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RESEARCH ON SUPPRESION SYSTEM ANALYSIS OF HIGH POWER NARROWBAND INTERFERENCE OPERATING IN PRESENCE OF HETERODYNE FREQUENCY

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KEYWORDS

radiometer receiver; suppression of narrow-band interference; microwave driving tool; automatic frequency adjustment; voltage adder; phase detector

ABSTRACT

The study is considered with the process of suppressing the narrowband interference which acts close to heterodyne frequency. the purpose of the study is to analyze the scheme in the structure of the radiometric receiver for narrowband interference suppression in presence of heterodyne frequency with the help of analytical analysis method. This method is based on automatic interference detection, its overlapping with heterodyne frequency and supporting heterodyne signal. the principle of modulation radiometer is realized in the interference suppression scheme. the modulation radiometer contains voltage switching center of "meander" type which controls highly-quality driving tool, total stress and phase detector. Circuits of automatic tuning frequency and heterodyne amplitude control are independent and operate permanently.

1. INTRODUCTION

The strong narrowband interference which is compared by the level to the local oscillator signal and acts near oscillator frequencies is considered to flow to the faucet and create distortion of received signals [1]. Taking into account the fact that such radiometers do not have a preselector and the following interference will easily get inside the faucet.

Interference frequency of is out-of-band of signal reception, so it remains hidden for common methods of protection from interference [2].

There is no way to combat such kind of interference [3] in analyzed literature. as a result, it is necessary to research on ways of suppressing the strong narrowband interference, serving near heterodyne frequency.

2. LITERARY REVIEW

The narrow band disturbance is considered to be suppressed by input chain, depending on the size of the carrier frequency tuning out noise from the central frequency of the input circuits [4]. the narrowband disturbance is out-of-band reception signal, so it crackdown turns unpredictable [5].

There is no way to fight against such class interference for purposes of radiometric admission in analyzed literature [6].

That is why the method of suppressing narrowband interference near the heterodyne frequency is based on the automatic detection of interference. the issue of its combination with local oscillator frequency and maintaining a constancy of heterodyne signal requires additional research.

3. THE OBJECT AND PURPOSE OF THE STUDY

The object of the paper is the process of suppressing the narrowband interference which acts close to heterodyne frequency.

The purpose of the study is the analytical analysis method and scheme in the structure of the radiometric receiver for narrowband interference suppression close to heterodyne frequency.

To achieve this goal, we should perform the following tasks:

1. to justify receiver scheme of power narrowband interference at its entrance.

2. to substantiate the work of microwave receiver key for managing the voltage summator and phase detector in case of strong narrowband interference operating close to heterodyne frequency.

4. the analysis of the suppression system of a strong narrowband interference, which acts close to heterodyne frequency.

The functional diagram of radiometer for power narrowband interference suppression operating close to heterodyne frequency. Fig.1

