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SYNTHESIS OF RADIOMETRIC RECEIVERS ON THE CRITERION OF STATISTICAL INVARIANCE TO FLUCTUATIONS OF STRENGTHENING AND NARROW-BAND INTERFERENCE

Для дистанційного вимірювання власного теплового електромагнітного випромінювання тварин був проведений синтез радіометричного приймача за критерієм статистичної інваріантності вихідного сигналу, тобто виміру корисної потужності випромінювання до потужності заважаючих впливів. Відповідно до отриманих виразів для імпульсної характеристики вхідного ланцюга і схеми квадратичного детектування була складена структура синтезованого радіоприймача.

Ключові слова: *радіометричний приймач, електромагнітне випромінювання тварин, флуктуації коефіцієнта підсилювача, вузькосмужна перешкода.*

1. Introduction

One of the features of the current stage of development of agriculture in Ukraine is the growth of economic and improving the logical preconditions to the level of the needs of industrial livestock, the fusion of veterinary and livestock science with industrial livestock and the strengthening of their influence directly on the production processes. Industrial livestock breeding makes a number of requirements to the veterinary industry for the specific features of its functioning in line production, taking into account biological, economic and organizational factors. Thus, systematic monitoring of animal health becomes a necessary condition for the optimal functioning of livestock complexes, and its improvement is one of the most important tasks of veterinary science and best practice [1].

As the analysis of literature on this issue shows, the deviation of temperature from the norm can be caused by the condition of content, diet, various physical loads. Therefore, temperature control should become an integral part of the technological process for production of livestock products [2, 3].

In veterinary practice, to measure the body temperature of the animal, a contact method of measuring temperature with a maximum thermometer of Celsius, an electric thermometer is used. Disadvantages of this method are that a malfunction of the thermometer or inept introduction into the rectum often leads to injuries or ruptures of the rectal mucosa, resulting in an inflammatory process. The disadvantages also include fixation of the animal, which leads to stressful conditions and reduces the resistivity of the animal's body. Temperature measurement by thermometers is unsafe for the maintenance staff and has measurement duration (10–15 min per animal) [4]. In this regard, it is not possible to control the temperature of the animals in a herd with a large number of heads.

Therefore, there is a need for express contactless methods for controlling the temperature of animals. Thermal imagers should be assigned to non-contact instruments for measuring bodies [5]. However, the use of thermal imagers is associated with the following difficulties: fixation of the animal; special preparation of the skin surface of the animal for measuring temperature readings. Therefore, preference should be given to a remote method based on the reception and determination of the intensity of thermal radiation of the internal tissues of animals in the radio range. To date, it has been proven that many metabolic processes in cells occur in the extremely high frequency field (EHF) of the millimeter wavelength range (30–40 GHz), which is created by mushroom-like ensembles of mitochondria. The power of electromagnetic radiation of tissues and organs of animals is 10^{-15}–10^{-20} W.

Radiothermometry has a number of positive properties, which include:

- diagnosis of diseases in the early stages due to a sufficiently large depth of detection of anomalies (3–10 cm);
- the possibility of non-invasive detection of pathology of internal organs before the onset of structural changes detected by X-ray or ultrasound studies;
- complete harmlessness for animals and for staff;
- possibility of repeated measurements.

From the analysis of existing radio measuring receivers of electromagnetic radiation it follows that their sensitivity of measurements in the millimeter range does not exceed 10^{-10} W and depends on the fluctuations of the amplifying coefficient and the effect of narrowband interference.

Therefore, the need to develop a radiometric receiver for the remote measurement of electromagnetic thermal radiation (temperature) of animal organs and tissues is an urgent task. The radiometric receiver will allow contactless control of the temperature of both the skin and the internal organs of the animal, without fixing it, at any time of the day and under any weather conditions [6].

