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Shallow water waveguide stochastic model parameters estimation

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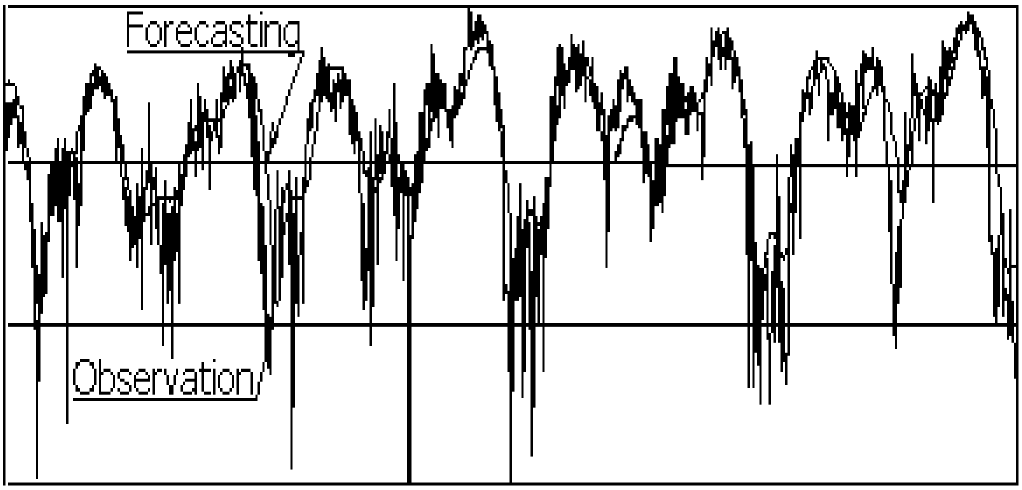
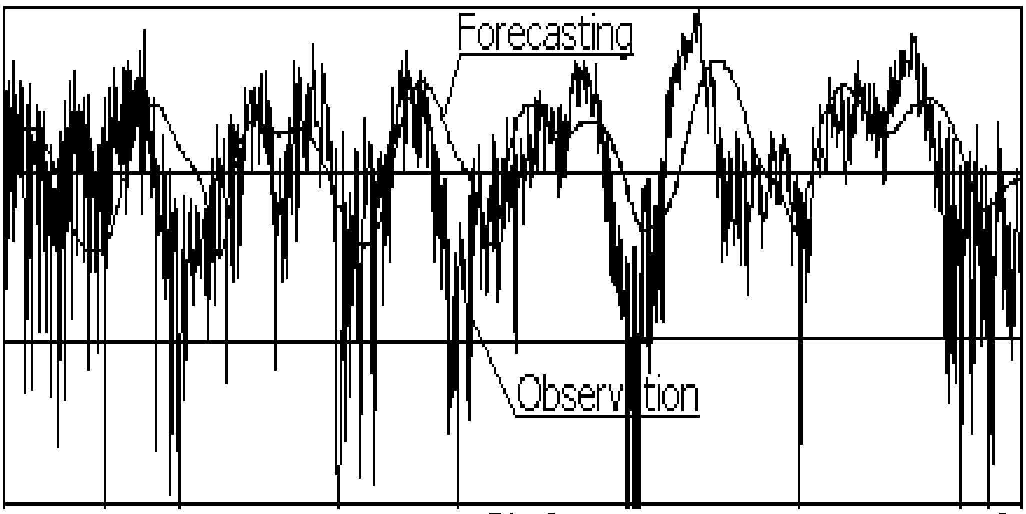
The tone source observed energy values are forecasted by the model with the estimated parameters values not contradictory from the stochastic hypothesis test point of view at the distances between 20 and 130 waveguide depth. The model described the main interference picture peculiarity in the three wavelength depth waveguide and hence it may be used as the underlying for experiment planing. The estimated parameters value error characteristics analysis makes it plain that forecasting necessary parameter estimates are very mach correlated. Its correlation is pregnant with poorly conditioned Guesse matrix. There are illustrations of observations and forecasting results.



Pic.1.

There are coincidence of observations and mode field model forecasting results in some wavelength (λ) depth waveguide only if one takes into consideration stochastic component of the signal even in the case that is in the fig.1.

