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# RELIABLE PARAMETRIC FILTERING FOR VIDEO SYSTEM NOISE IMMUNITY

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**ABSTRACT**

The article discusses issues of robust signal filtering by a newly developed method devoid of the following disadvantages of known systems, namely: - working only with a fixed spectrum of the input signal; - inability to operate in signal processing systems with a changing spectrum; - narrow band. The filtering method is based on: - elimination of operation at a single fixed frequency and the possibility of working in systems with a changing spectrum is achieved by using a clock pulse generator, the frequency of which varies depending on the width of the input signal spectrum due to the use of frequency-dependent coefficients;
- elimination of the lack of narrowband, which is achieved by using a signal spectrum width analyzer and a nonlinear variable filter capacitance (varicap) depending on the width of the signal spectrum.
The substantiation of the proposed method is given, which allows processing signals with varying spectrum width, increasing their noise immunity and reducing the level of pulse interference, including in video surveillance and television systems. Modeling and experimental studies have been carried out to confirm the operability of this method.

**Keywords:** *Robust Filtering; Bandwidth Changing; Nonlinear Filter; Video Pulse*

## 1. INTRODUCTION

Initially, during digital processing, preprocessing of images is carried out, which consists of several different operations. It is needed because its values need to be adjusted, since the transducer has non-linear characteristics. Therefore, it is necessary to improve the brightness and contrast indicators, to restore geometric distortions to a minimum value [1], [2].

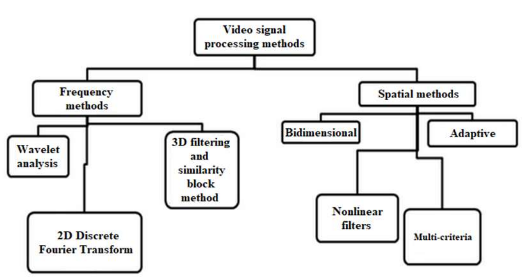


*Figure 1: Classification of video signal processing methods*

Methods of qualitative improvement of the video signal are divided into categories:
- frequency methods;
- spatial methods.

The frequency method is based on the conversion of a video signal into a Fourier series. It is used during spectral analysis, in which a complex useful signal is decomposed into several simple signals (oscillations) in order to determine the operability of each signal (oscillations) in a complex signal [1], [2].

The spatial method refers to the image plane; it is based on direct manipulation of the resulting pixels. Some local transformations operate simultaneously both with the values of pixels in the ambit and with the corresponding values of some matrix having the same dimensions as the ambit. Such a matrix is called a filter, mask, kernel, or template. The values of the matrix elements are called coefficients [1], [2].

Currently, there is no generalized theory of improving the quality of signals. Only human perception can determine the image quality of a particular method. This is a subjective process that defines the concept of a “high-quality image” in comparison with an elusive reference image; this becomes the reason for the need to collate the effectiveness of the algorithm [1], [2], [3].

During digital processing, it is necessary to obtain an image in the form of electrical signals. Such signals can be easily digitized as a combination of numbers, and then they can be processed on a computer. There are many ways to convert a video image into discrete numbers [1], [2], [3].

Video images transmitted via communication channels are affected by various types of interference, which complicate the task of visual and automatic monitoring and also its analysis. There are many different ways to filter or smooth out the useful noise-contaminated component, which depends on the correctly chosen mathematical model of the video image and interference. Mathematical models of the useful and noisy components of the video image are divided into groups:

- additive;
- multiplicative;
- mixed, or combined [1], [2], [3].

Currently, the use of the models above presupposes the presence of known knowledge about the original image. The absence or reduction of this information makes it practically impossible to use the models [4], [5], [6].

Taking into account all the aforementioned, when considering a large number of video signal processing methods, the question of choosing one or another method is always acute, because each method has its undeniable advantages and disadvantages. At the same time, some of the methods have been studied quite deeply, while the other requires thorough mathematical calculations.

Due to the fact that this work is devoted to physical research, one of the spatial methods was chosen for further deeper study, namely: the method of nonlinear filtering, which was well studied with narrowband signals. At the same time, studies of this method for broadband signals are insufficient, and for signals with varying spectrum widths have not been conducted at all [7], [8], [9].

The development of digital systems, which have made great strides forward, does not diminish the improvement of analog systems, which are advisable to use in some cases. In the process of transmission and conversion using radio engineering systems, video signals are exposed to various interference, distortion, noise, which in some cases leads to a deterioration in visual quality [10] and a decrease in the signal level (cutoff). The main disadvantage of the video surveillance system is its susceptibility to weather impact (rain, fog, snowfall, etc.), which degrades the quality of the video system.

Therefore, the urgency of finding new ways and opportunities to improve the quality of video signals is one of the priority areas of signal processing.

Today, with the constant growth in the demand for the signal quality indicator, its further increase is an indispensable condition for a new qualitative breakthrough in the development of the video surveillance market.

The greatest uptime of the video surveillance system can be achieved with the help of properly thought-out design solutions.

Such a factor is an improvement in the quality of video signals by conducting research and identifying shortcomings by developing new methods of filtering and signal processing.

Currently, there is no generalized theory of improving the quality of signals. Only human perception can determine the image quality of a particular method. This subjective process defines the concept of a “high-quality image” in comparison with an elusive reference image, which is the need to compare the effectiveness of the algorithm.

Taking into account all the above, when considering a large number of methods for processing video signals, the question of choosing one or another method is always acute, since each method has its own undeniable advantages and disadvantages.

In addition for determining the main characteristics of the video camera, the methods of processing video information and filtering systems were considered in the work to improve the quality of the video signal.

*Analysis of filtering systems*

In modern security video surveillance systems, widely used methods of information processing (multi-criteria and linear) are insufficiently effective. Therefore, it is proposed to use a robust method of information processing based on the application of the criteria of the Neyman–Pearson lemma, which is used to process signals with a variable bandwidth of the spectrum and images obtained from the output of a CCD (a device with a charging connection) and a photosensitive matrix of a video camera.

