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The Simulation and Optimization of Fragment Elements of Network Clock Synchronization

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SUMMARY

Purpose of this paper is optimization of fragment elements of Network Clock Synchronization to improve its interference immunity. For it, we use method of digital simulation, based on application of main clauses of theory of digital filters. According to algorhythm of this method, parametric optimization of fragment elements has been performed. As a result - the decrease of more than twice of main quality criterion. There is a need to emphasize, that the spectrum of possibilities of considered method is extremely wide. It can be successfully used for investigation of the information and communication systems.

INTRODUCTION

The problem associated with synchronization in digital systems is of paramount importance. This problem should be resolved comprehensively since the timing of digital transfer system (DTS) and network synchronization technique are interconnected.

Digital networks are based on existing DTSs, within which the timing have been created independently without regard for the requirements imposed by the digital network. Low stability of DTS makes difficult to develop high effective clock synchronization. When the network is created on basis of compound channels, the task becomes more complicated. The primary varieties of synchronization techniques are as follows : master-slave method, mutual synchronization and plesiochronous (autonomous) mode of clocks. The circuit of sychronization consists of a great quantity of clocks being synchronized and located

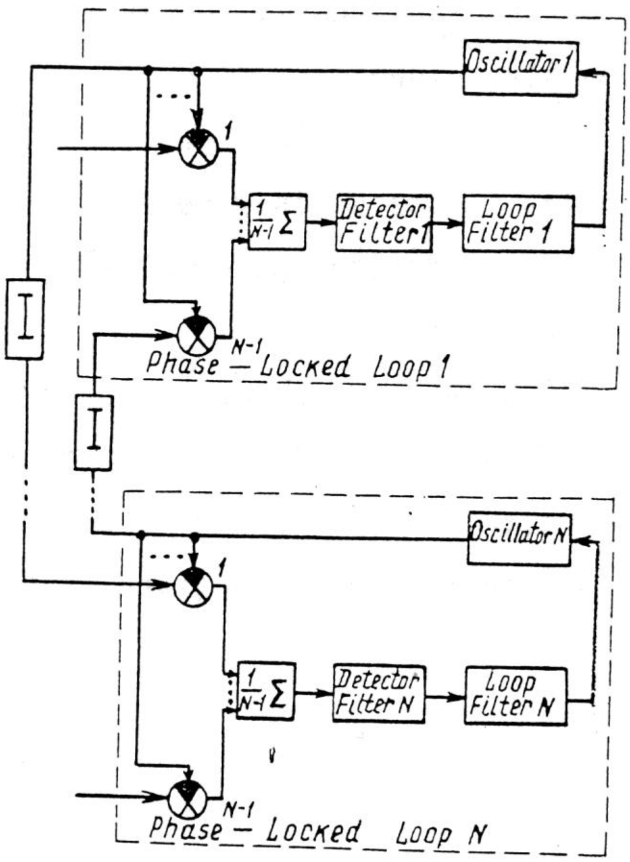

Fig.1 Block diagram of NCSS in mutial synhronization.

at switching nodes. Due to complexity and immensity of the task for analysis and synthesis of the network clock synchronization system (NCSS), analytical methods are low-effective and for that reason it is advaisable to use a method of simulation.

The essential element of NCSS is phase - locked loop (PLL). Generally, NCSS network can be considered as multiply connected automatic con-

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trol system, where individual PLLs are separate arrangements of this system.

As indicated in Fig.1, the model of the PLL and communication channel are the main parts of NCSS's model.

GENERAL CONSIDERATION

Let us use the simulation method based on application of main clauses of theory of digital filters. Because of identity of principal techniques in developing of digital filters and digital models, elaborated method is referred to as the method of digital simulation. A universal digital model of linear section in form of difference recursive equation is used in digital simulation :

$$Y[n*T] = \frac{1}{B_l}\{ \sum_{\nu=0}^{l} A_{l-\nu} \times X[n*T-\nu*T] - \sum_{\nu=1}^{l} B_{l-\nu} \times Y[n*T-\nu*T]\} \quad ..(1)$$

where

$Y[n*T]$ - output variable,

$X[n*T]$ - input variable (signal) of arbitrary kind,

A_i B_i - factors characterizing simulated section,

l - the order of operational transfer function of simulated section.

The determination of A_i, B_i factors is most formalized :

$$A_l = S_l \times a_l \qquad B_l = S_l \times b_l \quad ...(2)$$

where

A_l B_l - matrixes of recursive equation factors,

S_l - matrix of transfer from L- transformation (usual Laplace transformation) to Z-transformation,

a_l b_l - factor vectors of operational transfer function of simulated sections.

The transfer from L-transformation to Z-transformation was accomplished by Boxer-Thaler method .

