Implementation of the Real-Time Assessment of Dynamic Allan Deviation and Dynamic Time Deviation

Michal Kasznia
Chair of Telecommunication Systems and Optoelectronics
Poznan University of Technology
Poznan, Poland
mkasznia@et.put.poznan.pl

***Abstract*—In the paper the realization of the methods enabling real-time computation of dynamic Allan deviation and dynamic time deviation is described. The idea of real-time analysis of timing signals using dynamic approach is described first. Then the main features of the algorithms enabling the analysis and their implementation are presented and discussed.**

Keywords—timing signal, Allan deviation, time deviation, real-time computation

I. Introduction

Allan deviation ADEV and time deviation TDEV are the parameters used for characterization of the signals generated by the clocks. Time deviation is commonly used for evaluation of the synchronization signals in the telecommunication network. The limit values of TDEV for some network interfaces are defined by the telecommunication standards [1, 2, 3]. These parameters allow the variations of time interval provided by the synchronization signal to be assessed and the type of phase noise affecting the signal to be recognized. Dynamic parameters of timing signals (dynamic Allan deviation DADEV and dynamic time deviation DTDEV) [4, 5] bring more detailed information about the analyzed signal. The characterization using dynamic parameters allows to recognize the variations of the phase noise affecting the analyzed signal.

The evaluation of the synchronization signal is commonly a two-stage process – the calculation of the parameters follows the time error measurement. However, the application of the real-time computation of these parameters performed during the time error measurement allows to simplify the evaluation procedure of the timing signal. The maintenance team of the telecommunication network can track the parameters' values in the real time during the measurement and perform suitable reactions immediately.

The computation methods enabling assessment of the dynamic parameters in the real time were previously proposed and tested [6]. The experimental tests have proved the ability of the computation of dynamic parameters in the real time during the time error measurement performed with the sampling interval τ_0=1/30 s (often used in the characterization of timing signals in the telecommunication networks). In the paper the results of the implementation of the algorithms enabling joint real-time assessment of dynamic ADEV and dynamic TDEV are presented.

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II. Idea of Dynamic Parameters

The idea of the evaluation of the timing signals using dynamic parameters consist in the analysis using a set of the curves representing ADEV or TDEV plotted in the form of a three-dimensional graph as a function of the observation interval τ and the measurement time t. As a result we can recognize the changes of the type of phase noise affecting analyzed timing signal. The changes of the slope of the parameter's curve indicate the changes of the noise type [4, 5].

In order to obtain such form of graph, the following computation procedure must be performed. First, the data sequence (time series of the time error samples measured at some network interface) is divided into equal segments (slices) with the length of T_s. Depending on the time shifts between the initial points of the segments we can consider overlapping data segments and non-overlapping data segments [7]. Then the calculation of the parameter's value for a required range of the observation intervals for each data segment is performed. The results of calculation are plotted in a form of three-dimensional graph.

III. Real-Time Computation of Dynamic Parameters

The algorithm of the real-time assessment of the dynamic parameters must enable to perform necessary computations for all observation intervals and all data segments within one sampling interval. Therefore it needs a specific data arrangement and organization of the calculations.

In order to compute the dynamic parameters in the real time, the rearranged forms of the ADEV and TDEV estimators, suitable for the real-time computation, can be used [8, 9]. The value of the parameter currently computed (for the current sampling instant i) depends on the currently measured sample, small number of previously measured samples, and the values of sums accumulated in the previous sampling instant. ADEV estimator's formula for a current instant i is given in the form:

$$A\hat{D}EV_i(n\tau_0)=\sqrt{\frac{1}{2n^2\tau_0^2(i-2n)}\left(A_{i-1}(n)+\left(x_i-2x_{i-n}+x_{i-2n}\right)^2\right)} \qquad (1)$$

were $A_{i\text{-}1}(n)$ is the sum of squares of second differences of time error samples