As a new approach in this direction, a method of nonlinear robust filtering is proposed; it applies a parametric method for detecting non–stationary signals under the action of arbitrary interference. This method makes it possible to organize the functioning of the system using signals with varying bandwidth, both in conditions of statistical uncertainty and in conditions of strong interference. The development of new mathematical models and processing algorithms is based on the principles of the theory of robust statistics and Markov random processes, and the algorithms are implemented in the form of nonlinear differential equations system [5], [11].

The synthesis of robust detectors is performed initially according to the consistency criterion (synthesis of the basic structure in the form of the type and order of a linear differential equation), and then the main and final synthesis of a nonlinear equation takes place [7]. The initial synthesis of the robust processing algorithm is performed using the appropriate reference signal, and the final one is executed on the basis of a weak robust nonparametric detection criterion. This criterion was developed on the basis of the invariance condition for the Fokker-Planck-Kolmogorov equation (FPK) [7] and can be written as:

$$\frac{d\rho\left(y,\overrightarrow{\lambda_{c,}},t\right)}{d\overrightarrow{\lambda_c}} = 0, \qquad (1)$$

where $d\rho\left(y,\overrightarrow{\lambda_{c,}},t\right)$ is the one-dimensional probability distribution density (PDD) of a nonlinear system in the corresponding Fokker–Planck–Kolmogorov equation.

Consistency criterion is the mathematical basis of the nonlinear robust filtering method. The physical basis is energy transformations in parametric nonlinear dynamical systems.

Most applications of parametric devices involve harmonic impacts, both for the input signal and the pump signal. In information systems, under the influence of interference, the operation is closer to the pulse mode. Consider the state of a nonlinear capacitance under the influence of an information signal *S(t)* and a pump oscillator signal $S_n(t)$ as shown in Figure 2. Figure 2 shows the nonlinear capacitance $C(u)$ and indicates: *FP*– filter-plug pump, *FS*– filter-plug signal, $C(n)$ – nonlinear capacitor, $e_s$ – signal voltage source, $e_p$ – pump oscillator.

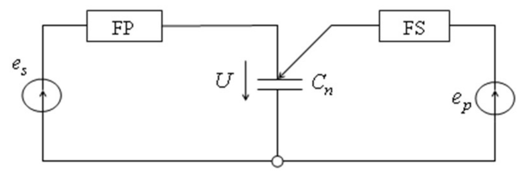

*Figure 2: Equivalent Circuit Diagram Of Nonlinear Capacitance Inclusion*

During determination of the state in the circuit according to Fig. 1, for pulse modes, the pump oscillator signal can be selected in the form of a periodic sequence of rectangular pulses of a sufficiently high pulsing ratio cycle with a certain repetition frequency $\Omega_R$ . Then the pump signal can be written as the following harmonic series:

$$S_\rho(t) = \sum_{k=0}^{N} A_k \cos(k \cdot \Omega_R t + \varphi_k). \qquad (2)$$

In this case, the information signal for obtaining compact and visual energy ratios can also be taken as harmonic type:

$$S(t) = E\cos(\omega t). \qquad (3)$$

With stochastic pumping (2) will represent short quasi-periodic sequences $\{\zeta_i\}$. Then some sequences $\{\zeta_i\}$ for (2), (3) will be

$$k_i \cdot \Omega_{Ri} - \omega = \omega, \qquad (4)$$

that is, for some components, the harmonic pump components will be chosen with the frequency of the information signal. Since it can be written as $\sin(\omega t + \varphi_k) = \cos(\omega t) - (\frac{\pi}{2} - \varphi_k)$, then, for frequencies according to equation 4, the components of the current in the capacitance characterize the active load, the power of which is:

$$P_\omega = -0{,}5E^2 \sum_i \Delta C_{iQ} E^2 \cos({}^{\pi}/_{2} - \varphi_{iQ}) . \qquad (5)$$

The summation in equation 5 is performed according to the sequences $\{\zeta_i\}$. At the values of the initial pump phases $\varphi_{iQ} = -{}^{\pi}/_{2}$, the active power according to equation 5 becomes negative

$$P_\omega = -0{,}5E^2 \sum_i \Delta C_{iQ} , \qquad (5a)$$

that is, it comes from the parametric capacity to the source of the information signal. As a consequence of this, the power of the information signal increases. As a consequence, the signal energy increases due to stochastic pumping. In robust stochastic systems, phase rotation $(-{}^{\pi}/_{2})$ is carried out as a consequence of the operations of ideal differentiation and inversion.

For finite information signals, decomposition can be carried out in a harmonic basis, but at the same time robust systems will be more difficult, for example, during their unification [8].

Algorithmically nonlinear stochastic systems follow from robust synthesis algorithms, respectively, as the synthesis of optimal linear algorithms, which can be obtained on the base of the Bayesian theory of statistical solutions. Moreover, during linearization, the robust properties of nonlinear systems degenerate and only linear – in the particular case, optimal – filtration is realized.

*Detection and filtering of video pulses*

Nonparametric detection and identification of signals against a noisy background can be formulated so that the following is observed:

$$\zeta(t) = z(t)\theta + n(t), \quad t \in [0,T], \qquad (6)$$

where $z(t)$ is a signal with unknown parameters (not a stationary random process with an arbitrary distribution, but partially given statistical characteristics), $\theta \in 0,1$ (0 is the absence of a signal, which is a simple null hypothesis – $H_0$; 1 – is the presence of a signal, nonparametric given hypothesis - $H_1$), for $\theta = 1$, equation 6 is an identification task, $\vec{n}(t)$ is a broadband noise with some distribution, T is the observation interval.