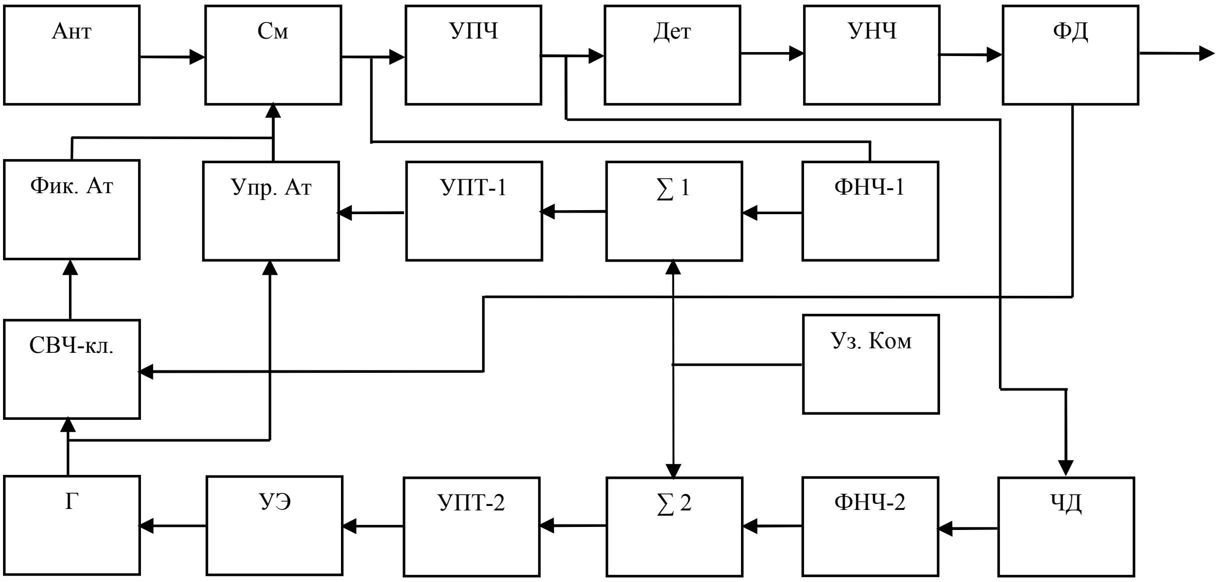

Fig. 1. the functional diagram of radiometer for power narrowband interference suppression operating close to heterodyne frequency.

To determine the capabilities of the developed device we are going to value the degree of narrowband interference suppression, functioning near heterodyne frequency.

The analysis will be based on the following hypothesis.

1. Contaminating signal is harmonic and operates on a constant frequency at constant amplitude of $A_{П}$.

2. the control device of mixer direct current, controlled attenuator, slop detector and operator are considered to be inertialess devices, where only liner parts of their static characteristics are used and, consequently, are characterized by conversion transconductance $S_i = S_{AT}, S_{Д}$ and $S_{У}$.

3. Gain factor value of the first DC amplifier is calculated in terms of conductance. Gain factor value of DC amplifier and the second DC amplifier is calculated with the help of conductance $S_{Д}$ and $S_{У}$. So we suppose the gainfactors to be:

$$K_{УПТ_{1,2}} = K_{УПЧ} = 1 .$$

4. the first and the second 1-St and 2-nd LPF (low-past filters) are represented as linear circuits that consist of RC elements with transfer function:

$$K_{\Phi}(P)=\frac{1}{T_{P}+1}. \qquad (1)$$

What is more, time constants of the 1-st and the 2-nd filters are chosen in terms of $T_1 > T_2$.

5. Automatic frequency control circuit (AFC) and automatic amplitude control (SSN) of heterodyne are independent and operate permanently.

At first, we should define the necessary value of heterodyne signal amplitude at interference attack.

In such steady state regime the signals of heterodyne and noise disturbance are presented in the form of:

$$u'_{\Gamma}(t) = (U_{\Gamma} - \Delta U_{\Gamma})Cos(\omega t + \varphi),$$
$$u_{\Pi}(t) = A_{\Pi} Cos\, \omega t, \qquad (2)$$

Where φ is the phase angle between the fluctuations of local oscillator and noise.

Taking into account the requirements of amplitude constancy of heterodyne signal, we will write:

$$u'_{\Gamma}(t) + u_{\Gamma}(t) = (U_{\Gamma} - \Delta U_{\Gamma})Cos(\omega t + \varphi) + A_{\Gamma} Cos\, \omega t = U_{\Gamma} Cos(\omega t + \varphi), \quad (3)$$

From this it follows that:

$$\sqrt{\left[A_{\Pi} + (U_{\Gamma} - \Delta U_{\Gamma})Cos\, \omega\right]^2 + (U_{\Gamma} - \Delta U_{\Gamma})^2\, Sin\, \varphi} = U_{\Gamma}. \qquad (4)$$

With the help of (4) we will find the necessary changes in the amplitude of frequencies:

$$\Delta U_{\Gamma} = A_{\Pi} Cos\varphi + U_{\Gamma} - \sqrt{U_{\Gamma}^2 - A_{\Pi}^2 Sin\varphi}. \quad (5)$$

Considering that $A_{\Pi} << U_{\Gamma}$, we, finally, write down the following:

$$\Delta U_{\Gamma} = A_{\Pi} Cos\varphi. \qquad (6)$$

Due to independence of HRA functioning schemes and automatic control amplitude (ARA) the actuating error regulation of these schemes is also believed to be independent. in this case, the error suppression of interference will be determined as the sum of the average squares of the error of each scheme.