$$A_{i-1}(n)=\sum_{j=2n+1}^{i-1}\left({}_m x_j-2{}_m x_{j-n}+{}_m x_{j-2n}\right)^2, \quad i>2n$$

and x_i denotes the time error sample measured at the sampling instant i. The value of time deviation for the current sampling instant i is estimated using the formula:

$$T\hat{D}EV_i(n\tau_0)=\sqrt{\frac{1}{6n^2(i-3n+1)}\left[S_{ov,i-1}(n)+\left(S_{i-1}(n)+\Delta_i(n)\right)^2\right]} \quad (2)$$

where $S_{ov,i}(n)$ and $S_i(n)$ are the sums updated for each sampling instant i, given in the forms:

$$S_{ov,i}(n)=S_{ov,i-1}(n)+S_i^2(n)$$

$$S_i(n)=S_{i-1}(n)+\Delta_i(n), \quad i>3n$$

$$S_{3n}(n)=\sum_{j=2n+1}^{3n}\left(x_j-2x_{j-n}+x_{j-2n}\right), \quad j>2n$$

and $\Delta_i(n)$ is a third difference of the time error samples:

$$\Delta_i(n)=-x_{i-3n}+3x_{i-2n}-3x_{i-n}+x_i$$

The sum $S_{3n}(n)$ is the first item of the overall sum $S_{ov,i}(n)$. If a personal computer is used to control the measurement process, the time error samples are simultaneously stored on the hard drive and in the cyclic buffer created in the computer memory. All computational operations are performed on the samples stored in this buffer to reduce the time of data access. The buffer must have the length of $3n_{max}+1$ items (where $\tau_{max}=n_{max}\tau_0$ is the maximum observation interval considered), in order to store all samples necessary for the computation.

When computing the dynamic parameters in the real time, the values of ADEV and TDEV are calculated using the formulas (1) and (2) for specific segments of data.

We consider non-overlapping data segments when the time shift t_s between the initial points of successive segments is equal to or greater than the length of the segments T_s. In this case each segment can be analyzed independently during the real-time computation process of dynamic parameters. This process runs in the same way as the real-time computation process of usual Allan deviation or time deviation [8, 9] regarding that for each segment a new line of the three-dimensional graph is obtained. Only one set of observation intervals is analyzed for one sampling instant. The scheme of the real-time computation is presented in Fig. 1. The data segments (grey boxes) are successively analyzed. The operators of ADEV and TDEV sums (black and white lines) run along the incrementing data sequence within analyzed data segment (dark grey box).

The arrangement with overlapping data segments is considered when the time shift t_s between the initial points of successive segments is shorter than the length of the segments T_s. In this case more than one set of observation intervals have to be analyzed for one sampling instant (more than one curve representing the parameter is updated within one sampling interval) – each set is related with a different data segment. The computations for the shortest observation interval τ_{min} for all segments (overlapping for this sampling instant) are performed first. Then successive longer observation intervals (for a greater n) are analyzed. The configuration of this order of computation is presented in Fig. 2. Detailed procedure of the operations performed within one sampling interval is as follows [6]:

1. Read TE sample from the TE meter and store it in the data file and in the data buffer.
2. Read TE samples measured n, $2n$, and $3n$ sampling intervals earlier from the buffer.
3. Compute parameters' values successively for each overlapping data segment for the current n.
4. Execute Steps 2 and 3 for successively longer observation intervals (greater n).