This task, i.e. detection and identification of video signals, including both detection and joint assessment of unknown parameters, is performed on the basis of the methodology described in [12]. At the same time , a nonlinear robust dynamic system of at least the second order is used to process observations according to formula 6 based on the stochastic pumping phenomenon.

For the formation of the reference function, it is necessary to accept, for example, conditions of quasi-optimal detection of the given information signal. Then, for a sufficiently wide class of low-frequency signals, the reference signal will correspond to the pulse characteristic of a quasi-optimal linear filter (QLF) at least of the second order [13].

Thus, when using a single oscillatory circuit (SOS) of an L-shaped link as a second-order system, a nonlinear processing algorithm can be written in the form of a stochastic nonlinear differential equation (the state variable is indicated by the voltage on the capacitance of the SOS):

$$\frac{d^2u}{dt^2} + \frac{1}{RC90} \cdot \frac{du}{dt} + \frac{1}{C(u)} \cdot \frac{dC(u)}{du} \cdot (\frac{du}{dt})^2 + \frac{1}{LC(u)} = \quad = \frac{1}{LC(u)} \cdot \zeta(t). \qquad (7)$$

Here R, $C(u)$ is the resistance and nonlinear capacitance of a single oscillatory circuit, $LC(u) = {1}/{\omega_{0t}^2(u)}$ and the inductance can be taken as a constant.

Equation 7 can be written in the canonical form of a system of stochastic differential equations of the first order

$$\frac{du_1}{dt} = u_2;$$

$$\{du_2 = -\frac{u_2}{RC(\vec{u})} - \frac{u_1}{LC(\vec{u})} - \frac{1}{C(u)} \cdot \frac{dC(\vec{u})}{du_1} \cdot (\frac{du_1}{dt})^2 + + \frac{s(t,\vec{\lambda})+n(t)}{LC(\vec{u})}. \qquad (8)$$

The system of equations 8 describes the multidimensional Markov process $\vec{u}^T = (u_1(t), u_2(t))$ and then, for the final structural-parametric synthesis, including determining parametric dependencies $C(u)$, a weak robust detection criterion according to formula 1 can be applied as following (for $t = \tau_{imp}$ ):

$$dP(\vec{u},\vec{\lambda},t)\Big/_{d\vec{\lambda}} = 0. \qquad (9)$$

Here $\rho(\vec{u},\vec{\lambda},t)$ is the unsteady density of the probability distribution in the corresponding FPK equation, which can be compiled for the Markov diffusion process $\vec{u}^T = (u_1(t), u_2(t))$ according to the system of equations 8.

The conditions of equation 9 correspond to the fulfillment for the drift coefficients of the corresponding FPK equation the following ratios:

$$\alpha_i(\vec{u},\vec{\lambda},t) = const, \quad \frac{d\alpha_i(\vec{u},\vec{\lambda},t)}{du_i} = const, \quad \vec{\lambda} \to const \ (i = 1,2,3 \dots). \qquad (10)$$

The relations of equation 10 are the conditions of statistical nonparametric insensitivity of the processing algorithm in this problem when observing equation 6.

From the systems of equations 8 and 10, the following equations for the drift coefficients can be obtained:

$$\alpha_1(\vec{u}) = u_2;$$

$$\alpha_2(\vec{u}) = -\frac{u_2}{R(\vec{u})C(\vec{u})} - \frac{u_1}{LC(\vec{u})} - L\frac{dC(\vec{u})}{du_1} \cdot \qquad (11)$$

$$(\frac{du_1}{dt})^2 + \frac{S(t,\overrightarrow{\lambda})}{LC(\vec{u})} + \frac{N}{4} g_2(\vec{u},t) \cdot \frac{dg_2(\vec{u},t)}{du_2},$$

where $g_2 = (\vec{u},t) = {}^1/_{LC(\vec{u})}$.

Using equations 10, 11 according to the methodology described in [7], it is possible to obtain nonlinear dependencies in the form of

$$C(u_2) = C_0 \exp(k_2 u_2)\,, \quad 0 < t < \tau_{imp} \qquad (12a)$$

and

$$\frac{dC(u_2)}{du_1} = 0. \qquad (12b)$$

Here $C_0 = C(0)$ is a constant value, $k_2$ is the proportionality coefficient.

Figure 3 shows, according to Equation 8, a circuit diagram of a robust filter.

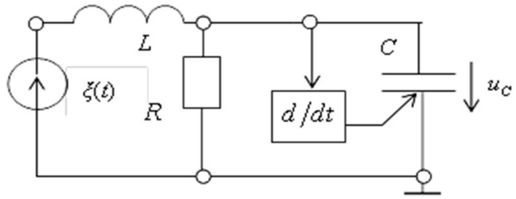


*Figure 3: Circuit Diagram Of a Robust Nonlinear Filter*

A nonlinear robust filter can be made on the basis of switchable capacitors (Figure 3). Its technology is very promising for the manufacture of various high-level analog integrated circuits. Filters based on switchable capacitors are discrete-analog processing devices, and the input voltage is discredited in time, but the level remains unchanged.

The main feature of such filters is the ease of adjusting the cutoff frequency using microprocessor control systems. The cutoff frequency is a linear dependence on the clock frequency applied to the filter. Therefore, they are called synchronous filters. Another important advantage is the absence of resistors and inductors in filter circuits (Figure 4) [8], [9].

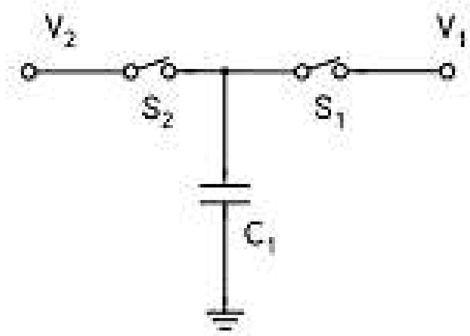


*Figure 4: Example Of Resistor Replacement With a Capacitor And Two Keys*

The principle of the synchronous filter operation is based on the fact that an analog signal is supplied to the filter input. The gain factor and cutoff frequency are set by 4-bit codes at the inputs G0–G3 and F0–F3. The output signal is removed from the OUT output. The cutoff frequency of these filters is fixed [8], [9].

