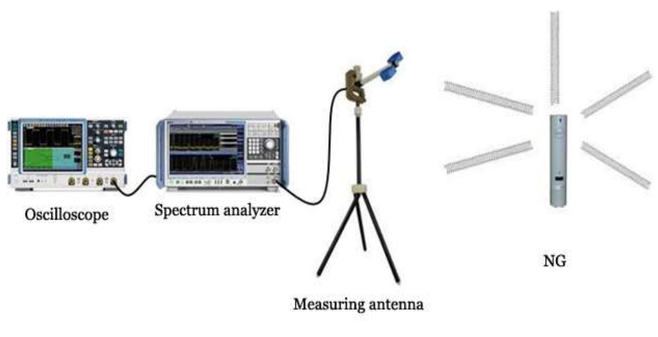

Figure 1. Scheme for connecting an oscilloscope to the NG

To obtain more reliable measurement results, the spectrum analyzer (SA) must have a bandwidth of at least 10 MHz. Taking into account the fact that the operating frequency range of modern NG, as a rule, is more than 1 GHz, in practice it is not possible to purchase such SA due to their very high cost or lack of production [16, 17].

Before starting measurements, it is necessary to study the operating instructions and technical documentation for the NG and measuring instruments. After that, make sure that the NG is working. To do this, when the NG is turned on with the help of the SA, it is necessary to make sure that there is a noise signal of the NG (Figure 2).

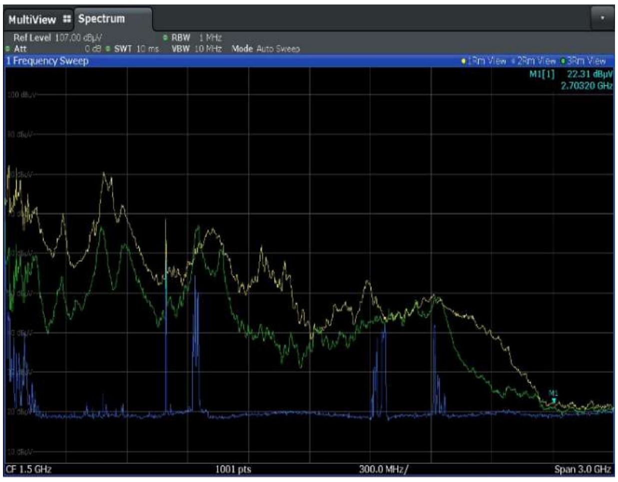

Figure 2. Ambient background and noise signal spectrum of the NG

Since the operating frequency range of the NG is much greater than the bandwidth of the SA, measurements must be carried out with division into subranges. The measured signals are transmitted from the SA to a digital oscilloscope. Further evaluation of the noise quality is carried out using a personal computer and the calculation of the obtained digital values from the oscilloscope.

An example of a spectrogram in the zero sweep and an oscillogram of the noise signal is shown on Figure 3.

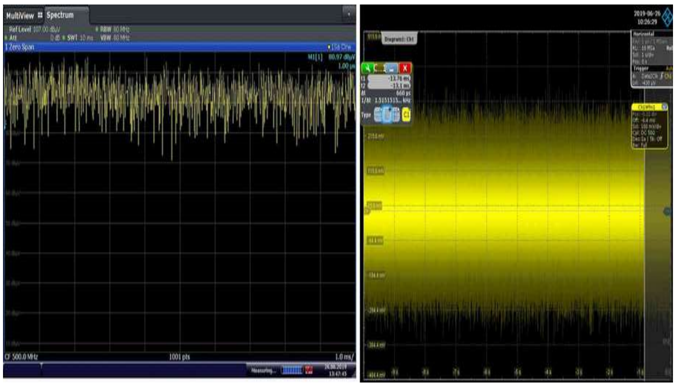

Figure 3. An example of a zero sweep spectrogram (in oscilloscope mode) and a noise signal oscillograms

The accuracy of the calculations performed is influenced by the sampling frequency of the instantaneous values of the amplitude of the masking noise interference. The downside of too large sample is a significant increase in resources for processing them, which is also not advisable. The most optimal would be to use a sample size of the order of 40 M Samples/s.

In addition, one of the effective ways to protect computer equipment from information leakage through the channel of side electromagnetic emissions and interference (SEMEI) is spatial electromagnetic noise [1, 18-25].