2. The object of research and its technological audit

The object of research is the process of synthesizing a radiometric receiver for remote measurement of its own thermal electromagnetic radiation of animals. From the analysis of existing receivers of electromagnetic radiation it follows that their sensitivity of measurements depends on the fluctuations of the amplifying coefficient (AC) [5]. This testifies to the great technical difficulties involved in eliminating or compensating for the influence of GF fluctuations in highly sensitive receivers. Rational ways to increase the sensitivity of radiometric receivers are as follows [6]:

– development of new schemes;
– improvement of known schemes (reduction of receiver noise, broadband bandwidth expansion, increase in integration time, stabilization of receiver elements).

The decrease in the level of internal noise is possible due to the use of low-noise elements and nodes, but this, like the extension of the bandwidth for AC, is limited by technical and design capabilities and is determined by the level of development of the element base for this period. All technical solutions used to create radiometric receivers are reduced to the following tasks:

– internal noise compensation;
– compensation of the instability influence of the amplification and conversion path on the receiver noise temperature;
– elimination of the instability influence of the amplification and conversion path on the receiver noise temperature;
– elimination of the instability influence of the amplification path and the conversion to a useful signal.

Thus, it can be concluded that in the construction of radiometric systems in the millimeter range, the following determining shortcomings should be considered:

– because of the low sensitivity of detectors and the absence of low-noise high-frequency solid-state amplifiers, radiometric receivers need to be built on a superheterodyne or modulation scheme;
– to ensure high sensitivity (less than 0.1 K) of the radiometric receiver, various methods must be used to eliminate the effect of instability of the amplification path on the output signal.

In this connection, it is necessary to find the structure of the receiver for measuring the thermal electromagnetic radiation of animals (temperature), which, along with all the advantages of the compensating one, would be insensitive to the AC fluctuations and to the effect of the most probable narrow-band noise in animal conditions.

3. The aim and objectives of research

The aim of research is synthesis of the structure of a radiometric receiver in the millimeter wavelength range by the criterion of statistical invariance to the AC fluctuations and narrow-band interference.

To achieve this aim, it is necessary to perform the following tasks:

1. Substantiate the generalized scheme of the radio receiver.
2. Obtain expressions for the impulse response of an input circuit and a quadratic detector without a narrow-band harmonic type noise.
3. Obtain expressions for the impulse response of the input circuit and the quadratic detector with narrow-band interference.
4. Justify the scheme of the synthesized radio receiver, which is invariant with respect to the AC fluctuations and completely invariant with respect to narrow-band harmonic of the harmonic type.

4. Research of existing solutions of the problem

Literature review shows that the productivity of farm animals depends on their content, the rational use of feed and surgical treatment, which is determined by a timely diagnosis [7, 8]. The solution of these questions is connected with the use of rapid methods of controlling the parameters characterizing the physiological state of animals. One of such informative parameters of the physiological state of animals is their own electromagnetic radiation (temperature), since all methods of measuring temperature are based on converting it to another physical quantity [9, 10]. Advantages of methods of radiothermal electromagnetic radiation for the analysis of the state of animals before the known (clinical and radiological diagnostics) are the absence of surgical intervention. Radiothermal method does not require special preparation of animals. With electromagnetic diagnosis of animals, they have no pain sensations [11].

The analysis of methods and devices for measuring the temperature of animals shows that there is a need to develop contactless devices. Non-contact devices allow controlling the temperature of both the skin and the internal organs of an animal without fixing it, at any time of the day and under any weather conditions [12, 13].