Due to the fact that this work is devoted to the substantiation of a method that allows processing signals with varying spectrum width, increasing their noise-proof feature and reducing the level of pulse interference for video surveillance and television systems. For a deeper study, one of the spatial methods was chosen, namely: the method of nonlinear filtering, which is based on the processing of narrow-band signals. At the same time, studies of this method for broadband signals are insufficient, and for signals with varying spectrum widths have not been conducted.

The analysis of literature sources proves that, at present, there is no description of a unified approach to the creation of image restoration systems with simultaneous effective allocation of a useful two-dimensional signal against the background of additive noise and preservation of brightness differences, transitions, boundaries and contours of objects in conditions of a limited amount of a priori information. When restoring by known methods, along with distortion suppression, the image is defocused, which in some cases greatly reduces the visual quality.

There is a device operating on the principle of robust estimation of the radio pulse carrier frequency (patent RU № 2267226 IPC H04L7/033, publication date 27.12.2005 [10]).

The circuit diagram of the device consists of a bandpass limiter amplifier, a tunable robust bandpass filter, a synchronizer, a threshold device, a phase-locked frequency system, adders, a tunable generator, a phase detector and a low-pass filter [10].

The disadvantages of such a device include:

– operating only with a fixed spectrum of the input signal;

– inability of working in signal processing systems with a changing spectrum [14].

There is a device using piecewise linear approximation (copyright certificate SU № 1624479 IPC 5 G06F15/353, publication date 30.01.1991) [11]. The disadvantages of such a device include:

– the need for a priori information about the function of the useful signal;

– useful component error has a nonlinear dependence and reaches its maximum values at the boundaries of the approximation interval;

– with a non-polynomial model for evaluating the useful component, the objective function of the least squares method does not always exist due to the nonlinearity of the system of equations being solved.

There is a device that implements a method for identifying a trend by multiplying estimates of its single initial implementation (patent RU № 2207622, IPC 7 G06F 17/18, publication date of the application 10.10.2002) [12].

The disadvantages of such a device include:

– impossibility of implementing the known multiplying estimates of a single original signal realization method in real time;

– lack of practical recommendations for choosing the number of partition intervals and the number of multiplying estimates;

– high computational costs.

In technical essence, the closest analogue of the invented robust nonlinear filter specified in this article is a parallel signal processing device (patent RU № 2362208, IPC G06F17/18, publication date of the application 20.07.2009), implementing a multi-criteria method of signal processing [15].

In comparison with previous devices, such a disadvantage as the need to remember the values of the entire input implementation was eliminated here.

One of the main disadvantages that all the above-mentioned devices had, namely, large computing costs, was not eliminated.

A series-parallel signal processing device is also known (patent RU № 2321053, IPC 7 G06F17/18, publication date of the application 27.03.2008) [16].

The disadvantages of such a device include:

– operating at a single fixed clock frequency, which limits its use, excluding the possibility of its utilizing in equipment with a changing signal spectrum.

There is a device that allows detecting and eliminating the values of pulse noise with a limited amount of a priori information about the statistical characteristics of an undistorted image, pulse noise and acting additive interference (patent RU № 2449355, IPC G06F17/17, publication date of the application 27.04.2012 [15]). The block diagram of this device implementing the considered algorithm contains a block for storing measurement results, a block for setting the number of thresholds, a block for forming thresholds, discriminator blocks, blocks for storing penalty values, a block for setting the detection interval, blocks for detecting intervals of unsteadiness of penalty values, zeroing blocks, a summation block, a threshold block, a clock pulse generator [17].

The disadvantages of this device include:

– a limited amount of a priori information about the statistical characteristics of an undistorted image;

– large computational costs that require an additional hardware and software device or the involvement of an additional mathematical calculations [18].

The most acceptable in terms of technical characteristics is the robust nonlinear filter scheme proposed in the article [19]. The disadvantages of this filter include:

– narrow band;

– operating with a fixed spectrum of the input signal.

The novelty of the proposed method makes it possible to eliminate the main disadvantages of existing devices. Elimination of operation at one fixed frequency is achieved by using a clock pulse generator, the frequency of which varies depending on the width of the input signal spectrum due to the use of frequency-dependent coefficients.

Eliminating the lack of narrowband is achieved by using a signal spectrum width analyzer and a nonlinear variable filter capacitance (varicap) depending on the signal spectrum width.

The block circuit diagram of the device for the proposed filtration method, shown in the figure 5, explains the principle of operation, where [16]:

RG is a reference generator;

DFDR – divider with a fixed division ratio (m);

PPD – pulse-phase detector;

LPF w/ VLS – low-pass filter with the voltage level storage;

VLC – voltage level converter;

VCG – a voltage-controlled generator;

DVDR – divider with a variable division ratio (n);

SWA – signal spectrum width analyzer;

SWCK – spectrum width converter -key (division ratio n);

RF – robust filter;

N. E. – nonlinear element (varicap).

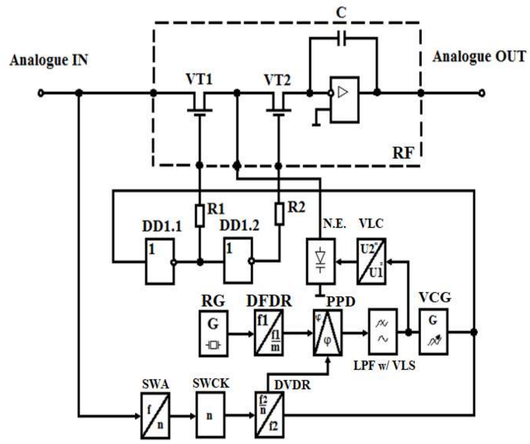


*Figure 5: Circuit diagram of a robust filter*

The new value of this research is as follows:

– a nonlinear robust filter has been developed (patent №1467 "Device for robust parametric filtering in systems with variable bandwidth" dated 16. 10. 2015) [16].