The recursive equation is called as the universal digital model of linear section since input variable (input signal) may be of arbitrary kind and the restrictions being due to complexity of simulated sections , have been removed. The concept of digital simulation should be explained.In simulating it is assumed that the model is developed on the basis of existing original (prototype), while the model shall be equal to original. An analog PLL may be used for a prototype. As the result of simulation there is a model of PLL on which base the digital PLL can be realized. Thus, having the analog PLL as an original, we can through digital simulation determine digital PLL with characteristics similar to original;

The digital model of PLL incorporates closure equation:

$$\varepsilon[n] = \Delta\theta[n] - \Delta\varphi[n] \quad ...(3)$$

and three recursive equations permitting the reception of signal at PLL output:

$$\Delta U_1[n] = \frac{1}{B_1}\{\varepsilon[n] + \varepsilon[n-1] + B_0 + \Delta U_1[n-1] \quad ...(4)$$

$$\Delta U_2[n] = \frac{1}{B_2 \times n}\{A_2 \times \Delta U[n] + A_1 \times \Delta U_1[n-1] + A_0 \times \Delta U_1[n-2] - B_1 \times \Delta U_2[n-1] + A_0 \times \Delta U_2[n-2]\} \quad ...(5)$$

$$\Delta\varphi[n] = A_1 \times \Delta U_2[n] + A_0 \times \Delta U_0[n-1] + B_0 \times \Delta\varphi[n-1] \quad ...(6)$$

Owing to increasing requirements to communication hardware and time of its manufacture currently there is a need to create an optimal communication system. More high quality performance of hardware and significant economic effect are provided at the cost of optimal design of the system.

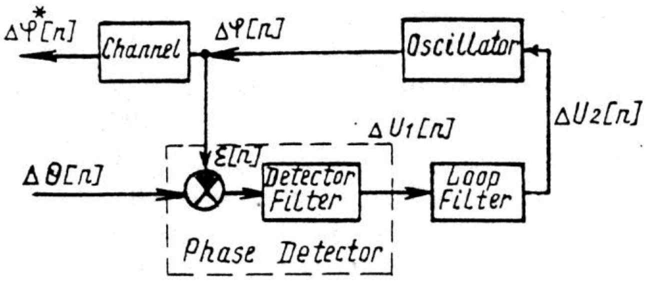

Fig.2 Block diagram of PLL.

The main requirements imposed to NCSSs are as follows: high accuracy synchronization, minimum time for synchronization, high in-terference immunity, independence of medium frequency from parameters of communication channels. The separate devices of NCSS (such as PLL) will provide the fulfilment of these requirements.

As outlined above, for solution of optimization task the criterion of quality (CQ) may be formulated. This task is multicriteria. The solution of the task is reduced to single criterion task through the choice of main CQ and transfer other function to category of constraints. The main CQ was selected starting from requirements to improve an interference immunity. For its quality assessment there have been used fluctuation phase dispersion of frequency pulses being at the PLL in random change of signaling pulse (SP) phase at the input of PLL. The rule of change of SP phase is Gauss with exponential autocorrelated function (AF). The CQ comprises maltitude of constraints that reflects high requirements to the accuracy of synchronization and admissible domain of parameter changes of low-pass filter (LPF) located in PLL. The task of parameter optimization of the PLL is reduced to determination of those parameters of proportionally integrated filter when the fluctuation phase dispersion at PLL output will be minimum.

The dispersion was calculated using the formula :

$$R_y[\Delta n] = \sum_{n=\Delta n}^{\infty} \omega[n-\Delta n] \times g[n] \qquad \ldots (7)$$

where

$R_y[\Delta n]$ - AF at output of the PLL,

$g[n]$ - reaction of PLL on the influence coincidental with AF of input random process,

$\omega[n-\Delta n]$ - weight function of the PLL.

When $\Delta n=0$, (7) gives the value of dispersion at output of the PLL. For determination of required signals there have been used a digital model of the PLL, allowing to determine a reaction at output of PLL in arbitrary input signals.

A random search method with return in case of unsuccessful step, was used as a method of optimization . According to algorithm of this method, the parametric optimization of PLL have been performed. As a result, the decrease of more than twice of phase dispersion at output of the PLL, has been achieved.

Before and after optimization the study of the PLL was conducted to confirm the correctness of the task. Recorded delay of PLL's transitional characteristic front with optimal parameters, indicates improving of the influence immunity. The checking of obtained results was also made by means of phase change simulation, namely the realization of random Gauss process with exponential AF was fed to input of the PLL. The fluctuation phase dispersion at output of the PLL was determined by statistical processing of output random process. The decreasing of dispersion in optimal parameters of the PLL, was confirmed in these experiments.

The digital model of communication channel has the following type:

$$\varphi^*[n] = (1-2\times\frac{\tau}{T}) \times \varphi[n] + (1+2\times\frac{\tau}{T}) \times \times \varphi[n-1] - \varphi^*[n-1] \qquad \ldots (8)$$

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where

τ - signal delay in communication channel,

T - discrediting period.

CONCLUSION

Based on received models of the PLL and communication channel, according to Fig.1 there have been developed a universal digital model of NCSS's fragment. Universality of the digital model lies in the possibility to receive from it a model of the NCSS of arbitrary structure. Using the universal digital model, there have been conducted experiments aiming to research timing characteristics of phase changes of separate NCSS's generators in different phase disturbance as well as here was assessment of stability of the NCSS using method of D-splitting.

In conclusion, there is a need to emphasize that the spectrum of possibilities of considered simulation method is extremely wide. This method can be successfully used for investigation of the NCSS as well as other complicated linear and nonlinear systems.

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