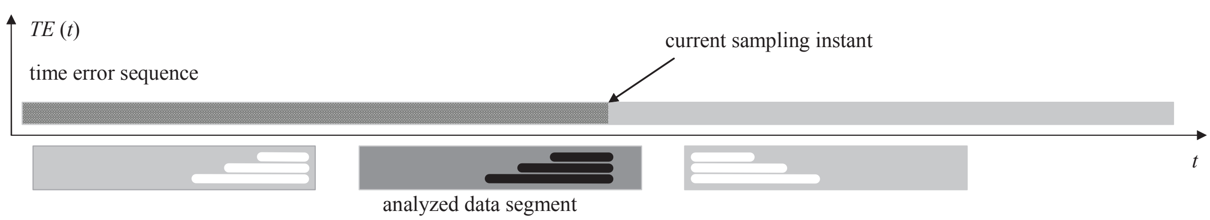

Fig. 1. Real-time computation for non-overlapping data segments; dark grey box – analyzed data segment, black and white lines – ADEV and TDEV sum operators (active – black line, inactive – white line)

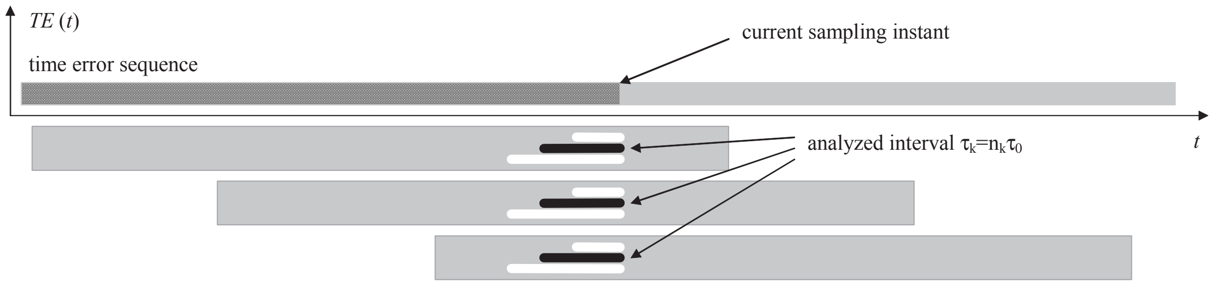

Fig. 2. Real-time computation for overlapping data segments; black and white lines – ADEV and TDEV sum operators (analyzed operator – black line, waiting for analysis – white line)

IV. Implementation of the Algorithms

The algorithms described above were tested in the computational experiments [6]. The results of the tests have proved the ability of joint real-time computation of the dynamic Allan deviation and dynamic time deviation for non-overlapping data segments, as well as for overlapping data segments during the time error measurement performed with the sampling interval τ_0=1/30 s. This sampling interval allows us to compute the values of the parameter for the minimum observation interval τ_{min}=0.1 s.

In order to implement these algorithms in a real measurement a modified version of measuring system SP-4000 designed in the laboratories of Poznan University of Technology [10] was used. This system consists of two separate units: a measuring unit and an external computer controlling the measurement and computation process. The measuring unit contains four time error meters, build-in rubidium oscillator synchronized to GPS signals as a source of reference signal, and additional devices enabling distribution of the reference signals and communication with the external computer. This system enables independent time error measurement in four channels, recording of measured values, *off-line* analysis using its usually software, as well as real-time multi-channel computation of the parameters [11].

The algorithms proposed bring a new functionality to the timing signal evaluation process. The main features of this software are following:

- TE measurement in one of four measurement channels;
- sampling interval range from 1/32 s to 1 s;
- real-time joint computation of usual ADEV and TDEV for the whole measured TE sequence;
- real-time joint computation of dynamic ADEV and dynamic TDEV for the selected TE segments;
- range of observation intervals from 0.1 s to 1000 s;
- number of observation intervals considered within one decade: 5, 10, or 20;
- graphic user interface enabling the presentation of measured TE values and computed parameters' values in the real time.

The example screenshots of the user interface showing the measurement and real-time computation process are presented in Fig. 3 and 4. Time error was measured in the selected channel with the sampling interval τ_0=1/32 s and a rubidium oscillator as a reference. Timing signals were obtained using an unsynchronized OCXO (Fig. 3) and a signal probe for the E1 (2048 kbit/s) telecommunication data stream (periodical wander was introduced during the measurement process). Successive points and lines on the 3-D plots are added when the sufficient number of samples has been measured.

