MEASUREMENT CREDIBILITY IN UNDERWATER ENVIRONMENT

W. Kicinski

The Polish Naval Academy, 81-919 Gdynia, Poland

Abstract: An approach to characterizing the measurement credibility and a methodology of statistical evaluation of measuring signals for measurement experiments in undersea environment has been proposed.
Keywords: credibility of the measurement, statistical evaluation

1   INTRODUCTION

The ambient noise may be said to be the residual noise background in the absence of any individual identifiable sources or that ambient noise indicates that wind-generated noise is predominant source of the total ambient noise is natural noise environment at a measurement site [1].

The characteristics of ambient noise such as RMS level, power density spectrum level, probability function, etc. have been calculated as average values from the data vectors that have been extracted from measuring signals collected during experiments in the underwater environment [4].

The essential problems in the ambient noise measurements are to establish an ensemble of the data vectors which are representative for the observed phenomenon, and to characterize the measurement credibility. These problems are extremely crucial for the coastal zone, where a man-made contribution to the ambient noise level is significant. At conclusion, the results of the ambient noise measurement might be different for the same sea states; therefore, they are difficult to compare and generalize.

The primary objectives of the paper are presenting an approach to characterizing the measurement credibility and proposing a methodology for statistical evaluation of the measuring data vectors collected under measuring processes in the undersea environment.

2   THE PROBLEM

The measurement of the ambient noises can be considered as a procedure of getting information from a set of noise signals (called the measurement signals) and presenting it in an useful form, i.e. in the form of underwater noises characteristics. It is widely recognized and usually assumed when reporting the result of the measurement that series of observations are obtained under repeatability conditions in the measurement environment. It implies that so called *influence quantities* [2], which can affect the measurement results (measurands), are approximately constant under measurement experiment. The measurement conditionalities of the ambient noises introduce some troubles in the approach to reproducibility of the measurement signals. Briefly, they may be characterized as follow:

  - activities of many sources of noise at the same time,
  - varying propagation of the acoustic waves in the underwater environment,
  - random influence of the surroundings on the measurement environment (especially in the coastal zone).

In the subject literature, the characteristics of ambient noises have been discussed as a function of the sea state or wind force. They have been treated simultaneously as the determinants of the conditions of the measurement experiments in underwater environment. It is necessary to point out, however, that both mentioned parameters determine only the influences of the natural forces on the sea surface and do not mirror the contribution of another noise sources in acoustic field. At conclusion, the determination of measurement conditions of ambient noises by the state of the sea or the wind force is subjective and implies the need of extending their descriptions by the additional parameter, which mirrors the credibility of measurement in underwater environment.

Having in mind that the measurands of ambient noises have been calculated as average values on the ensemble of measuring data vectors, the credibility of measurement may be defined as follows:

Definition

The credibility of measurement of ambient noises is the index of representability of the ensemble measuring data vectors that were collected in the measurement process of the characteristics of the phenomenon observed in underwater environment.

Then, the consideration of the credibility of measurement in underwater environment deals with the quality estimation of measurands of ambient noises, when *the influence quantities* could not be stabilised under measuring process.

The index of credibility for the results of the measurement of ambient noises characteristics may be considered as the fraction of measuring data vectors distinguished for the quality feature which is their similarity in statistical sense.

The maximum likelihood estimator of the fraction can be written as

$$\hat{F} = \frac{k}{K} \tag{1}$$

where:

κ - the size of the subset of measuring data vectors, which are representative for measuring conditions (the sea state or wind force are approximately constant),

K - the ensemble of measuring data vectors collected in the measurement process.

For large K the confidence interval for estimator (1) can be derived from

$$P\left\{\frac{k}{K} - z_a \sqrt{\frac{\frac{k}{K}\left(1-\frac{k}{K}\right)}{K}} < \hat{F} < \frac{k}{K} + z_a \sqrt{\frac{\frac{k}{K}\left(1-\frac{k}{K}\right)}{K}}\right\} = 1 - a \tag{2}$$

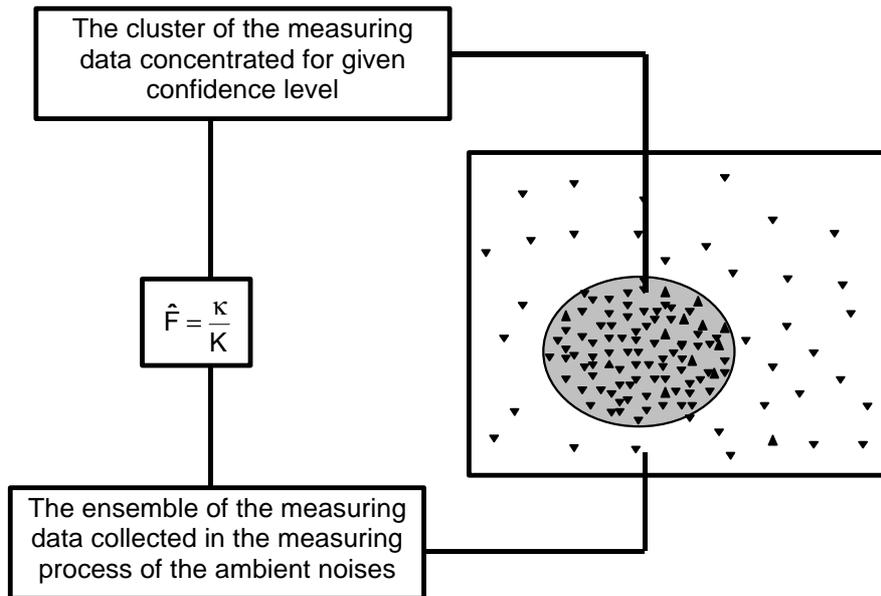where: $z_á$ - quantile of N(0,1) distribution on significance level á.

