Algorithm for the Synchronization in Radio Communication Systems with Coherent Discontinuous Variation of the Working Frequency

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Abstract – **An algorithm for the synchronization in radio communication systems with discontinuous variation of the working frequency is proposed in the paper.**

Keyword – **Spread spectrum communication systems**

The problem of the communication system synchronization lies in the combination in the time of periodic processes, describing the operation of the transmitter and the receiver. Even the precise knowledge of the time of the transmitter operation initiation and the perfect stabilization of the time standard is not a complete solution of the synchronization problem. This is especially valid for the mobile radio communication, where as a result of the change in the distance between the mobile objects arises indefiniteness in the delay of the received signals. In spite of it some authors [1,2] consider that in the future broad band systems with discontinuous variation of the carrier frequency will be used a combination of the method of autonomous synchronization in connection with the creation of compact highly stable frequency standards and methods of prognosticating of the distance between the transmitter and the receiver by additional means, including special computing facilities and providing the possibility for obtaining sufficiently precise information for the purpose of compensating the delay. With a view to this formulation, one of the purposes of this paper is to propose an algorithm for autonomous synchronization with prognosticating of random delay fluctuations.

The most universal approach to the problem of the synthesis of optimal algorithms for receiving is based on the theory of Markov for the nonlinear filtration. With a view to the delay compensation τ(t) in the signal propagation medium s(t), it should be emitted with advance in the, or it should be of the kind:

$$S_x(t) = s[t+x(t)].$$

When the delay τ (t) is available, the desired signal is described with the expression:

$$S_x[t-\tau(t)] = S\{t-\tau(t)+x[t-\tau(t)]\} \quad (1)$$

The problem, the solution of which is the subject of this paper, is to determine the value of x(t), at which is obtained the maximum root-mean-square of the displacement ε(t) at the time of receiving the signal at the receiver input with random delay τ(t) available, or

$$\varepsilon(t) = \tau(t)-x[t-\tau(t)]. \quad (2)$$

For the determination of x(t) can be used the total current information about the random delay, contained in the realized w(t) during the time interval [0,t] at the receiver input. This oscillation is a mixture of the desired signal and the noise:

$$w(t) = S_x[t-\tau(t)]+n(t). \quad (3)$$

The signal emitted by the transmitter in a random time t_0 enters the receiver's input through a channel with random delay at the time t_1, so that the evident equation:

$$T_0 = t_1 - \tau(t). \quad (4)$$

is justified.

The set problem could be reduced to the determination of the advance x(t), providing minimum root-mean-square of the displacement $\varepsilon(t_1)$ of the signal, received at the time t_1, based on the observation of the realization w(t) to the time of emitting the $w_0 = \{w(t), 0<t<t_0\}$.

As well known, the optimum root-mean-square estimate coincides with the arbitrary mathematical expectation:

$$X(t_0) = M\{\tau(t_1)| w_0\} = \int_{\infty}^{\infty} \tau_1 P_1(\tau| t_0)\, d\tau; \quad (5)$$

$$P_1(\tau | t_0) = P\{\tau(t_1) | w_0\}.$$

In order to avoid the process consideration at random times, it is reasonable to introduce the following process:

$$\tau_1(t_0) = \tau(t_1). \quad (6)$$

From (4) follows that

$$\tau_1(t_0) = \tau[t_0 + \tau(t_1)] = \tau[t_0 + \tau_1(t_0)]. \quad (7)$$

In this case for the probability density $P_1(\tau | t)$ could be said that it is the current presumptive density of the process probabilities $\tau_1(t)$;

$$P_1(\tau | t) = P\{\tau (| t_1)| w_0\} = P(\tau_1(t_0)| w_0\}.$$

The physical meaning of $\tau_1(t)$ is the delay of the signal emitted at the time t_0.

From (7) can be derived equation, determining the relation between $P_1(\tau, t)$ and $P(\tau, l| t) = P(\tau(t+l)| w_0\}$, or the a posteriori probability density of the random delay at the fixed time τ (t+l). If l is regarded as a random value with a probability density P(l), and τ (t+l) as a function of this value, than based on (6) the following is valid:

$$P\{\tau_1(t) = \tau | w_0\} = \int_{-\infty}^{\infty} P\{\tau(t+l) = \tau | w_0\} P(l)\, dl \quad (8)$$

From (7) follows that $l=\tau_1(t)$, or:

$$P(l) = P\{\tau_1(t)\} = l | w_)\} = P\{[l | t\}$$

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In this way a homogeneous integral equation of Fredholm of second type, providing the possibility for the determination of $P_1(\tau | t)$ at assigned probability density $P\{\tau,| t)$.

$$P_1(\tau | t) = \int_{-\infty}^{\infty} P(\tau; 1| t)\, P_1 (1 | t)\, dl. \qquad (9)$$

Equation (9) relates the probability characteristics of the $\tau_1(t)$ process to the characteristics of the $\tau(t)$ process. The algorithm of calculating of $P(\tau; 1| t)$ results from theory of the optimum nonlinear filtration. The random delay can accept non negative values, or $\tau_1(t)>0$, $P_1(\tau | t)=0$ for $\tau<0$. That is why in (9) only $P(\tau; 1| t)$ for $l>0$ is used, or, only the extrapolated probability density.

In practice always can be assumed that τ (t) is a component of a Markov process $\lambda(t) = \{\tau (t),\beta(t)\}$, and τ (t) is separated in an open type.

If S(t) is a synchrosignal, emitted by the monitoring station and the delay is the only random parameter of the $S_x(t)$ signal, then the assignment of τ defines completely the signal:

$$S_x[t-\tau (t)] = S\{t-\tau (t)+x[t-\tau (t)]\}$$

The realization of $w_0^{t-\tau\ (t)}$ in formula (1) is known, determined by previous observations.

So, the determination of the a posteriori probability density of the probabilities $P(\tau; 1| t)$, based on the observation w^t_0, is a problem of the Markov theory for an optimum linear filtration, that can be solved. The probability density can be determined by the equation

$$\frac{\partial P(\lambda; lIt)}{\partial l} = L\{ P(\tau; 1| t)\}, \qquad (10)$$

where L(.) is the presumptive operator of Focker – Plank - Kolmogorov [2].

The initial condition in this equation is determined by the expression:

$$P(\lambda;\ v=.0\ |\ t) = P(t,\lambda), \qquad (11)$$

where $P(t,\lambda)$. $P\{\lambda(t) | w^t_0\}$ is the current a posteriori probability density of the $\lambda(t)$ process at the observation $y^{ш}_0$, determined by the equation for the filtration equation of Stratonovich [2]. In this case it is of the following kind:

$$\frac{\partial \boldsymbol{P(T,\lambda)}}{\partial \boldsymbol{t}} = L\{P(t,\lambda)\} + [F_x(t,\tau) – F_x(t)]\, P(t,\lambda),$$

where

$$F_x(t,\tau) = \frac{2}{N} \{w(t)\, S_x(t-\tau) – ½\, S_x^0(t-\tau)\};$$

$$F_x(t) = \int F_x(t,\tau)\, P(t,\lambda)d\lambda$$

For the purpose of simplifying equations (10), (11) and forming the extrapolated probability density $P(\tau; 1| t)$ it is reasonable to apply the well known method of the Gaus approximation.

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