– a method for measuring the video signal with a robust nonlinear filter has been developed;

– removal of the dependence of the video output signal level on the passband of a nonlinear robust filter at the output of the clock pulse generator of the training television stand (GTI UTS-2010) for normal operation, under conditions of exposure to in-band pulse interference without a filter and with a filter for video signals with different bandwidth and different filter clock frequency.

The technical result obtained by using the proposed invention [14] significantly increases the noise immunity of signals in systems with a changing spectrum, in particular, in video surveillance and television systems (CCTV).

Thus, the proposed scheme in Figure 1 allows processing signals with a changing spectrum width, increasing their noise immunity and reducing the level of pulse interference in systems with a changing signal spectrum including video surveillance systems. It allows significantly expand the range of usage of the proposed device [11] depending on the supplied voltage from the voltage level converter and, accordingly, on the width of the input signal spectrum, as well as on the voltage-controlled generator, the output frequency of which is determined by the width of the input signal spectrum, i.e. the voltage supplied to the voltage-controlled generator from the pulse-phase detector through a low-pass filter with the voltage level storage.

The main input of the pulse-phase detector receives a fixed frequency signal from the reference generator through a divider with a fixed division ratio (m). The additional input of the pulse-phase detector receives a signal proportional to the output voltage frequency of the voltage-controlled generator and the width of the input signal spectrum of the divider with a variable division ratio (n). The division ratio (n) depends on the width of the input signal spectrum, which is determined by the signal spectrum width analyzer and the spectrum width converter-key. The signal from the voltage-controlled generator output with the required frequency is fed to the robust filter through the inverting circuits DD1.1 and DD1.2, which determine the opening and closing of the transistors VT1 and VT2 of the robust filter in the opposite phase [16].

## 2. STUDY OF PARAMETRIC ROBUST FILTERING ON THE NOISE IMMUNITY OF A VIDEO SYSTEM

The experiment was carried out in the laboratory "Television and CCTV systems" on the training television stand UTS-2010 on the subject "Device for robust parametric filtering in systems with variable bandwidth" for which the patent of the Republic of Kazakhstan №1467 was received [10]. Experimental studies of the effect of a nonlinear filter on a video signal under the influence of impulse noise were carried out in accordance with the structural diagram shown in Figure 6.

In this experiment, video cameras (NVC-SDN 500, VidaTec, NVC-825DN and NVC-825DN) with resolutions of 380, 420, 480 and 580 TVL were used during alteration the image from black and white to color.

The experiment was carried out on a TV installation UTS-2010, using equipment: an oscilloscope S1-220, a generator G4-151 and a power supply +5V. The accuracy of the measuring device is ±0.25 dB.

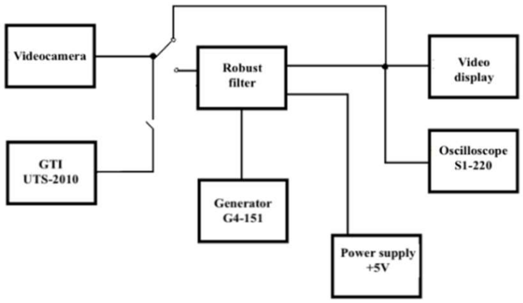


*Figure 6: Structural Diagram Of Equipment Connection For Experimental Research*

Figure 7 shows the stand where this experiment was carried out. In the experiment, we used video cameras with different resolution, a UTS-2010 television stand, a clock pulse generator (GTI) used as a noise generator, an S1-220 oscilloscope, a G4-151 generator, and a + 5V power supply. The layout shown in Figure 8 was used as a robust filter [20]. It is proved that this filter will operate from a clock generator under the condition:

$$f_{clock.} \geq 25 \bullet f_{clock.max.}.$$

The characteristics of video cameras are presented in Table 1.

The output signal from the video camera was measured:

– during normal operation;

– under conditions of influence of intracavity impulse noise without filter;

– under conditions of influence of intracavity impulse noise with a filter with different clock frequency.

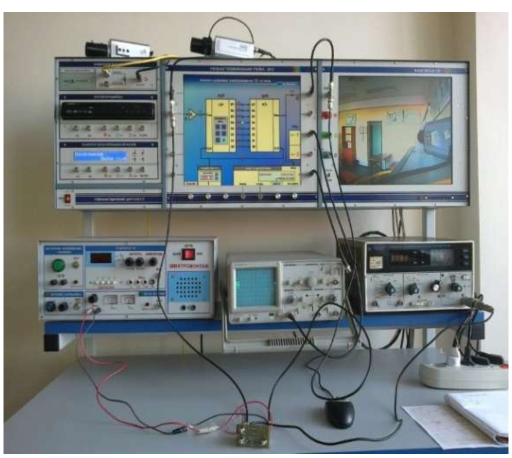

*Figure 7: External View Of The Stand For The Test Conduction*

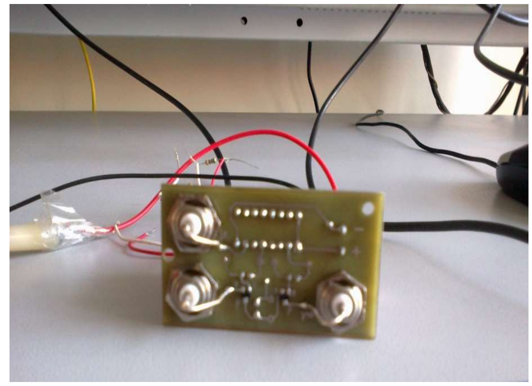

*Figure 8: The image of a filter*

*Table 1: Types Of Signal Sources And Their Characteristics.*

| Video camera type | Picture | Resolution (TVL) | Occupied frequency band, MHz |
|---|---|---|---|
| NVC-SDN 500 | Black and white | 380 | 4.5 |
| Vida Tec | Colored | 420 | 5 |
| NVC-825DN | Colored | 480 | 5.8 |
| NVC-825DN | Black and white | 580 | 7.5 |

Signal oscillograms are shown in Figures 9, 10, 11.

