CHARACTERIZATION AND COMPUTER MODELLING OF SYNCHRONIZATION NETWORK ELEMENT CLOCK ENSEMBLES

G. V. Konovalov,
Central Sience Research Telecommunication Institute, Moscow

Abstract – **The report is devoted to quality characteristics of synchronization network element clock ensembles. The computer model of such ensembles sets and methods of obtaining the proposed ensembles characteristics are demonstrated with the help of the program, developed by the author. The role of the mentioned characteristics in quality monitoring of synchronization network and the advisability to standardize them are considered.**

Index terms – **synchronization network, clocks computer simulation, network element clock characteristics in the time domain.**

I. Introduction

The report deals with the characterization and computer modelling of synchrosignals ensembles similar to those that are generated by clocks and distributed in a digital telecommunications synchronization network. In this network there are network element clocks that synchronize each other using well known "master-slave" principle [1-3]. As a matter of fact up-to-date telecommunications synchronization networks all over the world are hierarchial, "despotic" and have tree-like topology. At the highest (first) hierarchial level, a synchronization network (SN) has a primary master, called a Primary Reference Clock (PRC) or a Primary Reference Source (PRS). Synchronization signals (synchrosignals) from PRC or PRS are distributed over SN and synchronize slave clocks on its second and lower levels of hierarchy such as Stand Alone Synchronization Equipment (SASEs), Synchronization Supply Units (SSUs), SDH Synchronization Equipment Clocks (SECs), clocks in switches and cross-connectors and so on. Hierarchial quality levels of SN element clocks are specified by standard entities (UTU-T and ETSI) in [2,3], using standardized synchrosignals characteristics in the frequency and time domain. It is known that such characteristics, especially Maximum Time Interval Error (MTIE) and Time Deviation (TDev), play a major role for characterizing performance of the different individual clocks during audit and/or monitoring of the synchronization network [1-5]. Their role is also important when it is necessary to obtain quality characteristics of computer modelled individual synchrosignals.

The aim of the report is the consideration of not yet standardized generalized quality characteristics of the determined ensembles of synchronization signals, generated by clocks.

II. Generalized quality characteristics of clock ensembles

In author's opinion aforementioned characteristics deserve particular attention if considering some newly developed means for audit and/or monitoring of the synchronization network (For example, one of such means that described in [5] can monitor simultaneously quality parameters of eight synchrosignals). By such means, there a possibility arises to simultaneously monitor a certain set of synchronization signals viewed as a unified ensemble in accordance with a certain classification sign [6,7]. So both parameters and characteristics of controlled individual synchronization signals and the generalized characteristics of the whole ensemble may be obtained and analyzed. The formulae for the dependences of this kind of characteristics as functions of time are shown in Table 1 as applied to the ensemble from L synchrosignals, in which the l-th synchronization signal ($1 \le l \le L$) is a pseudoperiodic (ideally, a periodic) signal, described by the function

$$s_l(t) = A_l \sin[\Phi_l(t)] = A_l \sin[2\pi \nu_{noml} T_l(t)],$$

where A_l and ν_{noml} are the amplitude and nominal value of its clock frequency. In the formulae of Table 1 $T_l(t)$ is a l–th synchrosignal generated time function [1-4], which is a measure of conformance of time, to be determined on the l-th synchronization signal, and of the ideal time t (at $T_l(t) = t$ all L of the ensemble synchronization signals are identical with a ideal strictly periodic signal of nominal frequency ν_{nom}). For an ensemble from L

synchronization signals one can, along with the time function family $T_l(t)$, where $1 \le l \le L$, consider in the time domain also the function of average time $T_{av}(t)$, obtained by averaging the values $T_l(t)$ over the whole synchronization signal ensemble. Along with this ensemble characteristic, the function $T_{\max}(t) = \max_{1\le l\le L} T_l(t)$ and the function $T_{\min}(t) = \min_{1\le l\le L} T_l(t)$ are also defined in Table 1. The first of them gives an idea about the "maximum", while the second one about the "minimum" time, so that $T_{\min}(t) \le T_{av}(t) \le T_{\max}(t)$. The functions $T_{av}(t)$, $T_{\max}(t)$ and $T_{\min}(t)$ characterize the collective behavior of the whole synchronization signals ensemble and, thus, are generalized characteristics for them.

In this connection, for example, the time error function (TE – Time Error function) $TE_{ind}(t) = T_{ind}(t) - T_{ref}(t)$, where $T_{ref}(t)$ is the function of the time assigned by the significant moments of the reference signal from the reference clock, will be, at the correspondence of the index value ind to value l, an individual characteristic of the l-th ensemble synchronization signal, while at the replacement of ind by av, $\max$ or $\min$ it will be the corresponding generalized characteristic, i.e. the function of the error of the average, "maximum" or "minimum" time for the synchronization signal ensemble.

In a similar way, taking into account the standard definitions of the characteristics of an individually taken synchronization signal, the appropriate other generalized characteristics of an ensemble from L synchronization signals may be also defined. For example, the Time Interval Error function (TIE) $TIE_{ind}(t,\tau) = TE_{ind}(t+\tau) - TE_{ind}(t)$, where in this case t and $t+\tau$ are the times of the start and end of the duration interval τ.

