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SYNCHRONIZATION IN RADIO COMMUNICATION SPREAD SPECTRUM SYSTEMS

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Abstract:

Movable radio-communication systems are known to cause uncertain delay of the received signals as a result of the changing distance between the movable objects. In the promising wide-band systems with leap changing bearing frequency shall establish and maintain synchronization through a combination of autonomous synchronization made possible by the introduction of compact high-stability frequency references, and forecasting methods for the distance between the transmitter and the receiver using auxiliary devices such as dedicated calculating units, which will provide to obtain sufficiently accurate data to compensate for the delay. In view of this setting, here, an algorithm is suggested for autonomous synchronization with forecast of random delay fluctuations.

The problem of communication system synchronization lies in the time combination of periodic processes, describing the operation of the transmitter and the receiver. Even the precise knowledge of the transmitter's starting operation time and the perfect stabilization of the time standard are no complete solution of the synchronization problem. This is especially valid for mobile radio communication, where the change in the distance between the mobile objects generates indefiniteness in the delay of the received signals. Nevertheless, some authors [1,2] consider that in the future, broad band systems with discontinuous variation of the carrier frequency will use a combination of the method of autonomous synchronization in connection with the creation of compact highly stable frequency standards and methods of prognosticating the distance between the transmitter and the receiver by additional means, including special computing facilities and providing the possibility to obtain sufficiently precise information for the purpose of compensating the delay. With a view to this formulation, one of the objectives of this paper is to propose an algorithm for autonomous synchronization with prognostication of random delay fluctuations.

The most universal approach to the problem of the synthesis of optimal receiving algorithms is based on Markov's nonlinear filtration theory. To compensate the delay $\tau(t)$ in the signal propagation medium s(t), the signal should be emitted ahead of time, i.e. it should be of the kind:

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

When available delay $\tau(t)$, the useful signal at the receiver's input is described by the expression:

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

The problem, whose solution is the subject of this paper, is to determine the value of x(t), at which maximum root-mean-square of the displacement $\varepsilon(t)$ is obtained at the time of receiving the signal at the receiver's input with available random delay $\tau(t)$, or

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

To determine x(t) the total current information about the random delay can be used, which is contained in the realized w(t) during the time interval [0,t] at the receiver's input. This oscillation is a mixture of useful signal and noise:

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

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

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

is satisfied.

The described problem could be reduced to determination of the advance x(t), providing minimum root-mean-square of the displacement $\varepsilon(t_1)$ of the signal, received at time t_1, based on the observation of the realization w(t) by the time of the signal's emission $w_0 = \{w(t), 0<t<t_0\}$..

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

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

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

To avoid considering the process at random times, it is reasonable to introduce the following process:

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

From (4) it follows that

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

In this case with respect to the probability density $P_1(\tau \mid t)$ it could be said that it is the current presumptive density of the process's probabilities $\tau_1(t)$;

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

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

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

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

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

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

In this way, a homogeneous Fredholm integral equation of the second type can be defined, providing the possibility to determine $P_1(\tau \mid t)$ at assigned probability density $P\{\tau,l \mid t)$.

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

Equation (9) relates the probability characteristics of the $\tau_1(t)$ process to the characteristics of the $\tau(t)$ process. The algorithm of calculating $P(\tau;\, l \mid t)$ follows from the results of the optimum nonlinear filtration theory. The random delay can assume non negative values, or $\tau_1(t)>0$, $P_1(\tau \mid t)=0$ for $\tau<0$. That is why in (9), only $P(\tau;\, l \mid t)$ for $l>0$ or only the extrapolated probability density is used. In practice, it can always be assumed that $\tau\,(t)$ is a Markov process component $\lambda(t) = \{\tau\,(t),\beta(t)\}$, $\tau\,(t)$ being separated explicitly.

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 $P(\tau;\, l \mid t)$, 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

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

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

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

$$P(\lambda;\, v=.0 \mid t) = P(t,\lambda),$$

where $P(t,\lambda)$. $P\{\lambda(t) \mid w^t_0\}$ 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:

$$(11) \qquad \frac{\partial P(T,\lambda)}{\partial t} = L\{P(t,\lambda)\} + [F_x(t,\tau) - F_x(t)]\, P(t,\lambda),$$

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 $P(\tau; l\,|\,t)$ it is reasonable to apply the well known method of the Gaus approximation.

References

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СИНХРОНИЗАЦИЯ В СИСТЕМИ С РАЗПРЕДЕЛЕН СПЕКТЪР

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Резюме

В системите на подвижната радиовръзка вследствие на промяната на разстоянието между подвижните обекти възниква неопределеност в закъснението на приеманите сигнали. В перспективните широколентови системи със скокообразно изменение на носещата честота, за установяване и поддържане на синхронизация ще е възможно използване на съчетание на метода за автономна синхронизация във връзка с създаването на компактни високостабилни еталони на честота и методи за прогнозиране на разтоянието между предавателя и приемника с помощта на допълнителни средства, включващи специализирани изчислителни устройства и даващи възможност да се получи достатъчно точна информация с оглед компенсиране на закъснението. С оглед на тази постановка в настоящата работа е предложен алгоритъм за автономна синхронизация с прогнозиране на случайни флуктуации на закъснението.