Reconstruction of Algorithms for Spread Spectrum Signals Detection into a Frame of the Inductive Modeling Method

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Abstract. *An approach for development a high performance algorithm of spread spectrum signal detection is examined. A preliminary specification of detection tasks for a spectral description of signals is considered. As an example of detection a deterministic frequency hopped signal being in a mixture with a periodically correlated noise of a wide frequency band ADC is given. Methods of a spectrum analyzing of the mixture is discussed. Optimization of parameters of algorithms in the methods of spectral analyses for detection of spread spectrum signals is reconstructed as the inductive modeling method of handling of these parameters.*

Keywords

Spread spectrum signal, detect, periodical correlated ADC noise, spectral description, parameter optimization, inductive modeling method.

1 Introduction

Near thirty years ago was considered relations between the theory of communications and had been estate recently the inductive modeling (or heuristic self-organizations of models) in problems of engineering cybernetics [1, 2]. These relations were putting in a base of theoretical analyses of modeling tasks and were used for inference of the theory of disturb stable modeling [3] as well as for the polyharmonic modeling of processes and fields [4].

Nevertheless, the inductive modeling methods had been used in many practical applications except the communication. Nowadays in the communication are very common a spread spectrum signals, mean, for example, hopped carried frequencies is modulated by are coded messages. These signals bring effectiveness for applications but their spectrum occupied a band in many times wider than need for transmission of coded messages. These lead to dramatic difficulties at controls of communication channels for detection of non-authorization means of the communication and to development different methods for such signals detection are based onto spectral representation of signals.

Signals which spectra are variable in a wide frequency band had been meet in bioobjects (for example, human's hearth, pulse waves, evoked retinas potentials etc.) as well as at geoobjects, in the Space and the Oceans.

In this submission an example of a problem of the spread (is varied) spectrum signal detection is analyzed. An idea of the inductive method for determine of parameters of algorithm for this signal processing under its detection is posed.

2 Background of Algorithms for Spread Spectrum Signals Detection

As a background for an algorithm development we would put a method for resolving a task by given computational means. The method is developed in a frame of a mathematical model of a signal and a noise. So, the main target is to find a mathematical object with properties of a signal and a noise is suitable with the task.

2.1 Deductive method in detection of signals

The story of the detect ability verify has been completely presented by Capon while 1965. The question was what put on in a base for splitting by a threshold of a mixture of a signal and noise. Some stages of this must be admitted because of their conceptuality. The main stage was consideration of the mixture of a signal and noise representation. At the end result it stands as a spectral one under conditions for the detectably of a signal. It was considered by the property of probability distributions of signals and noises to be perpendicular as the necessary and sufficient conditions of detect ability [5].

In a common sense the spectra of a signal is distributed (namely, spread) onto time Tc (Fig. 1) in wide band Fc. So, we must do multiple spectral analyses — by comb-filter (many of a very narrow band filters) simultaneously in every discreet moments of time in band f or by a narrow-band filter being tuned (scanned) onto frequency band f sequentially in the time.

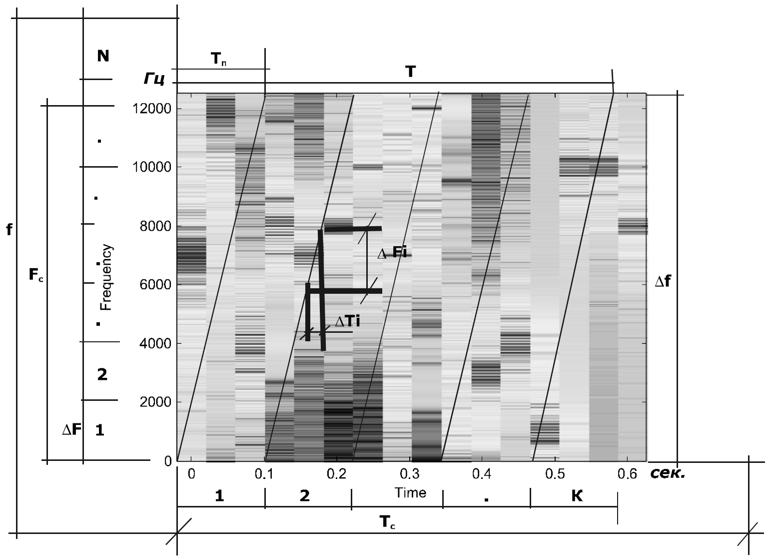

Fig.1. Schemas of spectral analyses

Usually the first method performs by N filters with ΔF frequency band and second method performs by K scans of ΔF frequency band filter.

Estimation of numbers of scans, filters in the comb filter, narrow frequency bands, the scan speed etc. (Fig.1) for given probabilities of detection and faults had been developed onto the Bayesians conception was given in [6].

For the spread spectra signal recently was considered the more common its spectral model as an almost periodically correlated process [7]. That permits doing the simultaneously spectral analyses, for example, by very narrow band comb filter banks are sequent in the time and without overlaps [7, 8]. Filters banks determine spectra of stationary components. A number of stationary components, a period of correlations are a priory unknown and do influence on probabilities of detection and faults.