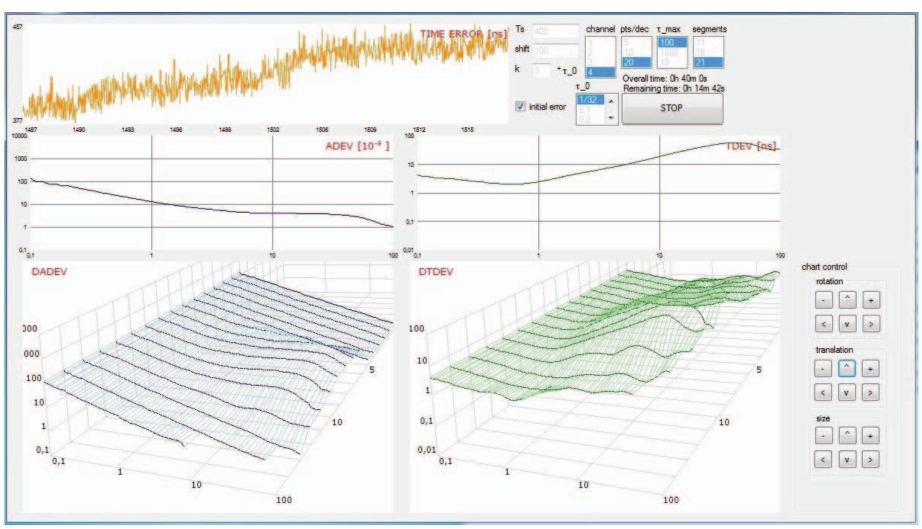

Fig. 3. Time error measurement and real-time computation of dynamic parameters for timing signal generated by OCXO

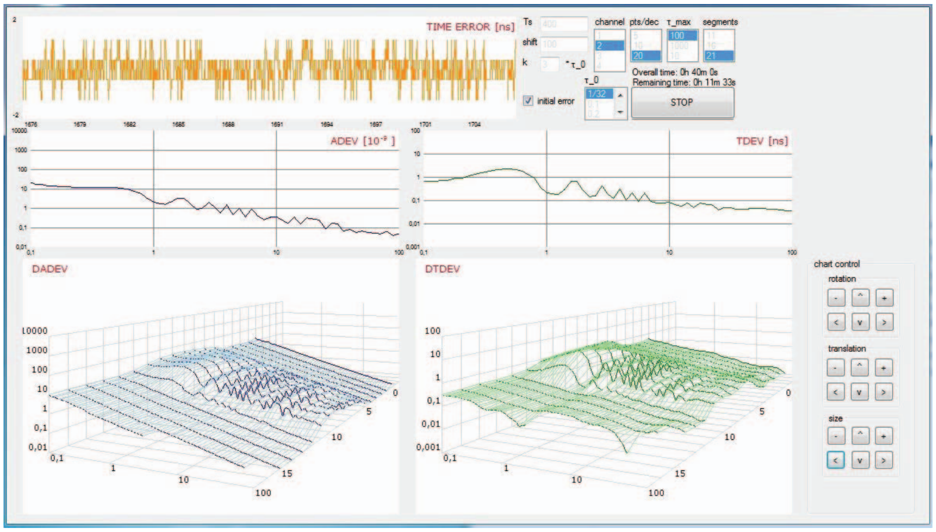

Fig. 4. Time error measurement and real-time computation of dynamic parameters for timing signal obtained from E1 data stream

V. Conclusions

In the paper the realization of the real-time computation of dynamic ADEV and dynamic TDEV has been presented. The solutions proposed make possible the cooperation between multi-channel time error measuring unit and the algorithms of the real-time assessment of the dynamic parameters. The solutions enabling the real-time analysis of the timing signals can be very useful in the service and maintenance of the telecommunication networks as well as in the analysis of the high quality timing signals.

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