At present, models and methods for remote studies of the radiation of living biological objects (humans and animals) in the infrared (IR) centimeter and decimeter wavelength ranges are known [14]. In the infrared range, radiothermal radiation originates from a depth of 10 μm, and a smooth, clean, dry surface of the skin is required to conduct the studies, which requires special pre-treatment of the skin of the animals. This preparation of the skin of animals is a significant disadvantage in the conditions of carrying out experimental studies in a given frequency range. Radiothermal radiation of centimeter and decimeter wavelength ranges, although it has a characteristic depth of attenuation in biological tissues up to several centimeters, does not provide the necessary spatial resolution for measurements from the open space. In addition, the use of contact antenna applicators in the natural conditions of animal maintenance is unacceptable due to the inevitable disagreement between the impedance of the animal skin and the contact antenna. This impedance mismatch is caused by the presence of hair, dust and dirt between the skin of the animal and the contact antenna [15]. From the analysis of biophysical and biochemical processes occurring in cells of a living organism, it follows that the kinetics of biological processes occur in the millimeter wavelength range and for it the cornified layers of the epidermis, the hairline, possible dust and dirt particles on the skin surface are transparent [16]. Therefore, it is advisable to study the radiothermal radiation of agricultural animals in the millimeter wavelength range. From the analysis of circuit solutions of radio receivers for remote measurement

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of the radiation of animals, it follows that their limiting (fluctuation) sensitivity depends only on natural noise and instability of the linear path AC [17]. This testifies to the great technical difficulties involved in eliminating or compensating for the effect of the AC fluctuations in high-sensitivity receivers. In this connection, it is necessary to find the structure of the receiver, which would be insensitive to the AC fluctuations and to the effect of narrow-band interference.

5. Methods of research

Let's consider the generalized scheme of the radiometric receiver, shown in Fig. 1.

The circuit (Fig. 1) consists of a series-connected linear input circuit, to which the input signal $u_S(t)$ and adaptive interference $u_I(t)$ come. The amplifier in the circuit is characterized by the power amplification $G(t)$, the band pass Δf and the intrinsic noise $u_N(t)$. In the scheme, the sign of $\Phi^2(\bullet)$ means the operation of generalized quadratic detection, and the sign $\langle\bullet\rangle$ is the averaging operation. On the basis of generally accepted assumptions, the processes $u_S(t)$ and $u_N(t)$ are assumed to be ergodic, normal random processes of the type of quasi-white noise acting in the band pass of the amplifier, and for the simplicity of the computation the noise $u_I(t)$ is purely harmonic [6]:

$$\langle u_S(t)\rangle = u_N(t) = 0,$$
$$\langle u(t)\rangle = \lim_{T\to\infty}\frac{1}{T}\int_0^T u(t)\,dt,$$
$$\langle u_S(t)u_S(t+\tau)\rangle = kT_S^0\frac{\sin\pi\Delta f\tau}{\pi\Delta f\tau},$$
$$\langle u_N(t)u_N(t+\tau)\rangle = kT_N^0\frac{\sin\pi\Delta f\tau}{\pi\Delta f\tau},$$
$$u_I(t) = U_{IO}\cos(2\pi f_I t+\varphi_I), \qquad (1)$$

where k – Boltzmann constant; T_S^0, T_N^0 – the spectral density of the noise temperature of the useful signal and the intrinsic noise of the radiometric receiver, with $T_N \ge T_S$; U_{IO} – amplitude of harmonic interference; f_I, φ_I – frequency and initial phase of interference oscillations.

The problem is solved in two steps: first, the radiometric receiver circuit is synthesized in the absence of interference, and then the case is considered when an additive mixture of harmonic interference of the useful signal acts at the output of the radiometric receiver. Let's pretend that $U_{IO}=0$. As a result of the transformations described in [6], the averaged value of the signal, after the quadratic detection scheme, will be determined by the expression:

$$\left(y(t)+u_N(t)\right) = \sqrt{1+g(t)},$$

where $y(t)$ – additive mixture of the signal passed through the input circuits; $u_N(t)$ – additive mixture of noise, in the bandwidth of the amplifier; $g(t)$ – random function, which determines the relative AC fluctuations, will be as follows:

$$\Phi^2(y,u_N,g) \approx \left(1+g(t)\right)\times$$
$$\times\int\int_{}^{\infty} h_2(\tau_1,\tau_2)\langle u_N(t-\tau_1)u_N(t-\tau_2)\rangle d\tau_1 d\tau_2, \qquad (2)$$

where $h_2(\tau_1,\tau_2)$ – the impulse response of the quadrator.