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Let’s define the error of automatic amplitude control scheme.

We’ll modify the scheme to be more convenient for analysis (fig. 2).

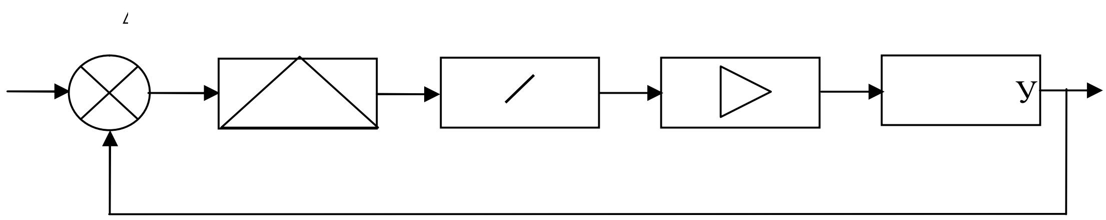

Fig. 2. the scheme of automatic amplitude control.

The master control is the desired value of heterodyne amplitude variation of ΔU_{Γ}.

Taking into account the given assumptions, the transfer function of the diagram is of the form:

$$K_A(p) = \frac{k_1}{T_1 P + k_1 + 1}, \quad (7)$$

where $k_1 = S_i = S_{AT}$ is a complete open-loop gain of ARA scheme.

Then an error status will be defined by the expression:

$$\Delta A_{\Pi_A} = C_{0_A} \Delta U_{\Gamma} = C_{0_A} A_{\Pi} Cos\,\varphi, (8)$$

where C_{0_A}. is a constant of position error which is defined as [7]

$$C_{0_A} = 1 - K_A(0) = \frac{1}{k_1 + 1}. \quad (9)$$

then:

$$\Delta A_{\Pi_A} = \frac{A_{\Pi} Cos\,\varphi}{k_1 + 1}. \quad (10)$$

The item (10) shows that increasing the gain constant of the scheme an error status can be achieved by any small value.

Let’s define the scheme error of automatic amplitude control (ARA) as a result of exposure of input circuit noise of the radiometer.

So if we consider the input noise to be the ordinary process that has a uniform spectrum and spectral density of S_0, we define the error variance in accordance with the expression [8]:

$$\sigma_A^2 = \frac{1}{2\pi}\int_0^\infty S_0 K_A^2(\omega) d\omega, \qquad (11)$$

Where $K_A(\omega)$ is a module of integrated ARA system frequency response.

Substituting expression (7) into (11), substituting R for $j\omega$ we get:

$$\sigma_A^2 = \frac{1}{2\pi}\int_0^\infty S_0 \frac{k_1^2}{\left|T_1 j\omega + k_1 + 1\right|^2} d\omega = \frac{S_0 k_1^2}{2T_1(k_1+1)}, \qquad \text{..............................(12)}$$

The expression number 12 shows that increasing the gain scheme leads to increasing the variance of the error. the error can be reduced by magnifying the T_1 that, in its turn, would affect the speed of ARA scheme performance.

