Efficiency of rejection of abnormal measurements of the phase difference in the survey location finder when receiving signals of the scanning radio-frequency source under the rough terrain

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Abstract. The paper presents the results of a study on rejecting anomalously large direction-finding errors from the results of instantaneous measurements of the ratio of the amplitudes of the output signals of the receiving antennas. Bearing rejection algorithms are based on theoretical dependences obtained for the normal model of fluctuations of the quadrature components of the output signals of the receiving antennas. The efficiency of algorithm rejection is determined by the terrain of open and semi-enclosed routes and may reach 54 percent.

1. Introduction
On the ground routes of radio line of sight or diffraction, the main factors that result in location finding errors are: terrain unevenness and terrain detail reflection of radio waves, as well as radio-wave diffraction on the edge of the forest range [1]. Other sources of location finding errors are the following: internal receiver noise, inaccuracy in amplitude readings of the received signal, mutual influence of antennas [2, 3]. Instrumental errors of location finding are normally regular (other than internal noise) and are corrected by calibration.

The location finding error due to the received signal distortion exposed to the radio path in the radio line of sight and diffraction is related to the signal-to-noise ratio and antenna orientation of the scanning radiation source [2]. It is theoretically and experimentally proved that when the transmitter beam of the transmitter antenna is maximized away from the finder direction, location finding errors increase on average [1]. Such situation is specific to the area of deep minima, where the signal-to-noise ratio is insignificant. However, abnormally high errors in location finding occur in the area of minima at the relatively large signal-to-noise ratio.

In particular, when finding the scanning source of radio-frequency by the phase method on ground routes of up to 30 km long within the centimeter range, it is found experimentally that for some intervals of the transmitter antenna angular positions, the bipolar shots of phase difference of the...
received signals up to $2\pi$ radians are observed [4]. As such, the location finding results have abnormally large errors.

The classic approaches to reduce the location finding errors are the following:

- exclusion (rejection) of abnormal reading of phase difference for further processing;

- balanced processing of measurement results (without abnormal measurement rejection) by the best effective location finding algorithm.

The balanced processing is effective if actual statistical features of the observed difference-phase processes and their statistical properties are quite correlative, which are set when optimizing the location finding algorithm. However, such correlation is rare in practice due to the diversity of the terrain of cross-over tracks. In addition, the location finding algorithm optimization is complicated by the non-stationary behaviour of the difference-phase measurements caused by the change in the angular position of the antenna of the scanning radio source.

When considering rejection methods, let us note the method of abnormal measurement elimination (sampling censoring), effective when there are sampling values that refer to the different general population and noticeably different from the values of the “open” sample. The three sigma method is known. However, with smaller sampling volume, censoring by these methods is inefficient [5, 6]. In work [6] authors consider theoretic science and rejection methods for abnormal measurements of physical parameters presented by stationary random processes, in particular, as discrete processes with nonzero coefficient of the adjacent sample correlation. Algorithms for abnormal reading filtration are known which are based on statistical features of the measured value. Such rejection algorithms are given, in particular, in works of Yu.I. Schur, Yu.K. Gavrilov, M.A. Bogoslovskaya [7]. In their works, they consider algorithms for abnormal bearing error elimination by compensation via the additional receiving channel, by comparing the signals of the total and difference channels, by angular strobing under the pre-identified information features.

The approaches above to eliminate the bearing results with abnormally large errors are applicable in radio direction finders or direction finders, processing the package (set) of received signals when determining the bearing.

The method applicable to survey location finders is known to reject the bearing results with abnormally large errors based on the bearing discarding by the restriction of the quadratic form [8]. Experimental verification of this method proved that increasing the accuracy of radiation source finding, depending on the threshold, is 5 to 14 percent.

The purpose of the report is to assess the effectiveness of abnormal reading rejection of the phase difference in the survey location finder when receiving signals from the scanning source of radio on radio paths in the rough terrain.

The algorithm efficiency is considered from the point of view of the accuracy increase of location finding as the readings are rejected.

2. The experimental data

Experimental data for the ground paths indicate the relationship between the standard deviation of fluctuations of the phase difference of signals and the ratio of their amplitudes in two- and multi-channel systems. Let us consider this ratio closer, and then, based on it we will reject measurements of the phase difference with abnormal large errors.

Dependencies of instantaneous amplitudes of the received signals and the phase difference between them based on the angular position of the transmitter antenna typical for ground routes of the rough terrain are shown in Figures 1a and 1b.
Figure 1. Specified dependencies of instantaneous signal amplitudes and the phase difference between them on receiving antennas "1" and "2" spaced into three wavelengths, the line-of-sight of 1 km long

The review of such materials evidence that instantaneous signal amplitudes at the outputs of spaced aerials in the area of the bipolar shot of the phase difference may obviously vary. This informative feature can be used to exclude the findings with abnormal errors.

This phenomenon analysis in theory under the normal signal model can allow the written provisional frequency distribution $W(\Delta \varphi / z)$ of phase difference $\Delta \varphi$ of signals at the fixed ratio of their amplitudes $z$ [9, 10]. As per the known $W(\Delta \varphi / z)$, the provisional RMS of phase difference may be found $\sigma_{\Delta \varphi(z)}$. The example of RMS dependence of the phase difference on varying ratios of instantaneous amplitudes is shown in Figure 2. These dependencies are reviewed to reveal that the ratio of signal amplitudes does not contain the Shannon data on the phase difference when the coherence parameter $g$ reaches two limit values: $g = 0$ (no direct signal) and $g \to \infty$ (no scattered signal).

The relationship between the standard deviation of the phase difference fluctuations and the ratio of instantaneous signal amplitudes at the outputs of spaced aerials can be the starting point for the synthesis of more advanced algorithms for location finding of the radio sources based on the results of the phase difference readings. In particular, the obtained data can be used for the amplitude selection of phase difference results with larger errors.

In practice, the coherence feature is usually taken as values ranging from one to several tens. Under such conditions, statistical features of the signal phase difference depend on the ratio of their instantaneous amplitudes. Rejection of bearings when the ratio of the measured amplitudes of received signals exceeds the certain threshold will result in potential increase in the accuracy of the survey phase finder.
3. Bearing rejection algorithm

Let us consider such rejection efficiency in relation to signal processing received at various rough routes in the line of sight and diffraction zone.

Below are the results of phase difference processing for various threshold values of $z_p$ with instantaneous measurement of amplitudes and phase difference between the received signals for the length of the pulse signal (Figure 3). Three surface routes were considered: line of sight (16.4 km) and semi-enclosed routes (19.0 km and 29.1 km).

The experimental verification of the phase difference rejection algorithm with respect to instantaneous amplitudes showed that the increase in the accuracy of the phase difference results depending on the threshold is 10 to 54 percent.

4. Conclusion

The results obtained allow us to draw the following conclusion. The efficiency of algorithm rejection is determined by the terrain of open and semi-enclosed routes and may reach 54 percent. Rejection of
measurements by the amplitude ratio is more effective as compared with the algorithm of the quadratic form restriction.

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