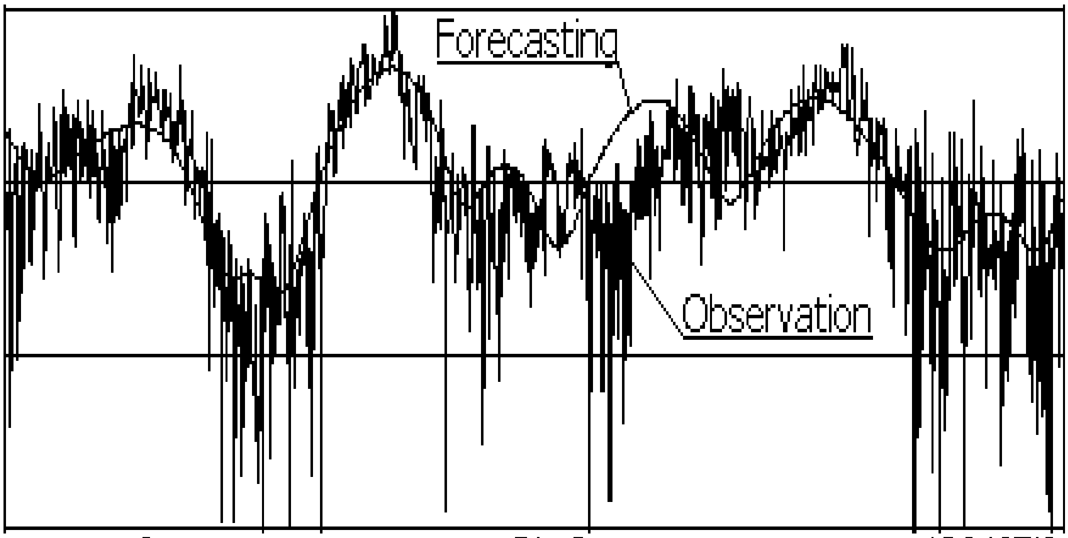


Pic.2.

The stochastic model [1] describes signal destruction or multiplicative noise. The waveguide model was selected for deterministic forecasts as follows. The water layer has constant thickness, density, sound velocity, zero was accepted as loss angle tangent. The water like sediment layer with constant thickness and analogous set of parameters except nonzero loss angle tangent value was accepted as ground model which followed by hard half space with longitudinal and transversal waves parameters. There are observations and forecasting results of interference in the 2,97λ depth waveguide under the circumstance of regular rectilinear tone source motion on 0,48λ depth in the vicinity of seabed receiver on the fig.1, there are 10dB among the horizontal lines. There are the distances at the leftmost and rightmost points to the receiver (and to the traverse point – in the brackets), traverse distance is equal 102λ. There is less exact result in another aqua territory region, it is in fig.2, where water depth is 2,73λ and traverse distance is 111λ. There are mach better observations and forecasting results coincidence in the second half of data alone in the fig.3, where in approximation another parameters used.

The straight energy observations and deterministic forecast residuals was approximated by stochastic component of model, which is proportional to deterministic one and consists of white and colored components. The colored component is proportional to colored noise which described by self regressive equation with white noise in right hand part. Kalman filtration (KF) may be used in observation treatment for such a model. There is no reason to reject stochastic model on 10% significant level in all above cases.

On the same time there is no possibility to estimate measurement error characteristics for modal parameter, which are necessary to make forecasting, because of poorly conditioned Guesse



174(134)λ Pic.3. 130(67)λ

matrix for objective function (OF_E) of mentioned parameters estimation. However the model may be used for experiment condition planing because of not contradictory forecasting with its usege. In the experimental data treatment it is possible to use logarithm of likelihood as an OF_E, then theoretical average of OF_E equals matrix determinant det(V), where V is forecasting error variance matrix of KF.

The forecasting error variance matrix has diagonal form diag[σ_i^2], but its different time moment elements aren't equal, $\sigma_i^2 \neq \sigma_m^2$ for $i \neq m$, besides theoretical average $M\{Y_i\}$ of observable values Y_i depend nonlinearly on estimated parameters in situations, where multiplicative noise takes place, this noise is characterized with the usege of self regressive model and KF is used in treatment. If one takes the matrix

$$X=\partial M\{Y_i\}/\partial\theta_* \mathrm{diag}[\sqrt{\sigma_i^2}]$$

as planing matrix then situation is analogous to mean square method.