The histogram of the amplitude distribution of the generated noise interference (Fig. 4) clearly reflects the results of using the method of assessing the quality of masking noise NG. On the left histogram, the entropy noise quality coefficient (ENQC) of the masking noise corresponds to 0.9, and on the right histogram only 0.7. In this case, the X axis indicates the number of intervals, the Y axis shows the number of sample elements in this interval.

In the case of a poorly selected primary noise source, a low ENQC can be observed. Also, a low ENQC value occurs with deviations in the power supply of the NG.

ENQC is an indicator of the approximation of the noise power distribution law to ideal (white) noise with a normal power distribution law.

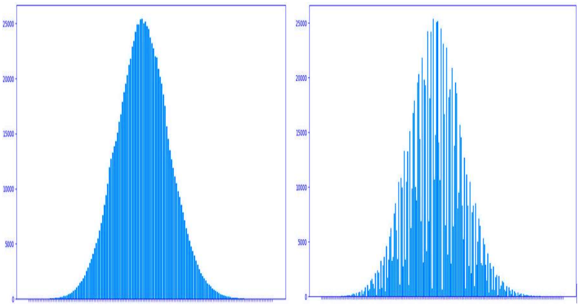

Figure 4. Histograms of distribution of noise signal amplitudes: a) – $K_{ш}$ = 0,9; b) – $K_{ш}$ = 0,7

A method is proposed for estimating the entropy noise quality coefficient (ENQC) of a noise generator using digital oscilloscopes and spectrum analyzers as measuring instruments.

The measuring setup for measuring and calculating the ENQC is shown in Figure 5.

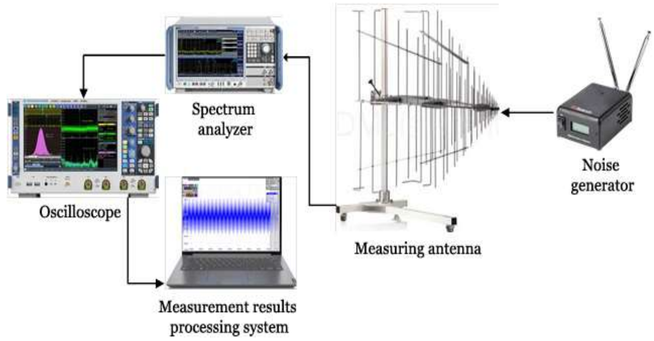

Figure 5. Measuring unit for measuring and calculating ENQC

The measuring antenna is installed at a distance of 1 m from the noise generator antenna and connected to the antenna input of the spectrum analyzer. Sets the maximum bandwidth *(ΔF)* of the spectrum analyzer. The noise signal received by the measuring antenna is fed from the output of the intermediate frequency of the spectrum analyzer to the input of the digital oscilloscope. Further, the instantaneous values of the masking noise amplitude digitized by the oscilloscope in the form of a .csv file are transferred for processing to a personal computer with the installed automated calculation software.

The essence of the proposed methodology for assessing ENQC is as follows:

1) By analyzing the spectrum of the NG noise signal, the frequency intervals are selected in which the greatest unevenness of the frequency response of the noise signal is observed. If several channels for generating masking noise interference are used in the NG, then at least one such interval must be selected in each of them.

2) The spectrum analyzer is tuned in turn to all the center frequencies of the intervals. In the spectrum analyzer, all received masking noise interference is converted from electromagnetic to electrical form and then, via an intermediate frequency, is transmitted to an oscilloscope for digitization.

3) Instantaneous values of the amplitude of the masking noise interference from the oscilloscope are sent to the signal processing system (personal computer with the calculation program) in the .csv format for further processing and calculation of the ENQC.

Below is the procedure for calculating the ENQC according to the statistics of the instantaneous values of the amplitudes of the masking noise interference of the NG:

1. The statistics of instantaneous values of masking noise amplitudes (n) with a volume of at least 10^6 elements is collected.