As follows from the theory of invariance [5] and from [6], in order for the average value of the output signal of the quadrator to be invariant to the AC fluctuations, it is necessary to satisfy the condition:

$$\int_{-\infty}^{\infty}\int h_2(\tau_1,\tau_2)\langle u_N(t-\tau_1)u_N(t-\tau_2)\rangle d\tau_1 d\tau_2 = 0. \qquad (3)$$

Thus, it is necessary to find the structure of a quadrator which impulse response $h_2(\tau_1,\tau_2)$ would satisfy condition (3). This condition has the following form [6]:

$$u_N^2(t) = kT_N^0\Delta f\sum_{=-\infty}^{\infty}\int_{-\infty}^{\infty}\int h_2(\tau_1,\tau_2)\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}\times$$
$$\times\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K}{2\Delta f}\right)}d\tau_1 d\tau_2 = 0, \qquad (4)$$

where $K/2\Delta f$ – the sampling interval determined by the bandwidth of the amplifier.

Since $h_2(\tau_1,\tau_2)$ does not depend on K, condition (4) can be satisfied if the equality for $\forall\in(-\infty;\infty)$:

$$0<q<1,$$
$$\int_{-\infty}^{\infty}\int h_2(\tau_1,\tau_2)\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}\times$$
$$\times\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K}{2\Delta f}\right)}d\tau_1 d\tau_2 = 0. \qquad (5)$$

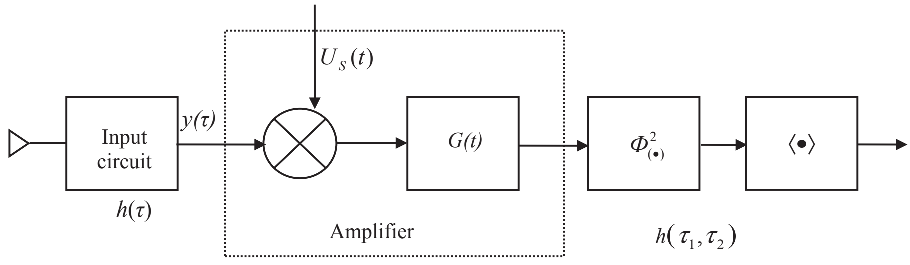

Fig. 1. Generalized functional circuit of radiometric receiver

Let's suppose that:

$$h_2(\tau_1,\tau_2)=q\delta\left(\tau_1-\frac{K}{2\Delta f}\right)(1-q)\delta\left(\tau_1-\frac{K}{2\Delta f}\right), \quad (6)$$

where $0<q<1$ – the weighting factor; l and $m=1, 2, 3...$ are positive integers. Then the equalities are obvious for all l, m, K and $l\neq K$, $m\neq K$:

$$\int_{-\infty}^{\infty}\delta\left(\tau-\frac{l}{2\Delta f}\right)\frac{\sin 2\pi\Delta f\left(\tau-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau-\frac{K}{2\Delta f}\right)}d\tau=$$

$$=\frac{\sin 2\pi\Delta f\left(\frac{2-K}{2\Delta f}\right)}{2\pi\Delta f\left(\frac{2-K}{2\Delta f}\right)}=0,$$

$$\int_{-\infty}^{\infty}\delta\left(\tau-\frac{m}{2\Delta f}\right)\frac{\sin 2\pi\Delta f\left(\tau-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau-\frac{K}{2\Delta f}\right)}d\tau=$$

$$=\frac{\sin 2\pi\Delta f\left(\frac{m-K}{2\Delta f}\right)}{2\pi\Delta f\left(\frac{m-K}{2\Delta f}\right)}=0, \quad (7)$$

if $l=K$ or $m=K$, then the first or the second integral is 1. However, since $l\neq m$, the equality [5] will hold for any l, K, m. Since m and m can take arbitrary values, $m=l$. Then,

$$h_2(\tau_1,\tau_2)=q(q-1)\delta(\tau_1)\delta\left(\tau_2-\frac{1}{2\Delta f}\right). \quad (8)$$