It is well known [2] that the optimal plan may be constructed by the matrix X column orthogonalisation because in linear dependency variance matrix is proportional to $[X^{\text{Ò}}X]^{-1}$.

The variance matrix is proportional to inverse Guesse matrix $(\partial^2 OF_E/\partial^2\theta)^{-1}$ and forecasting error variance matrix under the circumstance of non linearity. The matrix multiplication determinant is equal to multiplication of determinants. Hence the variance matrix minimization may be attained by making diagonal Guesse matrix $(\partial^2 OF_E/\partial^2\theta)$ under the circumstance of non linearity. The diagonal matrix eigenvectors collection forms unity matrix. Hence it is possible to do an optimal plan as follows.

The matrix $(\partial^2 OF_E/\partial^2\theta)$ may be transformed as follows $Ò^{Ò}diag(d)Ò$, where Ò is the matrix of eigenvectors with the elements t_{ij}. One has for squared module of difference between j-th eigenvectors with k-th column of unity matrix $\sum_{i=1,i\neq k}^{n}(t_{ij})^2+(t_{kj}-1)^2=\sum_{i=1}^{n} t_{ij}^2+(t_{kj}-1)^2-(t_{kj})^2=1+(t_{kj}-1)^2-(t_{kj})^2=2*(1-t_{kj})$.

One can rates it as k-th raw of new vector, all such vectors may be conformed to a matrix U with positive elements, so as $|t_{ij}|\leq 1$. One ought take n elements from the matrix so that only one element was been taken from every raw and column of matrix U. Last circumstance guarantee that each eigenvector has been used only one time. The selected element position is indifferent because of indifference of nearest eigenvector column number. The selected element ought to be the diagonal one in reformed matrix, so only one element may be taken from each raw and column. The elements sum ought to be as little as possible, if Guesse matrix became diagonal than sum equals zero. The minimal sum value finding corresponds to appointment task solution, which is one of classic task of operations research. The solution of such a task is well known by simplex method, and mentioned sum may be used as an objective function (OF_P) in experiment planning.

Hence one ought to find such the experiment conditions, which corresponds to Guesse matrix of waveguide identification OF_E, that is as close to diagonal as possible. One can satisfy diagonal form constraints by using in experiment planning OF_P, which is mentioned solution of appointment task.

In planning one can use only theoretical average $M\{OF_E\}$, which naturally has no fluctuations. It is possible to estimate fluctuation variance of used statistic by $var_{\theta j}\{OF_E\}\geq\{[\partial M(OF_E)]/\partial\theta_j\}/I(\theta_j)$ [3], where $I(\theta_j)$ is information quantity by Fisher for element θ_j in estimated parameters vector. Hence it is possible to calculate the elements of matrix K that is inverse to variance matrix as follows

$$K_{jm}=\{\surd[var_{\theta j}(OF_E)var_{\theta m}(OF_E)]\}^{-1}\partial^2 M(OF_E)/\partial\theta_j\partial\theta_m.$$

The mentioned estimate gives an opportunity to find such conditions, where Guesse matrix $\partial^2 M(OF_E)/\partial\theta_j\partial\theta_m$ is more near to diagonal not only in the point with model parameters, but in some vicinity of this point, i.e. for mismatched KF. The vicinity value $\Delta\theta$ gauge may be taken upon the above mentioned variance matrix K^{-1}. One can use the likelihood L as OF_E, so for theoretical average in the point $\theta+\Delta\theta$ one has $M(L)=det(V)+tr(V^{-1}W)+\Delta M\{Y\}^T V^{-1}\Delta M\{Y\}$,
where W – mismatched KF error variance matrix, $\Delta M\{Y\}$ – difference of theoretical average of observations.

The above mentioned formulas make it possible experiment planning with the quantitative insurance experimental signal treatment quality. The treatment quality may be described by measured parameters vector variation matrix, which was evaluated by transference of observance fluctuations over used model forecast variance. The admissibility of used shallow water waveguide acoustic fields forming model hypothesis have to been checked under the circumstance of known value of true hypothesis rejection probability. The true hypothesis rejection probability value don't use in the domestic practice of hydroacoustic experiment results treatment. It seems reasonable to adopt domestic practice with the known treatment precedence [4], because of mistake decision acceptance probability ought to specify before the planning and operation.

R E F E R E N C E S

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