Applied problems of information systems operation

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SIGNAL RELAY TIME MEASURER REFLECTED FROM A SMALL PURPOSE AT ITS LOCATION OVER THE SEA

Abstract. In the article possibility of account of phase fluctuations of signals reflected is examined from littlepitch aims location, during optimization of process of measuring of time of delay of signal. The process of optimization of measuring of distance to the aim on conditions of superrefraction is examined in supposition, that fluctuations of the signals reflected from лоцируемых aims up-diffused on a normal law, and the cross-correlation function of these fluctuations has an arbitrary kind. Within the limits of suppositions got correlation for the optimal estimation of time of delay of the reflected signals. Using the obtained ratios to determine the delay time and the variance of the group delay estimation, the target distance meter was synthesized under the radar of the target above the sea beyond the line of sight for the case when the correlation function of phase fluctuations is described by an exponential function. The proposed optimal estimation algorithm and rangefinder can be used to construct promising radar locations for low altitude targets. The use of such a meter can improve the accuracy of measuring the target range from 2 to 2,5 times.

Keywords: rangefinder; phase fluctuations; cross-correlation function; dispersion.

Introduction

Formulation of the problem. Usually, when working, developing and designing radar stations (RS), airspace intelligence engineers try to reduce the impact of additive interference (generator noise, active interference etc.) on the tactical and technical characteristics of the radar stations. The impact of multiplicative interference caused by the change in the refractive properties of the medium of propagation of radio waves on the operation of RS is not taken into account. This fact does not allow to fully realize the capabilities of RS for the detection and maintenance of air targets with a given accuracy. Analysis of the work [1, 2] showed that to improve the quality of radar at the location of the low altitude target, it would be advisable to conduct rapid diagnosis of propagation conditions in the inspection area RS.

It is known that a change in the type of refraction can cause both a decrease and an increase in the detection range of radar facilities. The reason for this phenomenon is the presence of inhomogeneities of the troposphere on the route. The presence of tropospheric inhomogeneities on the track of propagation of radio waves can in some cases increase the range of radio equipment [3, 4, 5]. However, the location of targets beyond the line of sight increases the errors of determining spatial coordinates. According to experimental data [6-11], in determining the target range beyond the line of sight for every kilometer of the distance to the object fluctuating measurement error range can reach ten meters, which does not allow to fully realize the capabilities of anti-aircraft missile systems for the destruction of low altitudes goals.

Analysis of recent research and publications. Analysis of recent publications has shown that when locating a low altitude target beyond the line of sight, using the phasometric distance measurement method, errors in measuring the range of that target increase. As shown in [8-11], this is due to the appearance together with the uncorrelated and correlated components of the phase fluctuations of the signals reflected from low-altitude targets, which are in the troposphere beyond the line of sight.

A number of papers [8-13] have become the theoretical basis for optimizing the signal delay measurement process. In these works, the process of optimizing the measurement of the distance to the target under the conditions of superrefraction is considered on the assumption that the fluctuations of the signals reflected from the low altitude targets are distributed according to the normal law, and the correlation function of these fluctuations has an arbitrary appearance. Within the assumptions, the ratios were obtained to optimally estimate the delay time of the reflected signals.

In order to be able to improve the accuracy of the determination of the range of aerial objects in a particular radar sample, it is necessary, first of all, to have adequate structural diagrams of the rangefinders. In the known literature [6], circuits of range meters for the case where the fluctuations of the phase of the signals reflected from the targets are distributed according to normal law are considered, and the correlation function of these fluctuations has an arbitrary appearance.

In this paper, we propose an optimal estimation algorithm and a device that implements this algorithm for the case where the correlation function of phase fluctuations is exponential.

The purpose of the article is to construct a structural diagram of the device of the delay time signal of the reflected from the low altitude target, provided that the fluctuations of the phase of the reflected signals are distributed by normal law, and the correlation function of the phase fluctuations is exponential.