We calculate the error suppression of interference with the help of HRA scheme influence.This influence will be expressed by changing the phase angle between the heterodyne variations and interference. in this case, the necessary amplitude amount of change of amplitude in terms of interference attack may be presented in the form of:

$$\Delta U_\Gamma(t) = A_\Pi Cos[\varphi - \delta\varphi(t)], \qquad \text{..(13)}$$

Where $\Delta\varphi(t)$ is change of phase angle by means of HRA scheme errors, which can be expressed with the help of error frequency regulation:

$$\Delta\varphi(t) = 2\pi\int_0^t \Delta f_\Gamma(t) dt. \qquad (14)$$

For increments such as $\Delta\varphi(t)$ expression number 13 can be converted into:

$$\Delta U(t) = A[Cos\varphi Cos\delta\varphi(t) + Sin\varphi Sin\delta\varphi(t)] \approx ACos\varphi + ASin\varphi\delta\varphi(t).$$

(15)

So, if we take 6 we get:

$$\Delta U_\Gamma(t) = \Delta U_\Gamma(t) - \Delta U_\Gamma = A_\Pi Sin\varphi\delta\varphi(t). \quad (16)$$

At fixed heterodyne frequencies and interference the frequency control error of heterodyne will be the following:

$$\delta\ f_{Г} = \frac{|f_{Г} - f_{П}|}{k_2 + 1}, \tag{17}$$

here $k_2 = S_{Д} S_{У}$ is a complete open-loop gain of HRA scheme.

Then from expression number 16 with the help of one number 14 we get:

$$\Delta U_{Г}(t) = \frac{2\pi|f_{Г} - f_{П}|t}{k_2 + 1} A_{П} Sin\varphi. \tag{18}$$

The expression number 18 shows that increasing k_2 at the starting point error of interference suppression can be reached by any small value. However, increasing the operatingtime of HRA the errorwillgrow.

We are going to define the error of interference suppression by means of internal noise influence of the receiver on the HRA scheme. we believe that operating noise which are considered to be ergodic normal and random process with a uniform spectrum and spectral density of S_0 act at the entrance of the HRA scheme.

With the help of expression number 16 we will write the expression for the fluctuation dispersion of amplitude noise by means of random fluctuations of heterodyne phase changes:

$$\sigma^2_{A\omega} = A^2_{П} Sin^2\varphi \sigma^2_{\varphi}, (19)$$

Where σ^2_{φ} is fluctuation dispersion of heterodyne phase based on the impact of noise on the HRA scheme, which can be determined with the help of the following expression:

$$\sigma^2_{\varphi} = \frac{1}{2\pi} \int_{-\frac{\Delta\omega_{ЭФ}}{2}}^{\frac{\Delta\omega_{ЭФ}}{2}} S_{\varphi}(\omega) d\varphi. \tag{20}$$

In this case $S_{\varphi}(\omega)$ is a spectral density of fluctuations of heterodyne oscillation phase; $\Delta\omega_{ЭФ}$ is an effective band of AFC scheme.

An effective band of AFC scheme can be obtained from the expression [9]:

$$\Delta\omega_{ЭФ} = \frac{1}{2\pi K^2_{\omega}(0)} \int_{-\infty}^{\infty} K^2_{\omega}(\omega) d\varphi, \tag{21}$$

Where $K_{\omega}(\omega)$ is the module of integrated frequency characteristics of AFC scheme.

Let us write an expression for $K_{\omega}(\omega)$ in the following form:

$$K_\omega(\omega) = \frac{k_2}{|T_2 j\omega + k_2 + 1|} = \frac{k_2}{\sqrt{T_2^2\omega^2 + (k_2+1)^2}}. \quad (22)$$

After combining the expression number 22 and 21 we get:

$$\Delta\omega_{ЭФ} = \frac{(k_2+1)^2}{2\pi k_2^2}\int_{-\infty}^{\infty}\frac{k_2^2}{T_2^2\omega^2 + (k_2+1)^2}d\omega = \frac{k_2+1}{2T_2}. \quad (23)$$

We will find the value of $S_\varphi(\omega)$ with the help of spectral density of fluctuation of heterodyne frequency $S_\omega(\omega)$:

$$S_\varphi(\omega) = \frac{S_\omega(\omega)}{\omega^2}. \quad (24)$$

$S_\omega(\omega)$ value on the basis of spectral noise density which operates at the entrance of the HRA scheme is determined by the expression:

$$S_\omega(\omega) = S_0 K_\omega^2(\omega)\alpha_{ПР\ Ш} = \frac{S_0 k_2^2 \alpha_{ПР\ Ш}}{T_2^2\omega^2 + (k_2+1)^2}, \quad (25)$$

where $(\alpha)_{SDP}$= 1 rad^2/wt is a single factor which takes into account the conversion of amplitude noise into frequencyfluctuation in HRA scheme.