2. Based on the collected statistics $X = \{x_1, x_2, \dots x_n\}$, a statistical series $\{x_{(1)} \leq x_{(2)} \leq \dots \leq x_{(k)} \leq \dots \leq x_{(n)}\}$ is constructed and the calculation of the average value ($\bar{X}$), the variance σ^2 and standard deviation (σ) is performed using the following formulas:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i. \quad (1)$$

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{X})^2. \quad (2)$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{X})^2}. \quad (3)$$

3. The obtained values of the statistical series $x_{(k)}$ are grouped by selected intervals that do not overlap $(x_{(j-1)}; x_j)$, j =1, 2, …, m, where m – number of intervals, x_j – their upper bounds. The interval width is recommended to be chosen according to the formula:

$$\Delta \leq \frac{(x_{(n)} - x_{(1)})}{2^r}, \quad (4)$$

where Δ – maximum interval width;

$x_{(1)}$ and $x_{(n)}$ – the minimum and maximum elements of the statistical series, respectively;

r – oscilloscope capacity.

By bandwidth, digital oscilloscopes can be very conditionally divided into three categories: entry level (100 MHz and below), intermediate level (200 MHz and 350 MHz) and professional level (500 MHz and above).

The interval width Δ_j is calculated according to the formula:

$$\Delta_j = x_j - x_{j-1}, \quad (5)$$

where j =1, 2, …, m.

It is recommended to choose all intervals equal in width.

4. After choosing the intervals Δ_j for the sample $X=\{x_1, x_2, \dots, x_n\}$, the number n_j^* of the sample values $x_{(i)}$ that fall into the corresponding intervals is calculated. Based on the obtained values of n_j^*, the corresponding relative frequencies (p_j^*) and relative densities of sample values in each interval (σ_j^*) are calculated:

$$p_j^* = \frac{n_j^*}{n}. \quad (6)$$

$$\sigma_j^* = \frac{p_j^*}{h_j}. \quad (7)$$

Formula (7) – what is equal to "h_j" in the denominator? Complement the j – number of the interval (discharge), j=1,.....m ?? H- is the entropy of the discharge, h=1, ...m.

The sum of the relative frequencies (p_j^*) must be equal to one, i.e:

$$\sum_{j=1}^{m} p_j^* = 1. \quad (8)$$

5. When in any of the intervals n_j^* turns out to be equal to 0, it is necessary to combine this interval with the previous interval (j-1) or with the next interval (j+1), recalculating the relative frequencies and densities in the new intervals, or change Δ, so that with a new partition, each of the intervals includes at least one sample value (x_j).

6. Based on the obtained data, Table 1 is compiled, which indicates the number of the interval (digit) j, the boundaries of the digit $x_{j-1} - x_j$, the number of digit n_j^*, the relative frequencies p_j^* and densities σ_j^* of sample values.

Based on this table, a histogram of the distribution of instantaneous voltage values of the masking noise interference is constructed.

7. For each digit of the histogram, the entropy (H_j) is calculated by the formula:

$$H_j = p_j^* \cdot \ln \sigma_j^*. \quad (9)$$

Table 1. Initial data for calculating EQNC

Interval (digit) number) j	1	2	…	m
Digit boundaries $[x_{j-1};x_j]$	$[x_0;x_1]$	$[x_1;x_2]$	…	$[x_{m-1};x_m]$
Value n_j^*	n_1^*	n_2^*	…	n_m^*
Relative frequency p_j^*	p_1^*	p_2^*	…	p_m^*
Relative densities σ_j^*	σ_1^*	σ_2^*	…	σ_m^*
Digit entropy H_j	H_1	H_2	…	H_m
Noise signal entropy H				

8. Next, the noise signal entropy (H) is calculated by formula (10), the entropy power of the noise signal ($P_э$) - by formula (11) and the entropy quality factor of the instantaneous values of masking noise interference voltages (K) - by formula (12):

$$H = -\sum_{j=1}^{m} H_j. \quad (10)$$

$$P_э = \frac{e^{2H}}{2\pi e}. \quad (11)$$

$$K_ш = \frac{P_э}{\sigma^2}. \quad (12)$$

The calculated value of $K_ш$ is compared with the normalized value of $K_{шм}$ set for this NG.

The proposed method has been tested in measuring the ENQC of noise generators installed at informatization facilities.

The tests were carried out using a laboratory complex consisting of an AI-5.0 active measuring antenna, a Keysight N9040B digital spectrum analyzer, a Keysight MSOS204A digital storage oscilloscope, and a laptop-based signal processing complex.

Figures 6-7 show the masking noise spectra generated by the noise generators LNG-503K, LNG-513K, Zont-1 NG, Sonata-P3.1, SEL 111K Chiffon and LNG- 504K" and in Table 2 there are the measured values of the ENQC of these generators, obtained during the research.

