Distributed Acoustic source localization algorithm

based on the array signal processing method

\[ \Delta x = x_{l} - x_{r} \]

\[ d = x_{l} - x_{r} \]

\[ L = x_{l} - x_{r} \]

The estimation of the spatial spectrum is used

and the function of the spatial spectrum

\[ P_{MUSIC} \] (classical multiple signal classification - MUSIC)

is calculated

Estimation of the shortest distance from

the OF to the source of acoustic impact.

\[ \alpha_{\text{est}} = \alpha \left( \frac{\Delta t}{k} \right) \]

\[ x_{\text{est}} = x_{l} \left( \alpha_{\text{est}} \right) - x_{r} \left( \alpha_{\text{est}} \right) \]

\[ g_{\alpha}(\alpha_{\text{est}}) \]

Determining the location of an intruder in 3D space.

\[ r_{i} = \sqrt{\left( x_{l}^{(i)} - x_{r}^{(i)} \right)^{2} + \left( y_{l}^{(i)} - y_{r}^{(i)} \right)^{2} + \left( z_{l}^{(i)} - z_{r}^{(i)} \right)^{2}} \]

\[ T_{\text{DOA}}(\alpha_{i}) \]

\[ \phi_{i} = \phi_{\alpha}(\alpha_{i}) \]

\[ \psi_{i} = \psi_{\alpha}(\alpha_{i}) \]

Determination of the sound source at the intersection of hyperbolae

obtained from TDOAs.

\[ \omega_{\text{est}}(\Delta \Phi) = \omega_{\alpha}(\Delta \Phi) \]

\[ \eta_{\text{est}} = \eta_{\alpha}(\Delta \Phi) \]

for all TDOAs, which were found

to be reliable, and 0 otherwise.

Algorithm for determining the location of an intruder

using time difference of arrival systems built on the DAS

\[ J^{\text{DOA}}(\alpha) = s(x)^{2} d(x) \]

\[ r = \left\| \hat{x} - c \right\| \]

\[ c_{i} = \text{c}_{i} \]

\[ \text{Dependence of the source localization} \]

\[ \text{error on the distance to the sound source.} \]

Simulation of data obtained and algorithms comparison

Test configuration with one fiber optic cable arranged in three planes.

Test configuration with three fiber optic cables arranged in three planes.

Spectral characteristic of the acoustic signal.

Amplitude (a) and phase (b) distribution on the fiber section in a configuration with a single optical cable.

Dependence of the source localization error on the distance to the sound source.

Despite the approximately equal error levels of the TDOA and AST methods, the AST method is most preferable, due to the more voluminous and more time-consuming calculations for TDOA. In turn, the ASP method shows a low error rate when the optical fiber is wound on the resonator structure, thereby reducing the calibration length of the DAS. It should be noted, that such configurations are not found in real operational conditions. The AST method requires further study and optimization of the mathematical model. A low-frequency signal has a greater effect on the DAS, but it has a tangible effect on all surrounding objects and structures leading to an increased proportion of parasitic influences on various sensor points.

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