Figure 1. The graphical interpretation of the fraction of the measuring data vectors

The metrological interpretation of the fraction may be stated as follow:

– the fraction characterises the influence degree of disturbance noise sources on underwater environment, where ambient noises have been measured,

– the confidence interval for fraction determines the lower and higher bound of probability which characterises degree of confidence for measuring data vectors of ambient noise.

There are several motivations behind to use the fraction as a parameter expressing the credibility of the measurement results in the underwater environment.

1. The shorter confidence interval, the higher degree of confidence for the measurement result for assumed the significance level á.

2. For the same value of, the measurement result with shorter confidence interval is more credible.

3. The confidence interval characterises indirectly the size of ensemble of collected data vectors in mea- suring process.

3   THE STATISTICAL EVALUATION OF THE MEASURING SIGNALS

For the statistical evaluation of the ambient noise signals it is assumed that they have been collected for specific sea state. The problem is to extract an cluster of measuring data vectors, which are concentrated in measurement space for given level of significance.

The single measuring data vector is a sequence of quantized samples of the noise signal on the output of measuring transducer (hydrophone).

Let

$$x_N^{(k)} = \left(x_1^{(k)}, x_2^{(k)}, ..., x_N^{(k)} \right) \tag{3}$$

to be the k-th, N-dimensional the measuring data vector.

The ensemble of the measuring data vectors collected in measuring process can be denoted as follows

$$
\begin{aligned}
x_N^{(1)} &= \left(x_1^{(1)}, x_2^{(1)}, ..., x_N^{(1)} \right) \\
x_N^{(2)} &= \left(x_1^{(2)}, x_2^{(2)}, ..., x_N^{(2)} \right) \\
&........................... \\
x_N^{(K)} &= \left(x_1^{(k)}, x_2^{(k)}, ..., x_N^{(K)} \right)
\end{aligned}
\tag{4}
$$

where k=1,2...K.

Next, let

$$y_P^{(k)} = \left(y_1^{(k)}, y_2^{(k)}, ..., y_P^{(k)} \right) = F\left(x_1^{(k)}, x_2^{(k)}, ..., x_N^{(k)} \right) \tag{5}$$

to be the result of transformation the k-th the measuring data vector to P-dimensional feature space. Then we have

$$
\begin{aligned}
y_P^{(1)} &= \left(y_1^{(1)}, y_2^{(1)}, ..., y_P^{(1)} \right) \\
y_P^{(2)} &= \left(y_1^{(2)}, y_2^{(2)}, ..., y_P^{(2)} \right) \\
&........................... \\
y_P^{(K)} &= \left(y_1^{(k)}, y_2^{(k)}, ..., y_P^{(K)} \right)
\end{aligned}
\tag{6}
$$

The ensemble of the measuring data vectors in the feature space can be denoted as

$$Y = \left\{ y_P^{(1)}, y_P^{2}, ..., y_P^{(K)} \right\} \tag{7}$$

Definition

On given level of significance, the subset Y' of elements of the Y set is representative for the measuring signal of ambient noise collected for the specific sea state, if

$$
\underset{y_P^{(k)} \in Y'}{\forall} \qquad D^2 = \left(\overline{y}_P - y_P^{(k)} \right)^T C^{-1} \left(\overline{y}_P - y_P^{(k)} \right) \leq c_{df,a}^2 \tag{8}
$$

where:

D^2 - Mahalanobis distance [3],

C - covariance matrix,

$\chi^2_{df,á}$ - quantile of $\div^2$ distribution for df degrees of freedom on significance level á.

In (8) the vector denotes a center of the cluster of measuring data vectors extracted from Y ensemble of vectors collected in measuring process of the ambient noise. The measuring data vectors being the members of the cluster have been applied to calculation of measurands of ambient noises. It means that the measuring data vectors rejected in statistical evaluation of the measuring signals may be classified as so called outliers in the measuring process.

4   CONCLUSION

An original approach to characterising the measurement credibility and the methodology of statistical evaluation of measuring signals in underwater environment has been proposed.

The parameter expressing credibility of measurement treated simultaneously with the description of the sea state in the Beaufort scale better characterise the measurement conditions in the underwater

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environment, where the *influence quantities* could not be a'priori assumed as constant.

For statistical evaluation of measuring signals the methods of the time series analysis and the discriminant analysis may be applied.

The described methodology has been successfully applied by author in evaluation of characteristics of the ambient noise in coastal zone of the Baltic Sea. The third octave spectrum of the noise signals can be considered as the feature space of the ambient noises [5].

In authors opinion, the fraction as the parameter of the measurement credibility may be applied in measurement environments, where *influenced quantities* could not be a'priori assumed as constant.

ACKNOWLEDGMENT

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AUTHOR: W. KICINSKI, Department of Hydroacoustics, The Polish Naval Academy, Smidowicza 71 , 81-919 Gdynia, Poland, Phone: Int. ++48 58 6262903, Fax: ++ 48 58 6254846
E-mail: amw@beta.nask.gda.pl , wkicinski@amw.gdynia.pl