Next, let's find an expression for the impulse response of the input circuit $h(\tau)$. As shown in [6], the useful signal at the output of the quadratic detector, taking into account [8], will have the form:

$$y^2(t)=u^2_{S\,out}(t)=$$

$$=q(q-1)\sum_{K_1=-\infty}^{\infty}\sum_{K_2=-\infty}^{\infty}u_S\left(t-\frac{K}{2\Delta f}\right)u_S\left(t-\frac{K_2+1}{2\Delta f}\right)\times$$

$$\times\int_{-\infty}^{\infty}\int h_2(\tau_1,\tau_2)\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K_1}{2\Delta f}\right)}\times$$

$$\times\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K_2+1}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K_2+1}{2\Delta f}\right)}\cdot h(\tau_1)h(\tau_2)d\tau_1 d\tau_2=$$

$$=q(q-1)KT_S^0\Delta f\sum_{K=-\infty}^{\infty}\int_{-\infty}^{\infty}\int h_2(\tau_1,\tau_2)\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}\times$$

$$\times\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}\cdot h(\tau_1)h(\tau_2)d\tau_1 d\tau_2. \quad (9)$$

Because,

$$u_S\left(t-\frac{K_1}{2\Delta f}\right)u_S\left(t-\frac{K_2+1}{2\Delta f}\right)=kT_S^0\Delta f\delta_{k_1,k_{2+1}},$$

where $\delta_{k_1,k_{2+1}}$ – Kronecker symbol. It is seen from (9) that the useful signal will be maximal if the maximum expression is maximal:

$$\sum_{K=-\infty}^{\infty}\int_{-\infty}^{\infty}\int\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}\times$$

$$\times\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}\cdot h(\tau_1)h(\tau_2)d\tau_1 d\tau_2. \quad (10)$$

This condition will be satisfied if, in turn, the integrals are maximal, at least for one K.

$$\int_{-\infty}^{\infty}\frac{\sin 2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_1-\frac{K}{2\Delta f}\right)}\cdot h(\tau_1)d\tau_1,$$

$$\int_{-\infty}^{\infty}\frac{\sin 2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}{2\pi\Delta f\left(\tau_2-\frac{K+1}{2\Delta f}\right)}\cdot h(\tau_2)d\tau_2. \quad (11)$$

It follows from (11) that in (10) the product $h(\tau_1)h(\tau_2)$ should give an expression of the form:

$$\delta\left(\tau_1-\frac{K}{2\pi f}\right)\cdot\delta\left(\tau_2-\frac{K+1}{2\pi f}\right). \quad (12)$$

Let's suppose that,

$$h(\tau)=\mu\delta(\tau)+(1-\mu)\delta\left(\tau-\frac{1}{2\Delta f}\right), \quad (13)$$

and taking K=0, after substituting into (10), it is easy to verify that the maximum condition is satisfied, and (9) can be written in the form:

$$\langle u^2_{S\,out}(t)\rangle=q(1-q)\mu(1-\mu)kT_S^0\Delta f, \quad (14)$$

where μ – the weighting factor for the input circuit.