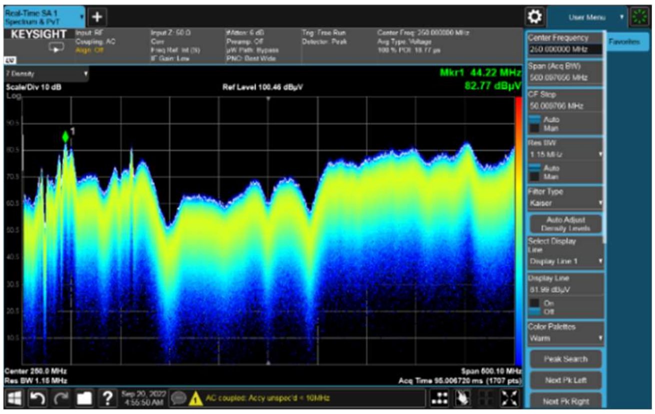

Figure 6.1 measuring range up to 500 MHz

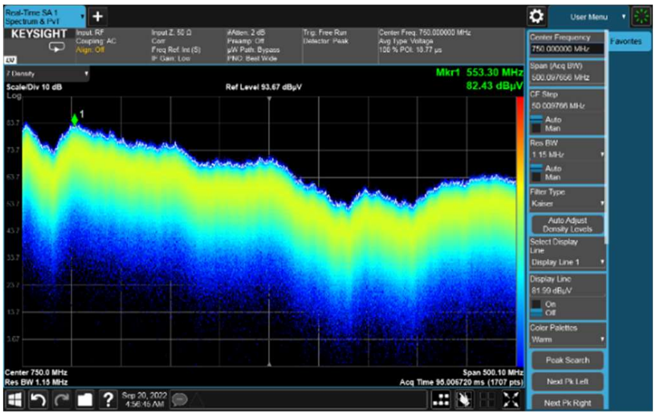

Figure 6.2 measuring range up to 500-1000 MHz

Figure 6. Masking noise spectra generated by noise generators in the ranges up to 2 GHz "LNG-503K" (6.1), (6.2).

Figure 7.1 measuring range up to 500 MHz

Figure 7.2 measuring range up to 500-1000 MHz

Figure 7. Oscillogram of masking noise generated by noise generators in the ranges up to 2 GHz "LNG-503K" (7.1), (7.2).

Table 2 shows the measured values of the EQNF of different NG, and the results show compliance with their passport values.

Table 2. Calculated values of EQNC of some NG

Noise Generator Model	Spectrum analyzer measurement range, MHz	Spectrum analyzer bandwidth, MHz	Measured value of EQNC
"LNG-503K"	up to 500	500	0,96
	500-1000		0,96
	1000-1500		0,99
	1500-2000		0,98
"LNG-513K"	up to 500	500	0,99
	500-1000		0,86
	1000-1500		0,99
	1500-2000		0,98
"Sonata-P3.1"	up to 500	500	0,99
	500-1000		0,99
	1000-1500		0,99
	1500-2000		0,98
"Zont NG"	up to 500	500	0,99
	500-1000		0,99
	1000-1500		0,98
"LNG-504K"	up to 500	500	0,76
	500-1000		0,98
"SEL 111K" Chiffon "	up to 500	500	0,99
	500-1000		0,98
	1000-1500		0,99
	1500-2000		0,98

The proposed method makes it possible to measure the EQNC of the NG with sufficient measurement accuracy.

V. RELATED WORK

The proposed method can be implemented as a mobile hardware-software complex for assessing the quality of masking noise interferences in spatial noise systems. This complex includes an SDR (Software Defined Radio) receiver equipped with a broadband measurement antenna and connected to a controlling computer (laptop) with installed software.

An SDR is a radio receiver that processes signals digitally and allows for the adjustment or modification of operational radio frequency parameters, including frequency range, modulation type, or output power, through software.

The mobile hardware-software complex for assessing the quality of masking noise interferences is illustrated in Figure 8 (general view of the device).

The complex includes a measurement tool—the SDR receiver 1, connected to the controlling computer 2 via a USB cable 3.

The controlling computer 2, equipped with application software, is designed to manage the operation modes of the SDR receiver 1 and calculate the quality of masking noise interferences based on the entropy quality coefficient of instantaneous voltage values. A primary converter—the receiving (measurement) antenna 4—is connected to the input of SDR receiver 1 via a connecting cable 5. The masking noise interferences (electromagnetic noise) 7, generated by the spatial electromagnetic noise system 6, are received by antenna 4.

