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IMPROVEMENT OF ACCURACY AND STABILITY OF OPERATION OF A TRACKING DIRECTION FINDER BASED ON BIASED ESTIMATION METHODS

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The accuracy and stability of operation of an angle discriminator can be improved through correction of its output signal based on generation of the estimate with the least full quadratic error. The paper gives an analytical expression of probability density of this estimate, which makes it possible to evaluate its effectiveness and to determine the best application conditions.

The modern procedures of statistical data processing use the maximum likelihood method for estimation of parameters. Such estimation is asymptotically nonbiased and effective when the volume of measurement data increases substantially. The only way to improve the estimation accuracy under conditions of low-information measurement sampling is to neglect the requirement of unbiasedness and to use the methods of biased estimation.

In accordance with the regularization method, one widely used approach is the following version of biased estimation $x_{\text{p}} = rx_{\text{mlm}}$ of the parameter x, where r is the reduction coefficient, and x_{mlm} is the maximum probable estimate.

The full quadratic error for the estimate x_{p} has the form

$$f(x_{\text{p}}) = (r-1)^2 x^2 + r^2 \sigma^2 = \sigma^2 \left\{ (r-1)^2 \delta^2 + r^2 \right\}$$

where $\sigma = \sigma(x_{\text{mlm}})$ is the mean square deviation, and $\delta = x/\sigma$.

As shown by investigations, for the values $\delta < \sqrt{2}$ the full quadratic error of the biased estimate is less than the variance of nonbiased estimation. For instance, at $x = 1$, $\sigma(x_{\text{mlm}}) = 1$, and $r = 0.5$, the gain is double.

The physical analysis of the gain due to application of the compressing procedures shows that the coefficient of reduction r has to be based on the information about the predicted value of the parameter to be estimated. Obviously, the optimal reference value will coincide with the true value of the parameter sought. If the latter is unknown, it is natural to assume that the true value of the required parameter may be replaced by the unbiased estimate value, which is maximally close to it. Then the reduced estimate takes the form

$$x_{\text{p}} = \frac{x_{\text{mlm}}^2}{x_{\text{mlm}}^2 + \sigma^2(x_{\text{mlm}})} x_{\text{mlm}}$$

where x_{mlm} is a normally distributed random quantity, whose probability distribution density is described by the following expression:

$$P(x_{\text{mlm}}) = \frac{1}{\sqrt{2\pi}\,\sigma} \exp\left(-\frac{(x_{\text{mlm}} - x)^2}{2\sigma^2} \right), \quad \sigma = \sigma(x_{\text{mlm}}).$$

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