The oscillograms and images show that the nonlinear robust filter, although it reduces the level of the useful signal, filters the impulse noise. True, this only happens at certain clock frequencies that switch the filter capacitance. In further experiments, the task was set to determine the clock frequencies and their relationship with the passband of the robust filter.

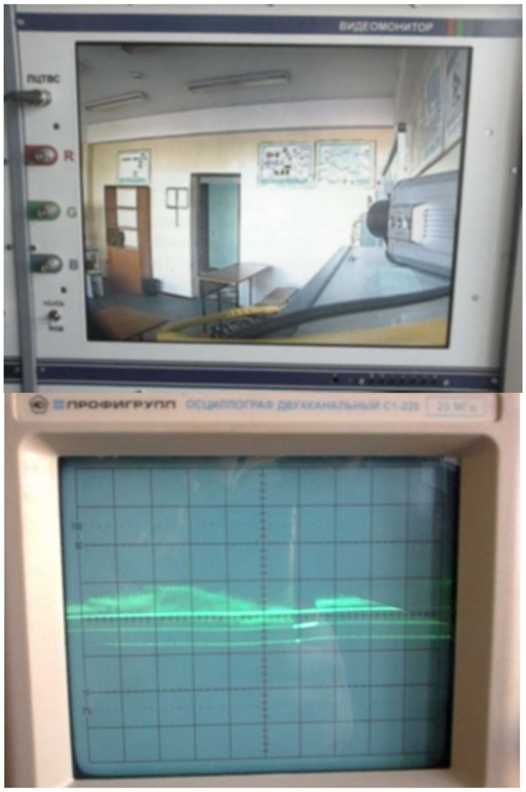

*Figure 9: Image And Oscillogram Of a Video Signal During Normal Operation Without Interference*

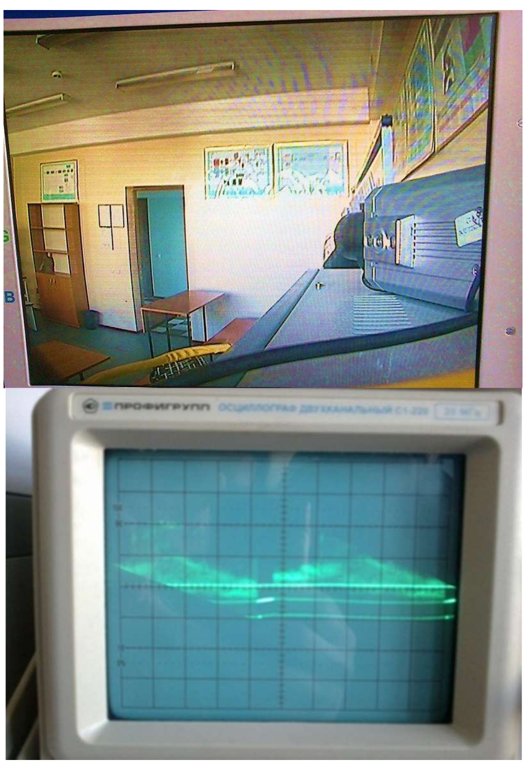

*Figure 10: Image And Oscillogram Of a Video Signal In The Presence Of Impulse Noise*

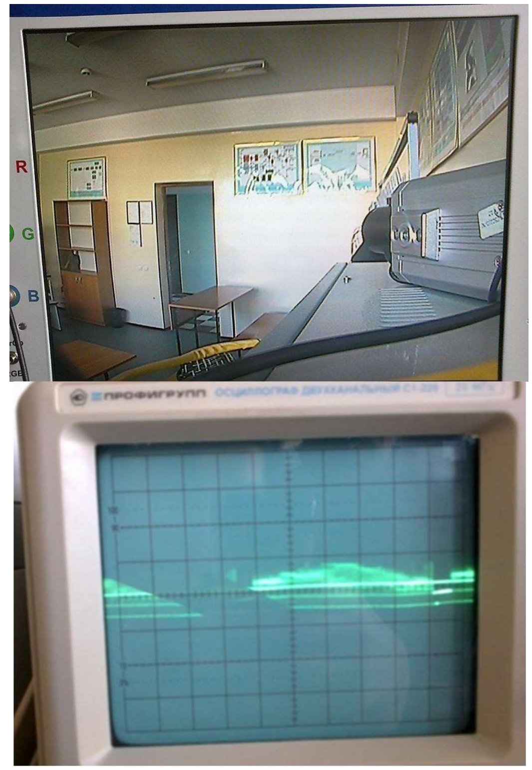

*Figure 11: Image And Oscillogram In The Presence Of Interference With a Working Filter*

A number of experiments were carried out, the conditions and results of which are presented in Tables 2-5 and in the graphs (Figures 12-15) [2]. Experimental frequencies:

- $f_{imp.noise1}$= 3,33 MHz;
- $f_{imp.noise2}$= 4,0 MHz;
- $f_{imp.noise3}$= 5,0 MHz;
- $f_{imp.noise4}$= 6.67 MHz.

In this experiment, the value of the actual clock frequency was equal to $f_{clock.fact.}$=113.52 MHz, the value of the calculated clock frequency was equal to $f_{clock.calc.}$=115 MHz at $U_{m.in}$=1,0 V.