Main part

As was established in [7-11], the phase fluctuations of the frequency components of the signal reflected from the low altitude target at its location above the sea are distributed according to normal law. This allowed us to optimize the process of measuring the range by the criterion of maximum logarithm of the likelihood ratio. According to this criterion, [12, 13] obtained the relations for measuring the delay time and the variance of the estimation of the group delay using the correlation function of phase fluctuations, which is given in the general form.

As shown in [12-14], the Optimal Delay Time Estimation is as follows:

$$\hat{t}_з = \frac{\int_{-\infty}^{\infty} y(\Omega) R(\Omega) d\Omega}{\int_{-\infty}^{\infty} \Omega rect(\Omega/\Delta\Omega) R(\Omega) d\Omega}; \quad (1)$$

where $y(\Omega) = x(\Omega) + n(\omega_0 + \Omega)$ – the input signal having the form of the sum of the expected signal, x(Ω) and phase noise n(ω₀+Ω); ΔΩ – the width of the probe signal spectrum; ω_0 – carrier frequency; $R(\Omega)$ – a weight function.

According to [12-14], the ratio for the variance of the estimation of the group delay time is written as follows:

$$\sigma_t^2 = \frac{144}{\Delta\Omega^6} \int_{-0,5\,\Delta\Omega}^{0,5\ \Delta\Omega} \int \Omega\Omega_1 \Phi(\Omega, \Omega_1) d\Omega d\Omega_1; \quad (2)$$

where $\Phi(\Omega, \Omega_1)$ – the correlation function of the phase fluctuations of the frequency components of the signal.

Since, when the signal is propagated to and from the target, the effect of the medium is on its frequency components, the equation with the weight function will, in this case, be:

$$\int_{-0,5\Delta\Omega}^{0,5\Delta\Omega} \Phi(\Omega, \Omega_1) rect\left(\frac{\Omega}{\Delta\Omega}\right) R(\Omega_1, t_з) = x(\Omega). \quad (3)$$

If the phase fluctuations of the frequency components of the signal are described by an exponential correlation function:

$$\Phi(\Omega, \Omega_1) = \sigma_\varphi^2 \exp\left\{-\frac{1}{\rho}|\Omega - \Omega_1|\right\}, \quad (4)$$

then the integral equation for finding the weight function will be:

$$\begin{gathered}\int_{-0,5\Delta\Omega}^{0,5\Delta\Omega} \exp\{-|\Omega - \Omega_1|/\rho\} R(\Omega_1, t_з) \times \\ \times \sigma_\varphi^2 rect(\Omega/\Delta\Omega) = \Omega t_з rect(\Omega/\Delta\Omega).\end{gathered} \quad (5)$$

To solve it, we differentiate twice the left and right parts, give similar and, given that $R(\Omega, t_з) = t_з R(\Omega)$, we get:

$$R(\Omega) = \frac{\rho}{2\sigma_\varphi^2} \left\{ \begin{gathered} \frac{\Omega}{\rho^2} rect\left(\frac{\Omega}{\Delta\Omega}\right) - \left(\frac{\Delta\Omega}{2\rho} + 1\right) \times \\ \times \left[\delta(\Omega + \Delta\Omega/2) - \delta(\Omega - \Delta\Omega/2)\right] \end{gathered} \right\}, \quad (6)$$

where $\delta(\Omega \pm \Delta\Omega/2)$ – delta function.

Determine the variance of estimation of the optimal measurement of group delay in this case. Substituting (5) into (2), we obtain:

$$\sigma_{t\ onm}^2 = \frac{\sigma_\varphi^2}{\Delta\Omega^2} \cdot \frac{12c}{1 + 3c + 3c^2}. \quad (7)$$

We get an expression for an algorithm for optimal measurement of group delay (range to target). Using the relation (5), respectively, we obtain the finite relation:

$$\begin{gathered}\hat{t}_з = K_1 \cdot \int_{-0,5\Delta\Omega}^{0,5\Delta\Omega} \Omega y(\Omega) d\Omega + \\ + K_2 \left[y(\Delta\Omega/2) - y(-\Delta\Omega/2) \right],\end{gathered} \quad (8)$$

where K_1 and K_2 – weighting factors.