Thus, the input circuit of the radiometric receiver must contain a linear block with an impulse response of the form (13). Let's take into account that at the output of the radiometric receiver there is a harmonic interference, having the form (1), where $U_{IO}\neq 0$. The interference signal, taking into account [6] and starting from the invariance condition, that is, the identity of the interference signal at the output of the linear circuit to zero, will have the form:

$$U_{I\,OUT}=U_I\ \mu\cos(2\pi f_I t+\varphi_I)\times$$

$$\times U_{IO}(1-\mu)\cos\left[2\pi f_I\left(t+\frac{1}{2\Delta f}\right)+\varphi_I\right]=0,$$

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from which obtain the necessary conditions $\mu = 1 - 0.5$:

$$2\pi f_I t + \varphi_I + \frac{2\pi f_I}{2\Delta f} - 2\pi f t - \varphi = (2n+1)\pi, \qquad (15)$$

after the transformation:

$$\frac{1}{2\Delta f} = \tau = \frac{n + \frac{1}{2}}{f_I}. \qquad (16)$$

Thus, under the conditions (8), (13), (14) the synthesized radiometric receiver is invariant in the mean square sense with respect to the AC fluctuations and is completely invariant with respect to harmonic interference.

6. Research results

In accordance with the expressions obtained for the impulse response of the input circuit (13) and the quadratic detection circuit (8), let's compose the structure of the synthesized radiometric receiver. The functional diagram of such receiver will have the form shown in Fig. 2.

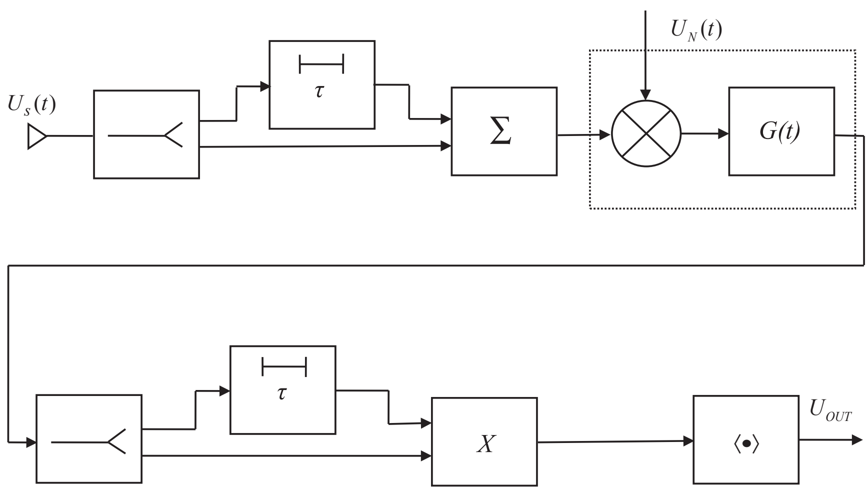

Fig. 2. Functional diagram of the synthesized radiometric receiver

In this radio receiver, the input signal coming from the antenna in the input circuit is divided by power into two components, one of which is delayed by a time τ, and then these components are added together in the adder. Then there is amplification followed by division into two components, one of which is delayed for the same time τ, and then these components are multiplied, and their product is averaged.

The delay time in the delay blocks is chosen by a large correlation interval, i. e. $\tau \geq 1/2\Delta f$. To obtain the circuit, with the invariance achieved to internal noise and harmonic interference, with allowance for (13) it is possible to write:

$$u_{OUT}(q,t) = u_c^2(t)\mu(1-\mu)q(1-q). \qquad (17)$$

Let's determine the optimal values of the coefficients μ and q, which take into account losses due to separation of signals in the first and second divisors and depend on the power ratio at their inputs. To achieve the maximum of the output signal, the product of the coefficients in (15) must reach its maximum. It is seen from (15) that this will be achieved at $\mu = q = 0.5$.

$$q_{OUT\,xs} = \left(\frac{P_S}{P_N}\right) = \frac{u^2_{S\,OUT}(t)}{\sigma_{SK}} = \frac{u^2_{S\,OUT}(t)4\sqrt{2}}{\sqrt{u_N^4(t)}} \times$$
$$\times \sqrt{\frac{\Delta f}{\Delta F}} = \frac{4\sqrt{2}}{16} \cdot \frac{kT_S^0 \Delta f}{kT_N^0 \Delta f} \cdot \sqrt{\frac{\Delta f}{\Delta F}} = \frac{1}{2\sqrt{2}} \cdot \frac{T_C^0}{T_N^0} \sqrt{\frac{\Delta f}{\Delta F}}. \qquad (18)$$

It follows from the obtained expression that the real sensitivity of the synthesized radiometric receiver due to the absence of influence of the AC fluctuations will greatly exceed the real sensitivity of the compensating radiometric receiver.