Table 2 shows the values of the voltages taken from the oscilloscope when applying different frequencies.

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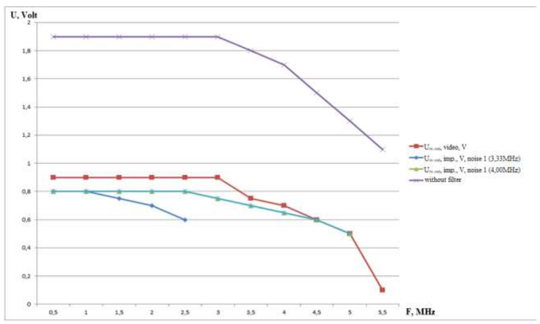


*Figure 12: Signal Levels Obtained In Experiment 1*

It can be seen from the graph that the 3.33 MHz impulse noise is cut off at the clock frequency of 80 MHz, the 4 MHz impulse noise is cut off at the clock frequency of 115 MHz, which corresponds to the calculated clock frequency of the generator.

During the second experiment, a VidaTec video camera was used with TVL = 420 and a color image with the setting of the parameters of the television installation, at which the frequencies of the impulse noise from the GTI UTS-2010 $f_{imp.noise}$ at $U_{m.nom}$=2,0 V were [15]:

- $f_{imp.noise1}$= 3.33 MHz;
- $f_{imp.noise2}$= 4.0 MHz;
- $f_{imp.noise3}$= 5.0 MHz;
- $f_{imp.noise4}$= 6.67 MHz.

In this experiment, the value of the actual clock frequency is equal to $f_{clock.fact}$=123.33 MHz, the value of the calculated clock frequency at $U_{m.in}$=1.0 V is equal to $f_{clock.calc}$=125 MHz.

Table 3 shows the values of the voltages taken from the oscilloscope at various frequencies.

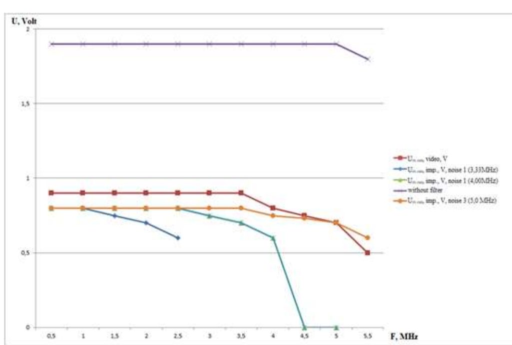


*Figure 13: Signal levels obtained in experiment 2*

In this case, impulse noise of 3.33 MHz is cut off at a clock frequency of 80 MHz, a pulse noise of 4 MHz is cut off at a clock frequency of 100 MHz, a pulse noise of 5 MHz is cut off at a clock frequency of 123 MHz, which corresponds to the calculated clock frequency of the generator [20].

During the third experiment, an NVC-825DN video camera was used with a TVL = 480 and a color image with the parameters of a television installation, at which the frequencies of pulse noise from GTI UTS-2010 at $U_{m.nom}$=2,0 V were:

- $f_{imp.noise1}$= 3.33 MHz;
- $f_{imp.noise2}$= 4.0 MHz;
- $f_{imp.noise3}$= 5,0 MHz;
- $f_{imp.noise4}$= 6.67 MHz.

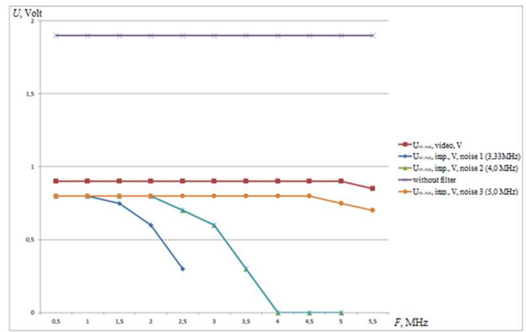


*Figure 14: Signal levels obtained in experiment 3*

The pulse noise of 3.33 MHz is cut off at a clock frequency of 95 MHz, the pulse noise of 4 MHz is cut off at a clock frequency of 110 MHz, the pulse noise of 5 MHz is cut off at a clock frequency of 140 MHz, which corresponds to the calculated clock frequency of the generator [16].

In this experiment, the value of the actual clock frequency is $f_{clock.fact}$=148.75 MHz, the value of the calculated clock frequency is $f_{clock.calc}$=150 MHz at $U_{m.in}$=1.0 V [21].

Table 4 shows the values of the voltages taken from the oscilloscope when applying different frequencies

During the fourth experiment, an NVC-825DN video camera was used with TVL = 580 and a color image with the following parameters of the television installation, at which the frequencies of pulse noise from GTI UTS-2010 at $U_{m.nom}$=2.0 V were:

- $f_{imp.noise1}$= 3.33 MHz;
- $f_{imp.noise2}$= 4.0 MHz;
- $f_{imp.noise3}$= 5.0 MHz;
- $f_{imp.noise4}$= 6.67 MHz.

In this experiment, the value of the actual clock frequency is $f_{clock.fact}$=148.75 MHz, the value of the calculated clock frequency is $f_{clock.calc}$=187.5 MHz at $U_{m.in}$=1.0 V. At these frequencies, the filter does not work [23].

Table 5 shows the voltage values taken from the oscilloscope when applying different frequencies.

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Figure 15 shows the dependence of the output maximum voltage on the clock frequency at different values of pulse noise.

The pulse noise of 3.33 MHz is cut off at a clock frequency of 110 MHz, the pulse noise of 4 MHz is cut off at a clock frequency of 130 MHz, the pulse noisee of 5 MHz passes, so we can conclude that the filter does not work at these frequencies. These values are due to the fact that it was not possible to set a higher frequency of the master generator, since the maximum frequency of the generator G4-152 is 150 MHz.