The weights are as follows:

$$K_1 = 12\left[\Delta\Omega^3 \left(1 + 3c + 3c^2\right)\right]^{-1}; \quad (9)$$

$$K_2 = \left(3c + 3c^2\right)\left[\Delta\Omega\left(1 + 3c + 3c^2\right)\right]^{-1}; \quad (10)$$

The scheme of the device that implements the obtained algorithm (8) is shown in Fig. 1.

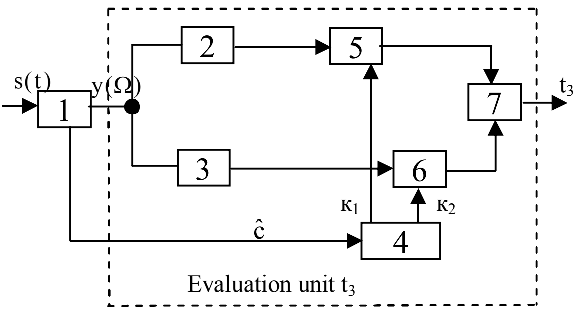

Fig. 1. Scheme of the evaluation device t₃

The operation of the device is as follows. The implementation of the radar signal is accepted

$$\begin{gathered} S(t) = (1/(2\pi)) \cdot \exp\left(j\omega_0\left[t - \varphi_0(\omega_0)/\omega_0\right]\right) \times \\ \times \int_{-\infty}^{\infty} G(\Omega) \exp\left(j\left\{\Omega\left[t - \varphi'(\omega_0)\right] - n(\omega + \Omega)\right\}\right) d\Omega \end{gathered}$$

enters the block of formation of linear phase induction of frequency components of signal 1 (block of formation y(Ω) and relative interval of correlation of phase fluctuations $\hat{c}$).

From the output of block 1,the implementation of the phase in y(Ω) enters the block estimation delay. In this block, according to algorithm (8), an optimal estimate t₃ is formed. In this case, in block 2, the integral is calculated $\int_{-0,5\Delta\Omega}^{0,5\Delta\Omega} \Omega y(\Omega) d\Omega$ and in block 3, the ratio is calculated $\left[y(\Delta\Omega/2) - y(\Delta\Omega/2) \right]$ in accordance with algorithm (8).

The output of block 2 is connected to the input of one of the blocks 5, the other input of which receives a voltage proportional to the coefficient k1 formed in block 4. The output of block 5 is connected to one of the inputs of block 7, the other input of which is connected to the output of block 6, one of the inputs of which is connected to the output of block 3, and the other with the output of the block 4 on which the voltage is generated, proportional to the coefficient к$_2$. The weights к$_1$ and к$_2$ correspond to the coefficients of the additives of formula (8) and are determined in the block of formation of weights 4, which receives the estimated value of the relative correlation interval of phase fluctuations $\hat{c} = 2\hat{\rho}\Delta\Omega^{-1}$ from block 1. In blocks 5 and 6, multiplication is carried out, and in block 7 - summation of the voltage supplied to their inputs.

We compare the variance of the optimal measurement of the group delay of the algorithm (8) with the variance of the measurement error according t_3 to the algorithm, which does not take into account the correlation of phase fluctuations. According to (2), for the variance of the measurement error according to an algorithm optimal for uncorrelated phase fluctuations, we obtain the relation:

$$\sigma_t^2 = 12\sigma_\varphi^2 / \Delta\Omega^2 \times$$
$$\times \left\{ c - \frac{3}{2} c^2 (1+c) \left[e^{-2/c} + 1 + c\left(e^{-2/c} - 1 \right) \right] \right\}. \quad (11)$$

Using relation (11), we estimate the gain (B) in the accuracy of measurement t_3, which is ensured by using the proposed optimal algorithm, using the expression:

$$B = \sigma_t^2 / \sigma_{t_{onm}}^2 . \quad (12)$$

The results of calculation B are shown in Fig. 2.