At the replacement of ind by av, $\max$ or $\min$ we have accordingly the TIE definitions at the average, "maximum" and "minimum" times (see Table 1). In a similar way, formulae for other generalized characteristics of an ensemble from L synchronization signals can be obtained.

It should note that when measuring and calculating both the characteristics of the l-th synchronization signal of the ensemble and the considered generalized characteristics, one should, in principle, take into account the possible distinction of function $T_{ref}(t)$ from function $T_{idl}(t)$, coinciding with true time t. If it's possible, however, due to the high accuracy and stability of the reference oscillator, not to take into account its own time error

$$TE_{ref}(t) = T_{ref}(t) - T_{idl}(t) = T_{ref}(t) - t,$$

deeming it equal to zero, then in all the formulae containing $T_{ref}(t)$, instead of $T_{ref}(t)$ one should substitute t, i.e. the true (ideal) continuous time.

Under modern practice, digital measurement facilities are usually in use for making the TE and TIE measurements. So the measurement results correspond to certain discrete time samples t_i. Therefore, when the calculations are carrying out on the basis of measured TE-Time Error or TIE-Time Interval Error data, the calculated dependences are also computed at discrete points of time. In particular, at discrete samples x_i, taken at discrete points of time t_i, the formulae for such generalized characteristics of a synchronization signal ensemble as average, "maximum" and "minimum" MTIE (avMTIE, maxMTIE and minMTIE) have the form of the following relations:

$$\mathrm{avMTIE}(\tau, \mathrm{T}, \mathrm{L}) = \sum_{l=1}^{L} \{ \max_{j=1}^{N_T - N_\tau + 1} [\max_{i=j}^{N_\tau + j - 1} (x_i) - \min_{i=j}^{N_\tau + j - 1} (x_i)] \} / L,$$

$$\mathrm{maxMTIE}(\tau, \mathrm{T}, \mathrm{L}) = \max_{l=1}^{L} \{ \max_{j=1}^{N_T - N_\tau + 1} [\max_{i=j}^{N_\tau + j - 1} (x_i) - \min_{i=j}^{N_\tau + j - 1} (x_i)] \},$$

$$\mathrm{minMTIE}(\tau, \mathrm{T}, \mathrm{L}) = \min_{l=1}^{L} \{ \max_{j=1}^{N_T - N_\tau + 1} [\max_{i=j}^{N_\tau + j - 1} (x_i) - \min_{i=j}^{N_\tau + j - 1} (x_i)] \}.$$

In the above expressions $N_{\mathrm{T}} = \frac{\mathrm{T}}{\tau_0} + 1$ и $N_\tau = \frac{\tau}{\tau_0} + 1$ are accordingly the overall numbers of samples within the measurement interval T and within the observation interval τ, and value τ_0 corresponds to the period of samples taking. It is clear that at $L = l = 1$ each of these expressions corresponds to the well-known relationship for the MTIE of one synchronization signal. The corresponding formulae for avTDev, maxTDev and minTDev, characterizing the average, "maximum" and "minimum" time deviation (TDev) may be obtained in a similar manner.

During synchronization network monitoring, the comparison of the generalized characteristics of synchronization signal ensembles with the templates of the tolerable MTIE and TDev values for the various hierarchical levels of this network makes it possible to rapidly obtain a sufficiently full idea on the common behavior of sets (ensembles) of synchronization signals and to make conclusions on how much the indicators of their actual quality correspond to those required to ensure the proper functioning of the digital telecommunication network being synchronized. For example, the assessment of the generalized characteristics of the quality of some synchronization signal ensembles during audit and/or monitoring of certain synchronization network regions, can significantly contribute to obtain a clear idea of the quality of synchronization of digital networks in these regions. Such an assessment of the generalized characteristics of synchronization signal ensembles can be performed at monitoring of the synchronization signal quality at the inputs and outputs of SN network element using both the means of control built into its equipment and specialized measuring facilieties. At the same time, on the basis of the data on the generalized characteristics of the synchronization signal ensemble quality at the inputs of a SN network element, one of which is the main one while the others are standby synchronization signals, one can forecast the behavior of this network element at the possible switching operations over to standby inputs. On the other hand, the simultaneous control of output synchronization signal ensemble quality makes it possible to detect on-the-fly the cases where the parameters of these synchronization signals go outside the acceptable limits and, in this connection, to take necessary steps to remedy such situations in a timely manner.

III. Simulation

In order to confirm the feasibility of the assessment of the proposed generalized characteristics of ensembles, the computer program was developed by the author in the C++Builder-5 integration development environment. As it's in [9,10] this demonstration program uses multidimensional matrix approach to synchronization signal ensembles simulation and makes it possible to calculate the dependences, dealt with above, using both standard MTIE calculation methods, and using rapid ("fast") methods considered, in particular, in [1,4,6]. Besides, by means of the aforementioned program, one can compare the various algorithms to choose the main synchronizing clock from a synchronization signal ensemble at the input of a certain network element of the synchronization network. It's possible to use program to demonstrate the selection of input main synchrosignal for each of several network elements when this selection is based on the indicators of the actual quality of input synchronization signals, and not only, for example, on the data on the "quality levels", contained in the synchronization status messages [1-3,8].