An estimate of numbers of components, periods of correlations, parameters of narrow band filters had been achieved by the sequential optimization conception under a spectra variation criteria and probabilities of detection for given probabilities of faults had been estimated as well [7, 9].

2.2 Inductive method in detection of signals

Let us do attempt for reconstruction of the deductive method of detection of signals into a frame of the inductive modeling. The first question is can we find by the inductive modeling (like the harmonic algorithm GMHD [4]) a spectral representation with properties of a signal and a noise is suitable with the task of detection of spread spectrum signals. If answer is “Yes”, than we can find a threshold for splitting a mixture of a signal and noise, determining signal-to-noise ratio, detect the signal and estimate a probability of right detection. The second question is about complexity of the like GMHD algorithm for determining a spectrum of the mixture.

We have ADC in a wide frequency band of a spread spectrum signal — mean a time consequence. A formal theory of the inductive inference of such date and its using for their compression and prediction was developed by Solomonoff while 1956 (to see also [10]). In that theory significant role plays a universal probability distribution by Kolmogorov. We do know nothing probability distributions but for the detect ability we know a one their property to be perpendicular and the corollary of this property — to have spectra of time consequence on the ADC output. So, we can not get systems of LMS-like equations as in the harmonic algorithm [4] because of the spectrum is a more common entity apart of harmonic series. But when there are assumptions that the time consequence on the ADC output is cyclostationary than we have equations of spectrum estimations namely co phase (coherent), component or filters’ [8, 9]. The target of these equations is spectra of stationary components — power spectral densities. These equations are parameterized by numbers of components, periods of correlations, parameters of narrow band filters.

An estimation of a number of components *K*, periods of correlations *M*, points of FFT 2*L* (they all are interrelate with time of analyses *T* and its beginning point t_0), parameters of narrow band filters etc. had been achieved at the sequential optimization conception under criteria as variation of estimation of power spectral densities $\hat{f}_k$

$$\arg\min_{K,L\in \mathrm{N}} VAR_d \hat{f}_k(\lambda_l)\,, \tag{1}$$

where $VAR_d(\cdot)=\sum_{k=1}^{K}\sum_{l=1}^{L}\left\|f_k(\lambda_l)\right\|^2_{\varepsilon,\pi}$ is d- variation, $\left\|\cdot\right\|^2_{\varepsilon,\pi}$ — a norm in Hilbert spaces ε, or π , λ — a frequency [8, 9].

For example, for estimation of the power spectrum density by the covariation

$$\hat{C}(t,\tau)=\int_0^{t-\tau}\overset{\circ}{\xi}(t-u)\,\overset{\circ}{\xi}(t-u+\tau)h(u)du \tag{2}$$

of a centered process $\overset{\circ}{\xi}$ (namely time consequence on the ADC output) as function of two arguments a pulse function $h(t)$ is used — the coherent, when

$$h(t)\overset{\Delta}{=}\frac{1}{T}\sum_{n=0}^{T-1}\ \delta(t-nM)\,) \tag{3}$$

or the component, when

$$h(u)\overset{\Delta}{=}\frac{\sin[(K+\frac{1}{2})\lambda_0 u]}{T\sin(\lambda_0 u/2)}\,. \tag{4}$$

In general, $h(t)$ is designed as the pulse function of an optimal filter [8, 9]. The $\hat{C}(t,\tau)$ may be given as

$$\hat{C}(t,\tau)=\sum_{k=0}^{K-1}c_k(\tau)\exp(ik\lambda_0 t) \tag{5}$$

where $\lambda_0 = 2\pi / T_0, K \cong T / T_0, T$ — the sample interval and $c_k(\tau)$ can be given by the Fourier-Stielties integral

$$c_k(\tau) = \int_{-\pi}^{\pi} \exp(i\lambda\tau) dF_k(\lambda) \qquad (6)$$

where $F_0(\lambda)$ is bounded non decreasing function, $F_k(\lambda)$ are complex functions of the bounded variation.

Taking in mined a specific restriction, for example, are given by the theory of periodically correlated processes — the concentration of its spectral measure on lines $\lambda_1 = \lambda_2 + k\lambda_0$, the functions $F_k(\lambda), \quad k = 0, \pm1, \pm2, \pm3, ...$ are called spectral distribution, while $f_k(\lambda), \quad k = 0, \pm1, \pm2, \pm3, ...$ are called spectral density components of the periodical correlated random-process $\xi(t)$. We can assume their harmonizability, i.e. representation by Fourier-Stielties integral. Then the sequence $f_k(\lambda)$ is clearly a stationary random sequence.

So, with the inductive modeling view point the equation (1) for the spectral representation of spread spectrum signals under the task of their detection is an analogue for LMS equations in harmonic algorithms of GMHD.

3 Conclusion

In theoretical sense application results of the inductive modeling method are equivalence to the deductive ones. But at the applying of the deductive method for resolving of practical complex problems a difference appears apart of the inductive method. The complexity of algorithms were developed by the deductive method grows dramatically. Criteria for a method choice between of two of them are strongly related from ambiguity of data, a system and task are under exploration. In the common sense the deductive method serves for verification of the inductive one. The inductive method is more appropriate for bad established tasks but need well definite beginning date. The deductive method replaces the inductive one when task ambiguity decreases.

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