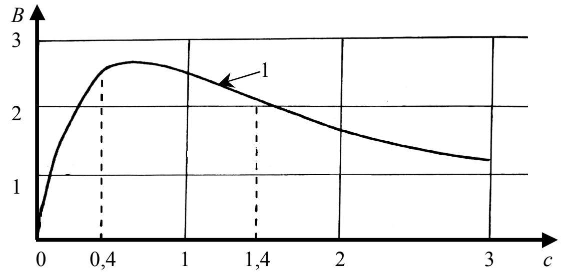

Fig. 2. Evaluation of the gain in the accuracy of measurement t_3

From the data shown in Fig. 2, it is clear that in the range of values of $c = 0,4 - 1,4$ the accuracy gain is from 2 to 2,5 times.

Conclusions

Therefore, the feature of measuring the distance to the low-altitude target framed at a distance, the greater the line of sight, is to take into account, together with the uncorrelated and correlated frequency components of phase fluctuations reflected from the target signal in the frequency domain. In this case, the estimated delay time of the reflected signal assuming a normal law of distribution of phase fluctuations in the frequency domain will be unchanged.

Using the obtained ratios to determine the delay time and the variance of the group delay estimation, the target distance meter was synthesized under the radar of the target above the sea beyond the line of sight for the case when the correlation function of phase fluctuations is described by an exponential function.

The proposed optimal estimation algorithm and rangefinder can be used to construct promising radar locations for low altitude targets. The use of such a meter can improve the accuracy of measuring the target range from 2 to 2,5 times.

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Вимірювач часу затримки сигналу, відбитого від маловисотної цілі при її локації над морем

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Анотація. В статті запропоновано алгоритм оптимального оцінювання часу затримки сигналу при радіолокації маловисотних цілей. Алгоритм враховує наявність фазових флуктуацій відбитих від маловисотних цілей сигналів, які обумовлені середовищем поширення радіохвиль. В роботі представлена структурна схема пристрою, який реалізує запропонований алгоритм оцінювання часу затримки. При цьому кореляційна функція фазових флуктуацій описується експоненційною функцією. Розрахунки, які наведені в статті, свідчать про те, що використання запропонованого вимірювача дальності дозволяє підвищити точність оцінювання дальності від 2 до 2,5 разів. Використовуючи отримані співвідношення для визначення часу затримки і дисперсії оцінки групової затримки, був синтезований далекомір до мети під РЛС мети над морем за межами прямої видимості для випадку, коли кореляційна функція фазових флуктуацій описується експоненційною функцією. Запропонований алгоритм оптимального оцінювання та далекомір можуть бути використані для побудови перспективних радіолокаційних локацій для маловисотних цілей. Використання такого вимірювача дозволяє підвищити точність вимірювання дальності до цілі від 2 до 2,5 разів.

Ключові слова: вимірювач дальності; фазові флуктуації; кореляційна функція; дисперсія.

Измеритель времени запаздывания сигнала, отраженного от маловысотной цели при ее локации над морем

О. В. Бесова, В. Д. Карлов, Е. В. Лукашук, В. Н. Петрушенко

Аннотация. В статье предложен алгоритм оптимального оценивания времени запаздывания сигнала при радиолокации маловысотных целей. Алгоритм учитывает наличие фазовых флуктуаций отраженных от маловысотных целей сигналов, которые обусловлены средой распространения радиоволн. В работе представлена структурная схема устройства, реализующего предложенный алгоритм оценивания времени задержки. При этом корреляционная функция фазовых флуктуаций описывается экспоненциальной функцией. Расчеты, представленные в статье, свидетельствуют о том, что использование предложенного измерителя дальности позволяет повысить точность оценивания дальности от 2 до 2,5 раз. Используя полученные соотношения для определения времени задержки и дисперсии оценки групповой задержки, был синтезирован дальномер до цели под РЛС цели над морем за пределами прямой видимости для случая, когда корреляционная функция фазовых флуктуаций описывается экспоненциальной функцией. Предложенный алгоритм оптимального оценивания и дальномер могут быть использованы для построения перспективных радиолокаций для маловысотных целей. Использование такого измерителя позволяет повысить точность измерения дальности до цели от 2 до 2,5 раз.

Ключевые слова: измеритель дальности; фазовые флуктуации; корреляционная функция; дисперсия.