DESIGN SCHEME FOR A TWO-CHANNEL SPATIAL SEPARATOR
OF SIGNAL AND INTERFERENCE
USING PRELIMINARY ORTHONORMALIZED INPUT PROCESSES

S. A. Metelev and Yu. V. Shishkin

We propose an algorithm for an adaptive spatial separator of signal and interference in which
the input processes are orthogonalized and normalized. It is shown that the weight coefficients of
the second adaptive summator can be expressed in terms of the weight coefficients which form the
first output of the separator. The interference immunity of the device is analyzed both analytically
and numerically. The conclusions were confirmed by a test with actual radio signals.

To suppress random and organized signal-like interference, not having a priori known differences
from a legitimate signal, separation algorithms, by which the signal–interference mixture is divided into
components [1–3], have been proposed for adaptive antenna systems (AAS). The algorithms given in [1, 3]
are based on the expansion of input processes with respect to the eigenvectors of the correlation matrix and
are efficient only if the powers of the partial oscillations are very different.

The variation in the parameters of most actual signal–interference radio channels causes fluctuations
in the level of the received radio waves. This impairs the quality of spatio-temporal signal processing (STSP)
using the algorithms proposed in [1, 3].

The optimal separator [2] is based on the mean-square error (MSE) criterion and uses a gradient
algorithm. Such a separator is intended for signals with angular-shift modulation (which permits easy
formation of a standard signal), which are most popular in discrete communication channels. The separation
efficiency in such a separator is almost independent of the type (noise-like or signal-like) and power of
interference.

The processing procedure in the separator [2] begins with the orthogonalization of input processes
and their normalization in automatic gain control (AGC) circuits. Next, the orthonormalized oscillations
enter two units operated by the MSE criterion based on the Widrow–Hoff algorithms with two orthogonal
standard signals formed by limitation of output oscillations. Widrow–Hoff algorithms ensure asymptotically
optimal processing of signals to minimize the MSE and maximize the signal/(interference+noise) ratio at
one output and the interference/(signal+noise) ratio at the other output. The second standard signal is
formed during compensation for the first standard signal from the limited second output of the separator,
using an orthonormalizer of standard oscillations. The orthonormalizer in the circuit of the second standard
slightly distorts the standard oscillation, which reduces the interference immunity of the second separator
output.

At the same time, the use of an orthonormalization preprocessor before the optimal algorithm for
minimization of MSE (MMSE) facilitates the construction of the second adaptive processor and makes
the second Widrow–Hoff unit unnecessary. In this paper, we study the design scheme and efficiency of such a
simplified separator.
1. FUNCTIONAL COUPLING BETWEEN THE WEIGHT COEFFICIENTS OF THE SEPARATOR

Consider the block diagram of the separator (Fig. 1), which represents a generalized algorithm for separation of two oscillations in two adaptive summators. The adaptive summators are preceded by an orthogonalizer and an AGC circuit for the orthonormalization of antenna oscillations. The weight coefficients are calculated in the adaptive processor by the MSE criterion, and it is not important in this case which algorithm, gradient or the one for direct inversion of the correlation matrix, is employed.

Assume that the complex amplitudes of antenna oscillations, \( \xi_1(t) \) and \( \xi_2(t) \), represent the sum of oscillations of the signal \( s(t) = a c_s(t) \) and interference \( p(t) = b c_p(t) \), which have different amplitudes in the separation branches (owing to the nonidentical radiation patterns of the receiving antennas) and different phases (owing to the spatial separation)

\[
\xi_1(t) = a_1 c_s(t) e^{i \beta_s} + b_1 c_p(t) e^{i \beta_p} + n_1(t) e^{i \eta_1(t)}, \\
\xi_2(t) = a_2 c_s(t) e^{i (\beta_s + \Delta \beta_s)} + b_2 c_p(t) e^{i (\beta_p + \Delta \beta_p)} + n_2(t) e^{i \eta_2(t)}. \tag{1}
\]

Here, \( c_s(t) \) and \( c_p(t) \) are the modulating functions of the sources for the legitimate signal and interference, respectively, \( \beta_s \) and \( \beta_p \) are the oscillation phases of the signal and interference in the first antenna, \( \Delta \beta_s \) and \( \Delta \beta_p \) are the differences of oscillation phases of the signal and interference between the second and first antennas, and \( n_1 \) and \( n_2 \) are the amplitudes and \( \eta_1 \) and \( \eta_2 \) the phases of uncorrelated noise in the separation branches.

The orthogonalization procedure is accomplished by the linear transformation of antenna oscillations and has many solutions. One possibility of such a transformation, by using the algorithm of a quadrature autocompensator (or Gram–Schmidt’s two-channel transformation), is considered below where the interference immunity of the separator is analyzed. The form of the orthogonalizing transformation is not important for the analysis of functional couplings between the weight coefficients of the separator. After the orthogonalization, the complex processes \( x_1(t) \) and \( x_2(t) \) are, as before, the sum of two oscillations: of the legitimate signal \( s(t) \) and interference \( p(t) \) (the action of thermal noise in the channels is neglected at first):

\[
x_1(t) = s_1(t) e^{i \varphi_s} + p_1(t) e^{i \varphi_p}, \\
x_2(t) = s_2(t) e^{i (\varphi_s + \Delta \varphi_s)} + p_2(t) e^{i (\varphi_p + \Delta \varphi_p)}, \tag{2}
\]

where we extracted the initial phases \( \varphi_s \) and \( \varphi_p \) and the phase differences \( \Delta \varphi_s \) and \( \Delta \varphi_p \) between oscillations.