RADIO MEASUREMENTS

INVESTIGATION OF THE CHARACTERISTICS OF SIGNAL FILTERS BASED ON AN INTERFERENCE COMPENSATOR WITH CROSS CONNECTIONS

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The operation of an interference compensator with crossed connections is analyzed. The gain of the filters in the compensator is determined taking into account the statistical properties of the processes at their inputs. The characteristics on the non-optimal and optimal filters and compensators are obtained when an additive mixture of signal, correlated interference and white noise acts on them.

Correlated spectrum-concentrated interference has a considerable effect on the quality of data-signal filtering. The optimal processing algorithms (see, for example, [1-3]) under these conditions involve considerable computational costs, particularly when the signal and interference are multidimensional processes. Under certain conditions, characteristic for practical situations, for example, if the interference power considerably exceeds the signal power, quasioptimal signal processing algorithms are synthesized [4]. In this paper we investigate an algorithm for filtering a signal on a background of correlated interference and Gaussian noise with independent values based on an interference compensator with crossed connections.

Formulation of the problem. Suppose the process at the output of a receiver at a discrete time \( i = 0, 1, 2, \ldots \) has the form

\[
y_i = H_x x_i + H_v v_i + \xi_i,
\]

where

\[
x_{i+1} = Bx_i + \eta_{i+1}
\]

is the data signal, \( \eta_i \) is the Gaussian noise with independent values, zero mathematical expectation and a correlation function \( M[\eta_i, \eta_j] = C \delta(i - j) \), \( M \) is the operation of mathematical expectation, \( \delta(i - j) \) is the Kronecker delta,

\[
v_{i+1} = Av_i + \zeta_{i+1}
\]

is the correlated interference, \( \zeta_i \) is Gaussian noise with independent values \( M[\zeta_i] = 0 \), \( M[\xi_i, \xi_j] = D \delta(i - j) \); \( \xi_i \) is the Gaussian noise with independent values \( M[\xi_i, \xi_j] = 0 \), \( M[\zeta_i, \zeta_j] = E \delta(i - j) \); \( A, B \) are the correlation coefficients between the \( i \)th and \( (i+1) \)th readouts of the interference and signal respectively, \( C, D \) and \( E \) are the variances of the noises, and \( H_x, H_v \) are the constant known parameters of the system. We will also assume that the noises in (1)-(3) are mutually independent, i.e., \( M[\eta_i, \xi_j] = 0 \), \( M[\eta_i, \zeta_j] = 0 \), \( M[\xi_i, \zeta_j] = 0 \). It is required to separate the signal (2) from the additive mixture (1) with the minimum distortions.

In a situation where the interference in (2) is not present (\( H_v = 0 \)), the signal filtering algorithm is defined by a Kalman filter.
where $\hat{x}_i$ is the optimum estimate of the signal when $H_v = 0$, $G_{i+1}$ is the gain of the filter, $P_i$ is the variance of the signal filtering error, and $P_{i+1,i}$ is the variance of the prediction errors per step.

The operation of filter (4) when the additive mixture (1) acts at its input was analyzed by statistical modeling on a computer of Eqs (1)--(4). In case (1) the signal/noise ratio $q_{s,n} = \frac{x_0}{\sigma^2}$, while the interference/noise ratio $q_{i-n} = H_v x_0 / \sigma^2$, are the variances of processes (2) and (3) respectively [5]. In Fig. 1 we show curves of the normalized variance of the signal filtering error $\sigma^2 = M(\hat{x}_i - x_i)^2/\sigma^2$, where $\sigma^2 = 0.086$ is the variance of the filtering error in the situation when $H_v = 0$, as a function of the interference/noise ratio $q_{i,n}$. When calculating the curves we took $q_{s,n} = 10$ dB and $B = 0.5$, while the correlation coefficient of the interference was found from the relation $A = B^2$, where $A$ is the ratio of the signal bandwidth to the interference bandwidth. In Fig. 1 we show three curves corresponding to three different values of $A$.

As can be seen from Fig. 1, for $q_{i,n} = 20$ dB and different values of $A$, we have $\gamma \sigma^2 = 20$ dB. The correlated interference has a considerable effect on the signal filtering quality according to algorithm (4), and hence it is necessary to synthesize other signal processing algorithms which take into account the statistical properties of the interference.

Characteristics of the Compensators. To solve the problem in question we can synthesize an optimal Kalman filter, which carries out the operation of simultaneous signal and interference filtering [1]. The results of modeling this algorithm are represented by curve 1 in Fig. 2. It can be seen from this figure that interference, whose bandwidth is much less than the signal bandwidth $\gamma \leq 0.001$, has a considerable effect on the filtering quality ($\sigma^2 \to 1$). This filter is optimum, but to design it in practice it is necessary to solve a system of matrix equations, which increases as the dimensionality of the vectors of the signal and interference parameters increases, and the calculations become even more complicated.

When the interference power is greater than the signal power, the processor is constructed on the basis of quasioptimal signal filtering algorithms (see, for example, [2]). One of the possible signal filtering algorithms is processing using an inter-