The device operates as follows.

By analyzing the spectrum of the masking noise signal generated by the noise generator 6, frequency intervals of the spectrum with the highest unevenness in noise frequency characteristics are selected. If multiple channels for generating noise interferences are used in the noise generator 6, at least one such interval must be selected in each channel;

SDR receiver 1 is sequentially tuned to the central frequency of each of these frequency intervals. Electromagnetic noise signals received by SDR receiver 1 are converted into electrical signals, digitized, and as instantaneous amplitude values of the noise signal, are sent to the controlling computer 2 for further processing and assessment of the quality of the masking noise interference 7. The achieved technical result leads to the mobility and autonomy of measurements, as well as to a reduction in the cost of assessing the quality of masking noise interferences formed by spatial electromagnetic noise systems.

The achieved technical result leads to the mobility and autonomy of measurements, as well as to a reduction in the cost of assessing the quality of masking noise interferences formed by spatial electromagnetic noise systems.

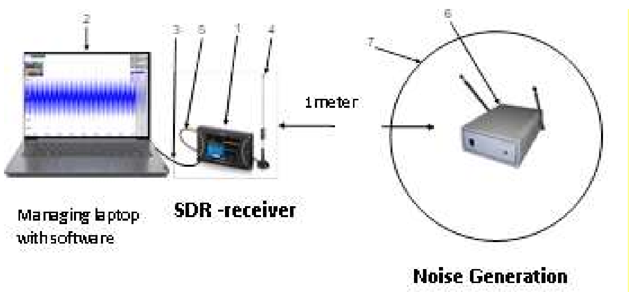

Figure 8 - Mobile hardware-software complex for assessing the quality of masking noise interference

VI. DISCUSSION

Carrying out manual calculations according to the developed method of assessing the quality of masking noise interference is a very time-consuming and time-consuming process. This is due to the need to process a large number of values.

In this regard, software has been developed to implement automatic calculation of measurement results. The program consists of several functions with the implementation of a mathematical model of a method for evaluating the quality of masking noise interference of noise generators.

The software allows receiving and storing information from the radio at specified frequencies, as well as conducting statistical analysis of the received data. The range of received frequencies depends on the hardware component of the analyzing complex.

Figure 9 shows an example of the program result for the automated calculation of values for the "LNG-503K" NG (measurements were carried out in 4 subbands - Fig. 9.1 up to 500 MHz, Fig. 9.2 500-1000 MHz, Fig. 9.3 1000-1500 MHz, fig. 9.4 1500-2000 MHz).