IV. Conclusions

In conclusion, the attention is paid to the fact that in case the usefulness in practice to monitor not only the quality parameters of individual synchronization signals on the synchronization network, but also the generalized quality parameters of synchronization signal ensembles, one can raise the question in regard advisability of standardizing the considered generalized characteristics of some synchronization signal ensembles in the international normative documents, relating to the synchronization networks and SN management. The analysis of the generalized parameters and characteristics during the audit and monitoring of SN element clocks quality taking into account its hierarchical levels. can contribute to the process of synchronization network improvement in the direction of their transformation into managed self-repairing (self-healing) digital telecommunication network synchronization networks [11].

REFERENCES

[1] S. Bregni, "Synchronization of Digital Telecommunications Networks". John Wiley and Sons, ltd. McGrow Hill. NY, 2002.
[2] ITU-T Recommendations G. 781, G. 783, G. 803, G. 810 – G. 813, G. 822, G. 823.
[3] ETSI Standards EN 300 462, EN 300 417-6-1, EG 201793.
[4] S. Bregni, S. Maccabruni, "Fast Computation of Maximum Time Interval Error by Binary Decomposition". IEEE Transactions on Instrumentation and measurement, vol. 49, No. 6, pp. 1240 – 1244, December 2000.
[5] "Multiple Monitor by Eight. Sync Audit System for Multiple Measurements". Chronos Times. Telecom News from Chronos Technology. Issue Number 22, 2002.
[6] G.V. Konovalov, "Calculation of Quality Characteristics for L Synchrosignals Ensemble with the Help of Fast Computation Methods". Metrology and Meausuring Technique in Telecommunications, № 5, pp. 25 – 30, 2002.
[7] G.V. Konovalov, "Monitoring of Synchrosignals Ensembles and Synchronization Network Management Taking into Account their Real Quality Characteristics". Materials of Scientific-technical Seminar "Synchronization, Generation and Processing of Signals". 3 – 5 July 2003. Yaroslavl State University, pp. 35-37, 2003.
[8] G.V. Konovalov "Computer Simulation of a Synchronization Network". Electrosvyaz, no. 6, pp. 30-34, 2001.

[9] G.V. Konovalov, “Multidmensional World of Digital Signals”. Krajove Symposium Telekomunikacji’99. v. B. Referaty sekcji 1. Problemy podstawowe. Instytut Telekomunikacji Politechniki Warszawskiej, pp. B-1.500-B-1.506, 1999.
[10] G.V. Konovalov, “Digital Telecommunication Systems Signals Modelling on the Basis of Multidmensional Signal Element Matrices”. Electrosvyaz, № 1, pp. 18–21, 2000.
[11] G.V. Konovalov, V.A. Netes, “Principles of Digital Telecommunications Synchronization Network Self-repairing (Self-healing)”. Proceedings of the Ukraine House of Economical Sientific and Technical Knowledge, №1, pp. 74-76, 2002.

Table 1. Some Generalized Characteristics of an Ensemble from L Synchronization Signals in the Time Domain

Average Time Function $T_{av}(t)=\sum_{l=1}^{L} T_l(t)/L$	Maximum Time Function $T_{\max}(t)=\max_{1\le l\le L} T_l(t)$	Minimum Time Function $T_{\min}(t)=\min_{1\le l\le L} T_l(t)$
Average Time Error Function $TE_{av}(t)=\sum_{l=1}^{L}[T_l(t)-T_{ref}(t)]/L$	Maximum Time Error Function $TE_{\max}(t)=\max_{1\le l\le L}[T_l(t)-T_{ref}(t)]$	Minimum Time Error Function $TE_{\min}(t)=\min_{1\le l\le L}[T_l(t)-T_{ref}(t)]$
Time Interval Error Function of Average Time $TIE_{av}(t,\tau)=TE_{av}(t+\tau)-TE_{av}(t)$	Time Interval Error Function of Maximum Time $TIE_{\max}(t,\tau)=TE_{\max}(t+\tau)-TE_{\max}(t)$	Time Interval Error Function of Minimum Time $TIE_{\min}(t,\tau)=TE_{\min}(t+\tau)-TE_{\min}(t)$
Average MTIE for ensemble $\mathrm{avMTIE}(\tau,\mathrm{T},L)$	Maximum MTIE for ensemble $\mathrm{maxMTIE}(\tau,\mathrm{T},L)$	Minimum MTIE for ensemble $\mathrm{minMTIE}(\tau,\mathrm{T},L)$

Note. Equations for the $\mathrm{avMTIE}(\tau,\mathrm{T},L)$, $\mathrm{maxMTIE}(\tau,\mathrm{T},L)$ and $\mathrm{minMTIE}(\tau,\mathrm{T},L)$ are in the text of the report