After inserting results in expression number 20 we write:

$$\sigma_\varphi^2 = \frac{1}{2\pi}\int_{-\frac{k_2+1}{4T_2}}^{\frac{k_2+1}{4T_2}}\frac{S_0 k_2^2 \alpha_{ПР\ Ш}}{\left[T_2^2\omega^2 + (k_2+1)^2\right]}d\omega = \frac{S_0 k_2^2 T_2 \alpha_{ПР\ Ш}}{(k_2+1)^3} arctg\frac{1}{4}. \quad (26)$$

Finally, the expression for the dispersion of noise amplitude fluctuation due to the impact of noise on the AGGH scheme will have the form:

$$\sigma_{A\omega}^2 = A_П^2 \frac{S_0 k_2^2 T_2 Sin^2\varphi \alpha_{ПР\ Ш} arctg 0{,}25}{(k_2+1)^3}. \quad (27)$$

The expression number 27 shows that $\sigma_{A\omega}^2$ can be reduced by increasing the open-loop gain of AFT scheme. Thiscoincides with the requirements the expressionnumber 18.

Total error at the expense of internal noise suppression in the given method of noise suppression can be written as:

$$\sigma_{Ш}^2 = \sigma_A^2 + \sigma_{A\omega}^2 = \frac{S_0 k_1^2}{2T_1(k_1+1)} + A_П^2 \frac{S_0 k_2^2 Sin^2 \varphi \alpha_{ПР\ Ш} arctg 0{,}25}{(k_2+1)^3}. \quad (28)$$

The analysis of the interference suppression method demonstrates the necessity of adding integrating element to direct branch of the network of ARA scheme. as a result it leads to reducing ARA scheme error. Moreover, the integrating element will help to have an error which is equal to zero. the error due to internal noise can be reduced by loweringthe gain constant of ARA scheme and increasing the filter time constant t_1. to avoid the interference suppression errors and to calculate the management errors of HRA scheme of heterodyne frequency (18), the integrating element should be placed in the chain of frequency control. in this case the HRA scheme error will be determined by internal scheme noise and can be made as small as possible by means of gain constant.

Let's appraise the significance of radiometer noise immunity using this scheme.

The mixer made on the basis of Schottky barrier diodes (DBSh) will have the best characteristics in this type of radiometers. it is reasonable to present a voltage diagram of Schottky barrier diode mixer with the help of power approximation of the following type at high input levels:

$$i(u) = i_0 u^m,$$

where *(m) is a* degree of approximation [10].

We suggest that in terms of identical frequencies of heterodyne interference and the expression to highlight the relationship between signal and noise on the basis of power at mixer and Schottky barrier diode mixer joint will have the form:

$$(\frac{P_C}{P_П})_{ВЫХ} = q_{ВЫХ} = \left[(1+\frac{1}{q_Г^2})^{m-1} - 1 \right]^{-2}, \quad (29)$$

Where $q_Г$ is the relation between heterodyne and interference on the basis of voltage.

4. CONCLUSION

1. the degree of suppressing narrowband interference is determined by automatic control circuit gain, dead time and constant cleaning of low frequencies in radiometer provided with Tracker System.

2. the application of automatic-frequency control circuit of automatic align of heterodyne amplitude in the radiometer scheme allows to suppress narrowband interference. it is important that the narrowband interference is similar to heterodyne frequency, not less than 90 Db. Moreover, the operation speed can be achieved at the level of 10^{-2}... 10^{-3} s.

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