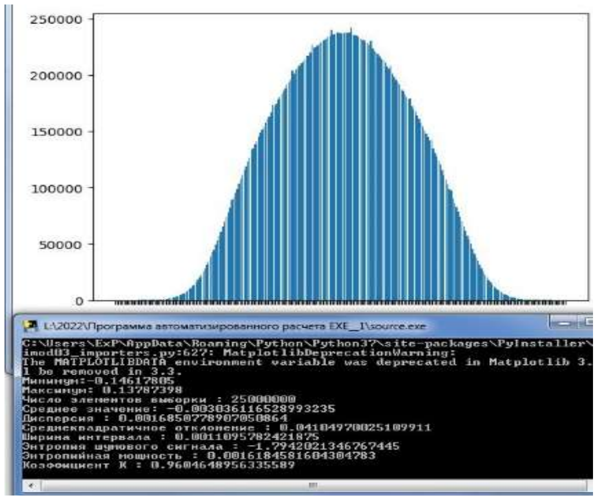

Figure 9.1 measuring range up to 500 MHz

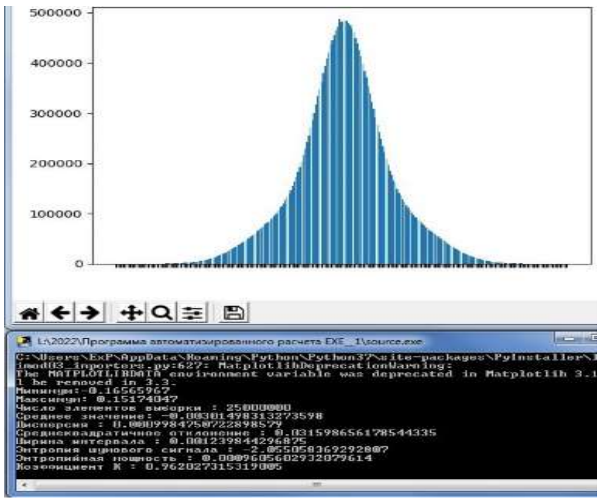

Figure 9.2 measuring range up to 500-1000MHz

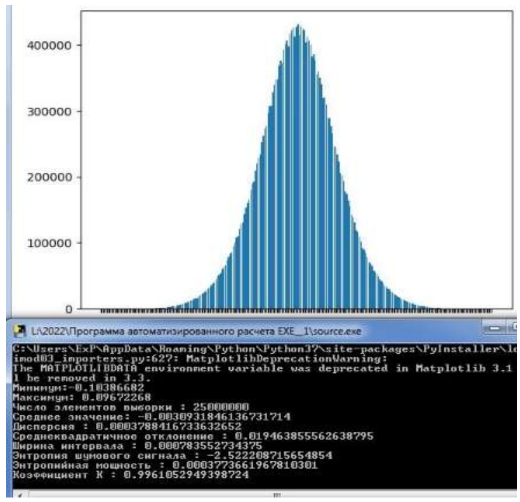

Figure 9.3 measuring range up to 1000-1500 MHz

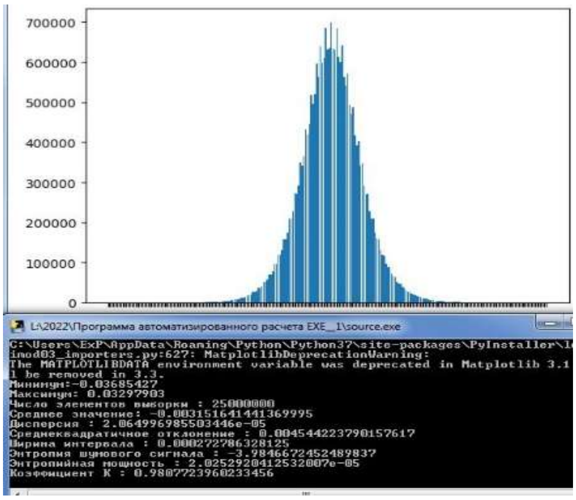

Figure 9.4 measuring range up to 1500- 2000 MHz

Figure 9. The result of the calculation program on the example of the noise generator "LNG-503K" divided into 4 subbands up to 2 GHz.

The low entropy quality coefficient of noise masking noise generators will not be able to ensure the security of the protected information. A low entropy quality coefficient can, for example, be observed with insufficient quality of the noise source (noise diode, transistor, resistor, etc.) or in other cases. Such cases include the possibility of regulating the level of the output signal of the NG, as well as the power supply of the NG with some boundary levels. For example, some manufacturers allow NG power supply within 220 V ± 10% at a mains frequency of 50 Hz. This means that the NG power supply is possible in the range of 187-253 V. In some NG with their power supply, a significant deterioration of the entropy quality coefficient was observed in the boundary values. Such a circumstance directly increases the threat of leakage of information protected with the help of GS.

VI. CONCLUSION

When evaluating the quality of masking noise interference, measurements should be made using spectrum analyzers or other similar receivers and digital oscilloscopes. The parameters of the measuring equipment must be selected according to the investigated NG.

It is not difficult to choose a digital oscilloscope with a bandwidth equal to the operating frequency range of the NG, but it is almost impossible to choose a spectrum analyzer or other measuring receiver due to the lack of such on the market. Even for the best spectrum analyzers in terms of their parameters, the bandwidth is much less than the operating range of the NG. Keysight N9040B spectrum analyzers have a maximum bandwidth of 1 GHz, and Rohde & Schwarz FSW 800 MHz. However, their cost is very high.

For this reason, when carrying out measurements on the air, the operating frequency range of the NG must be divided into smaller ranges that do not exceed the bandwidth of the measuring instruments.

As an affordable, compact, and mobile alternative, the use of a mobile hardware-software complex for assessing the quality of masking noise interferences in spatial noise systems is proposed. From a practical perspective, the use of such a complex will be universal for conducting measurements during the development and production of spatial noise systems, as well as for certifying such means, and also for evaluating their effectiveness at information technology sites.

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