7. SWOT analysis of research results

Strengths. To eliminate the drawbacks inherent in the contact method for measuring the temperature of animals, remote methods based on measuring the electromagnetic radiation of tissues and organs of animals should be used. The theoretical and experimental studies carried out have made it possible to create a radiometric receiver with parameters:

– frequency – 30...40 GHz;
– sensitivity of measurements – 10–17 W;
– the accuracy of determining the temperature of internal tissues – ±0.1 °C;
– depth of detection of temperature anomalies – 2–5 cm;
– measurement speed – 2–4 s.

The radiometric receiver created in the millimeter range exceeds the receivers in the decimeter and centimeter bands in many parameters by an order of magnitude. Such parameters include: sensitivity of measurements; accuracy of determining the temperature of internal tissues; speed of measurement.

The obtained advantage is due to the fact that the receiver has eliminated the dependence of the measurements on the AC fluctuations and the action of narrowband noise.

Weaknesses. The disadvantage of the receiver is that it requires further development to protect against industrial and broadband interference.

Opportunities. Practical testing of the radiometric receiver shows the possibility of displaying the temperature of internal tissues, obtaining a visual picture of the heat field, which allows the veterinarian to establish the correct diagnosis.

The use of a radiometric receiver for the diagnosis of the condition of animals allow:

– to reduce the consumption of medicines in the treatment of animals by 15...20 %;
– to develop a feeding ration and conditions for keeping animals and, as a result, increase productivity by 20...25 %;
– to save the economy (1000 head of cows) 5000... 6000 dollars USA.

Threats. The cost of modifying the receiver to protect against industrial and broadband interference will be approximately 10 % of the cost of the radiometric receiver.

8. Conclusions

1. The generalized radio circuit is justified. The peculiarity of this scheme is that it includes devices for quadratic detection and averaging.

2. An expression is obtained for the impulse response of the input circuit and the quadratic detector without a narrow-band harmonic type noise. The character of the impulse response is necessary in order for the average value of the output signal to be invariant to the AC fluctuations.

3. An expression is obtained for the impulse response of the input circuit and the quadratic detector with narrowband interference. The impulse response of the input circuit with narrowband interference is necessary for determining the scheme of the quadratic detector.

4. The scheme of the synthesized radio receiver, which is invariant with respect to the fluctuations in the amplification factor and completely invariant with respect to narrow-band harmonic type, is justified. The peculiarity of this scheme is that in this radio receiver the input signal coming from the antenna in the input circuit is divided by power into two components, one of which is delayed by the time τ, and then these components are added in the adder. Then there is amplification followed by division into two components, one of which is delayed for the same time τ, and then these components are multiplied, and the product of x is averaged.

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СИНТЕЗ РАДИОМЕТРИЧЕСКИХ ПРИЕМНИКОВ ПО КРИТЕРИЮ СТАТИСТИЧЕСКОЙ ИНВАРИАНТНОСТИ К ФЛУКТУАЦИЯМ УСИЛЕНИЯ И УЗКОПОЛОСНОЙ ПОМЕХИ

Для дистанционного измерения собственного теплового электромагнитного излучения животных был проведён синтез радиометрического приёмника по критерию статистической инвариантности выходного сигнала, т. е. измерению полезной мощности излучения к мощности мешающих воздействий. В соответствии с полученными выражениями для импульсной характеристики входной цепи и схемы квадратичного детектирования была составлена структура синтезированного радиоприемника.

Ключевые слова: радиометрический приёмник, электромагнитное излучение животных, флутуации коэффициента усиления, узкополосная помеха.

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