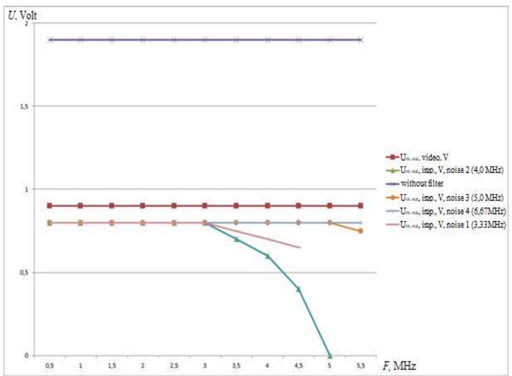


*Figure 15: Signal levels obtained in experiment 4*

According to the graphs (Figures 12-15), it can be concluded that out-of-band interference does not affect the level and quality of the signal, in-band interference does not have time to pass through the filter when it coincides with the filter cutoff frequency. With an increase in the filter clock frequency, the in-band pulse noise passing through the filter becomes more weakened [15], [22].

## 3. CONCLUSIONS

Conducted study on the effect of robust filtering on the noise resistance of a video system has shown the following:

– the instrumental method is the most acceptable for conducting objective control, taking into account subjective perceptions;

– experimental studies of the suitability of these measurement and video signal processing techniques have been carried out and the correctness of certain measurement and video signal processing techniques has been confirmed;

– the tasks that arose during the organization of measurements have been solved, namely, a laboratory stand has been developed and manufactured and control and measuring equipment has been selected, which combine a significant number of methods for measuring the parameters of the video system, which makes it possible to conduct applied research practically without limitation in the subject;

– based on the conducted research, it is shown that the developed nonlinear robust filter is able to reduce pulsed in-band interference and gives an increase in noise immunity compared to known structures up to (10-20) dB.

- based on the results of the experiments, the patent of the Republic of Kazakhstan No. 1467 registered on 19/04/2016 was obtained.

*Table 2: Signal Levels For 380 TVL, At $U_{m.in}$ = 1.0 V, At $U_{imp.noise}$ = 2.0 V.*

| Parameters | Received values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{clock}$, MHz | 60 | 70 | 78.35 | 80 | 90 | 100 | 110 | 113.52 | 115 | 120 | 125 |
| $F_{spectre}$, MHz | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| $U_{m.out}$, video, V | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.75 | 0.7 | 0.6 | 0.5 | 0.1 |
| $U_{m.out}$, *imp.*, V, noise 1 (3.33MHz) | 0.8 | 0.8 | 0.75 | 0.7 | 0.6 | - | - | - | - | - | - |
| $U_{m.out}$, *imp.*, V, noise 2 (4.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.7 | 0.65 | 0.6 | 0.5 | - |
| $U_{m.out}$, *imp.*, V, noise 3 (5.0 MHz) | - | - | - | - | - | - | - | - | - | - | - |
| $U_{m.out}$, *imp.*, V, noise 4 (6.67MHz) | - | - | - | - | - | - | - | - | - | - | - |

*Table 3: Signal Levels For 420 TVL, At $U_{m.in}$ = 1.0 V, $U_{imp.noise}$ = 2.0 V.*

| Parameters | Received values | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{clock}$, MHz | 50 | 60 | 70 | 80 | 82.1 | 90 | 100 | 110 | 120 | 123.33 | 130 | 140 |
| $F_{spectre}$, MHz | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| $U_{m.out}$, video, V | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 | 0.75 | 0.7 | 0.5 | 0.9 |
| $U_{m.out}$, *imp.*, V, noise 1 (3.33MHz) | 0.8 | 0.8 | 0.75 | 0.7 | 0.6 | - | - | - | - | - | - | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_{m.out}$, *imp.*, V, noise 2 (4.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.7 | 0.6 | - | - | - | - |
| $U_{m.out}$, *imp.*, V, noise 3 (5.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.73 | 0.7 | 0.6 | - |
| $U_{m.out}$, *imp.*, V, noise 4 (6.67MHz) | - | - | - | - | - | - | - | - | - | - | - | - |

*Table 4: Signal Levels For 480 TVL, At $U_{m.in}$ = 1.0 V, $U_{imp.noise}$ = 2.0 V.*

| Parameters | Received values | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{clock}$, MHz | 70 | 80 | 90 | 100 | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 148 |
| $F_{spectre}$, MHz | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
| $U_{m.out}$, video, V | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.85 | 0.7 |
| $U_{m.out}$, *imp.*, V, noise 1 (3.33MHz) | 0.8 | 0.8 | 0.75 | 0.6 | 0.3 | - | - | - | - | - | - | - |
| $U_{m.out}$, *imp.*, V, noise 2 (4.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.6 | 0.3 | - | - | - | - | - |
| $U_{m.out}$, *imp.*, V, noise 3 (5.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.7 | 0.6 |
| $U_{m.out}$, *imp.*, V, noise 4 (6.67MHz) | - | - | - | - | - | - | - | - | - | - | - | - |

*Table 5: Signal Levels For 580 TVL, At $U_{m.in}$ = 1.0 V, $U_{imp.noise}$ = 2.0 V.*

| Parameters | Received values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{clock}$, MHz | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 148.75 |
| $F_{spectre}$, MHz | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | 5.5 |
| $U_{m.out}$, video, V | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| $U_{m.out}$, *imp.*, V, noise 1 (3.33MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 | 0.7 | 0.65 | - | - |
| $U_{m.out}$, *imp.*, V, noise 2 (4.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.6 | 0.4 | - | - |
| $U_{m.out}$, *imp.*, V, noise 3 (5.0 MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.75 |
| $U_{m.out}$, *imp.*, V, noise 4 (6.67MHz) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

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